Abstract: This paper builds on the knowledge generated by the past studies on agricultural convergence and extends it in order to provide a more holistic analysis in geographical terms, and a more detailed analysis of the aspects that shape the overall performance of the countries. The paper adopts a global scale of analysis and assesses convergence in terms of value generation, energy efficiency, and technical efficiency. To do so, analysis is based on a series of regression models in order to examine if the policy changes that occurred in the beginning of the 1990s promoted the convergence of the agricultural sector’s performance across the globe. Two main types of convergence were tested. The first refers to the $\sigma$-convergence and the second type is this of $\beta$-convergence. The lack of any type of convergence regarding the generated value across countries around the globe has shown that the liberalization of the market has not brought about any substantial improvements in the position of the weakest countries. On the other side, a convergence of both $\sigma$ and $\beta$ type has been found for the energy efficiency of the countries. That is, it resulted in improvements in their energy efficiency. Policy changes of the early 1990s have substantially improved the position of the weakest countries. There was also a positive effect on the productivity of vegetable cultivations whilst it seems that they have slowed down a strong convergence process for fruit productivity.

Keywords: convergence; regression analysis; coefficient of variation; Uruguay Round; Common Agricultural Policy

1. Introduction

The agricultural economic sector accounts for 4% of the world gross domestic product (GDP) and its gross value added (GVA) exceeds $3 trillion [1]. For many countries, and especially for the developing ones, agriculture acts as the main driving force for economic growth and employment generation whilst contributing to the food and clothing security, and land utilization and protection [2]. From the middle of the previous century, and especially in the past 30 years, the global agricultural sector has undergone a structural transformation phase characterized by large gains in productivity, shifts of the production from low to high value crops, and improved marketability [3]. In addition, it is now commonly accepted that the productivity gains should be accompanied by the adoption of more environmentally friendly agricultural practices, in order for any negative externalities to be controlled and sectoral sustainability to be achieved [4,5].

Despite the great development of the agricultural sector at the global level, there is still a long way before all countries of the world exploit the full potential of agriculture for sustainable economic growth. This is because there is a huge gap between developed and many of the least developed countries in terms of adequate and skilled labor, effective institutional frameworks, market access,
and enough infrastructures [6]. By acknowledging this reality, many international organizations work toward the reduction of these inequalities through various policy frameworks and initiatives. The Food and Agriculture Organization of the United Nations (FAO) addresses sustainability through a five-pillar based strategic plan which promotes the efficiency of agriculture, the marketability of products, the higher contribution of the sector to national economies, the resilience of rural societies and ecosystems, and the better governance [7].

Moreover, the global sustainability of the sector is also promoted through the World Trade Organization (WTO). The Uruguay Round, which led to the establishment of the WTO, literally has set the basis for reducing trade barriers through the abandonment of protective measures such as price subsidies [8]. The liberalization of the market was also enhanced by the European Union’s (EU) Common Agricultural Policy (CAP) reform which took place in 1992, while the Uruguay round was still ongoing. With this new CAP, price support was scaled down and replaced by less trade distorting subsidy schemes, thus leading countries to specialize in the crops for which they pose a real comparative advantage [9]. According to Henke et al. [10] the new CAP reforms provided countries with the flexibility to draw their own path towards the supporting of their agricultural sector and thus develop payment frameworks that could really enhance sectoral competitiveness.

The policy interventions were aimed at promoting the liberalization of the global market which could also assist less developed countries to cope with the high competition of the developed ones. Therefore, from an academic point of view, it is very interesting to evaluate the effectiveness of these interventions and test the convergence among the different countries of the globe, towards a more efficient and, thus, sustainable agricultural sector. International literature includes studies which examine the general hypothesis of convergence among the performance of the national agricultural sectors in various regions of the world. In [11] a thorough review for studies covering the period before the Uruguay Round can be found. Regarding the more recent studies, Suhariyanto and Thirtle [12] have shown that no convergence in terms of total factor productivity (TFP) of the agricultural sector was found for 18 Asian countries in the period 1965–1996. In the same paper, Suhariyanto and Thirtle [12] compared the TFP of the Asian countries with that of Africa and found some convergence trends, as three African regions presented higher TFP growth rates than those of Asia. In addition, Coelli and Rao [11] assessed the technical efficiency of the agricultural sectors of 93 countries for the period 1980–2000 and found out that the less efficient regions in 1980, namely Asia and Africa, presented higher efficiency gains in the considered period.

In addition, Galanopoulos et al. [13] focused their analysis in the wider Mediterranean region and found no convergence trend for the productivity of different regions for the period 1961–2002. Moreover, Rezitis [14] tested the productivity convergence hypothesis on a sample of nine European countries and the United States for the period 1973–1993. The results of the analysis signified an absolute convergence trend in the sub-period 1983–1993. The agricultural productivity convergence hypothesis for the USA states and regions in the period 1960–1996 was also tested in the paper of Poudel et al. [15]. The hypothesis was rejected at the states level, but it was accepted only for some regions of the USA. In addition, Baráth and Fertő [16] and Kijek et al. [17] investigated the productivity convergence hypothesis for the EU countries for the periods 2004–2013 and 2004–2016, respectively. Both papers highlighted that a convergence trend exists among the countries of the EU. Finally, Csáki and Jambor [18] have tested the convergence hypothesis between the EU-15 countries and those of Central and Eastern Europe and the Commonwealth of Independent States. The authors tested the convergence, taking as a reference the partial productivity measures of land and labor production factors. The authors concluded that no real convergence has been realized in the period 1997–2016, whilst the performance gap remains larger for the Commonwealth of Independent States than for the countries of Central and Eastern Europe.

Considering the past studies on agricultural convergence, some key findings should be highlighted. More precisely, most of the previous papers concentrated only on particular regions of the globe, excepting the paper of Coelli and Rao [11] which covered a broader sample of countries. In addition,
the focus of most of the papers was on the productivity of agricultural sectors, thus leaving aspects such as the energy efficiency rather understudied. Moreover, all papers regarded as output the total production of the agricultural sectors without examining the records of the countries in individual crops cultivation. Such a research setting could not provide real insights regarding the true impact of the policy interventions on the global agricultural market as the interventions affect asymmetrically the various countries according to the crops on which they pose a competitive advantage.

The present paper builds on the knowledge generated by past studies on agricultural convergence under efficiency and sustainability terms on a global scale. It is well known that the last CAP reform emphasizes the convergence of direct payments under the First Pillar framework [19]. This is not the case of this paper because it extends existing knowledge in order to provide a more holistic analysis in geographical terms, but also in the particular aspects of the agricultural production that shape the competitive position of each country. The paper employs a series of regression models in order to examine if the policy changes that occurred in the beginning of the 1990s promoted the convergence of the agricultural sector’s performance across the globe. To do so, the period is divided in two distinct sub-periods; 1980–1992 and 1992–2016 and the convergence hypothesis is tested for both. This specific threshold is very important on both European and global basis, because, as it was stated above, it was the starting point for a series of strategic amendments at policy level. The common characteristic of these reforms and agreements was the alleviation of trade distorting policies and enhancement of sustainability and environmental protection in the rural environment [20]. Therefore, it is quite important to set 1992 as a division point for this assessment.

This analysis focuses on three different aspects of agricultural performance, namely value generation, energy efficiency, and productivity of various crops. These aspects are being described as indicators for assessing CAP performance on both performance and context levels [21]. All three of them are directly related to the sustainable use of production factors and natural resources, having as a target to improve operational performance of agricultural holdings, and at the same time mitigating the production of undesirable outputs of the production process. In other words, as the improvement of operational performance arises as the major global challenge of agriculture, this cannot be achieved without meeting specific environmental goals [7]. By doing so, the analysis sheds light on how the policy interventions affected the various elements that shape the competitiveness of the agricultural sector and its overall ability to act as a catalyst for sustainable growth. Finally, the analysis incorporates countries from all over the world, thus evaluating the global, rather than the regional, effect of policy interventions. The remainder of the paper is as follows. In Section 2 the formation of the models and the variables incorporated within them are presented in detail. In Section 3 the results of the convergence analysis for the value, energy efficiency, and crops productivity are presented. In Section 4 the results are being discussed, and finally, the paper ends up with a conclusion section in which the contribution of the paper to the theory of sustainable agriculture is presented, some key policy insights are highlighted, and some future research challenges are presented.

2. Materials and Methods

2.1. The Rationale of Convergence

The issue of convergence has been at the center of research on the development and regional economics domains. The debate around convergence lies at the different views of two distinct schools of economic thought. The first is the neoclassical one, which claims that convergence between poorest and richest countries occurs automatically due to diminishing returns of capital which lead the economies of the first type of countries to grow faster than these of the latter ones. On the other side, schools of thought like those of endogenous growth and new economic geography believe that inequalities tend to increase because of the cumulative effects of knowledge, technology, and production factors concentration in the developed countries [22–24].
In order to test the convergence hypothesis among various spatial entities, it was essential to define the dimensions of the economic performance to be used as the basis for analysis, as well as the indicator that would allow its quantification. Most of the relevant empirical studies have relied on indices such as the GDP or the productivity being expressed as the ratio of output to inputs of the production process [22]. Having the indicator at stake defined, there were two main types of convergence to test for. The first referred to the $\sigma$-convergence which measured the longitudinal dispersion of the indicator observations distribution across the entities under study, using statistical measures such as the standard deviation (StDev) or the coefficient of variation (CV). A declining trend of the StDev or CV estimations provided hints for convergence, whilst the opposite stands when the estimated values increased over time [25].

The second type of convergence was that of $\beta$-convergence. In order to test for the existence of such a type of convergence, a regression model was constructed where the independent variable took the prices of the chosen indicator at the initial year of the period under study and the dependent variable was formed by the growth rates of the indicator between the starting and last years of the considered period. A negative estimation of the regression coefficient of the independent variable denoted that $\beta$-convergence exists, whilst a positive one indicated that divergence was observed on the sample of spatial entities, as the more developed entities presented higher growth rates than those of the less advanced ones [23,26]. In general, the $\sigma$-convergence examines the evolution of the distribution of a given indicator whilst the $\beta$-convergence examines the shifts of the indicator within the same distribution [27].

2.2. The Indicators of Agricultural Performance of the Present Study

The present paper tested the hypotheses of $\sigma$-convergence and $\beta$-convergence across the globe. Although the regression models used for testing the convergence hypothesis cannot provide information for particular countries, they are still capable of capturing the global average trends and providing an evaluation of the policies’ effectiveness, which is the basic motivation behind the present paper. The convergence hypothesis testing was based on a series of agricultural sector performance indicators. The indicators were quantifying three dimensions of agricultural outputs. The first dimension was that of generated value. The indicator for measuring the generated value was the total gross production value (TGPV), expressed in million international dollars. The second dimension was that of energy efficiency. The indicator of energy efficiency was estimated based on Formula (1). This indicator depicted the ability of countries to use electricity sufficiently in the production process by generating the least possible emissions, as these were expressed in CO$_2$Eq. units. It was acknowledged that more sophisticated indices could provide more insights about the energy efficiency and the environmental performance of the countries such as those presented by papers of Vlontzos et al. [28] who used the data envelopment analysis, or Yan et al. [29] who relied on the energy generalized divisia index to evaluate the energy efficiency of a group of European countries. Nevertheless, such detailed data were not available for all the countries and especially for a longitudinal analysis such as that of the present paper. Therefore, a simpler indicator was selected in order to make a wider spatial analysis feasible.

$EE = \frac{EC}{EEm}$

where,

- $EE$ = energy efficiency
- $EC$ = electricity consumption (million KWH)
- $EEm$ = electricity emissions (CO$_2$Eq.-gigagrams).

The third dimension was that of productivity. Most of the past studies on agricultural productivity convergence have relied on the TFP concept [18]. The basic assumption for conducting comparative studies on TFP was that countries produce a similar mix of outputs. This was because the cultivation of different crops presented variable requirements of input factors and, thus, a country that specialized in
the cultivation of a crop with low capital requirements might have been rendered as more productive than a country where capital intensive cultivations prevailed. In order to test the productivity convergence hypothesis, the present paper followed a different path. More precisely, the analysis focused on different types of crops, namely cereals, coarse grains, pulses, vegetables, and fruits. These types of cultivations represented an adequate level of the crop production of each country. Moreover, their selection was based on the fact that FAO [30] provided relevant data that cover the time needs of the present paper. The disaggregated measurement of productivity came at the cost of less detailed data regarding the utilization of all production factors. Instead, the FAO database [30] included data regarding the yield of each crop, providing in this way an estimation of the land productivity. Even though this indicator abolished some critical information regarding the performance of each country, it still made feasible the comparison of countries’ performance and the effect of the policy intervention on the various types of crops, which makes a significant contribution to the available literature. The land productivity for each of the crops is given by the following ratio.

$$CP = \frac{TO}{CL}$$

where,

- $CP$ = crop productivity (cereals, coarse grains, pulses, vegetables, and fruits)
- $TO$ = total output (hgs)
- $EEm$ = cultivated land (hectares).

2.3. $\sigma$-Convergence and $\beta$-Convergence Tests

In order to test for the $\sigma$-convergence, the following formula was used to measure the dispersion of each indicator’s values across the various years of analysis.

$$CV = \frac{\sigma}{\bar{X}}$$

where,

- $CV$ = The coefficient of variation
- $\sigma$ = The estimated St. Dev of the observations
- $\bar{X}$ = The estimated mean of the observations.

Moreover, the $\beta$-convergence hypothesis was tested with the estimation of the following regression model [17]

$$\ln\left(\frac{Y_{i}^{TF}}{Y_{i}^{TS}}\right) = a + \beta\ln\left(Y_{i}^{TS}\right) + \epsilon$$

where

- $Y$ = the indicator under study
- $a$ = the constant regression term
- $\beta$ = the convergence coefficient
- $i$ = the index of the countries of the study
- $TF$ = the index denoting the final year of analysis
- $TS$ = the index denoting the starting year of analysis
- $\epsilon$ = the error term.

The model (4) was used in order to test the convergence hypothesis for all indicators of performance that were described in Section 2.2. Analysis was divided in two distinct periods. The first covered the period before the policy interventions being put into force (1980–1992), whilst the second covered the period from 1993 to 2016 which was the most recent year with available data for all the countries under consideration. The only variation was found for the energy efficiency indicator, as no data were available for the same period. Analysis for this indicator took place in the period 1992–2012, which
although smaller, it still provided insights for whether countries’ environmental performance had converged after the gradual liberalization of the global market.

It should be noted that the number of countries differed per specific indicator and their number was reported in the descriptive statistics tables of each indicator. The criteria for including the countries into the analysis was the data availability for the value generation and energy efficiency indicators and the constant production of output across the three years of analysis for the crop productivity indicator. The detailed list of countries for each indicator is available upon request to the authors.

3. Results

3.1. Testing the Value Convergence Hypothesis

The descriptive statistics of the TGPV indicator for the years 1980, 1992, and 2016 are presented in Table 1. The mean annual agricultural generated value showed positive trends in the period, as it increased from $7bn to more than $16bn between 1980 and 2016. The same trend was also observed both for the least and most developed market. The lowest value from agriculture was generated by Brunei Darussalam within the whole period, whilst the largest value generators varied across the years, as the USA, which generated the largest value in the initial period, was surpassed by China after 1992.

| Statistic       | 1980      | 1992      | 2016      |
|-----------------|-----------|-----------|-----------|
| Mean            | 7,081,843 | 9,516,503 | 16,786,146|
| St. Dev.        | 19,458,714| 28,845,176| 61,045,150|
| Min.            | 9969      | 12,439    | 50,261    |
| Max.            | 156,658,291| 246,825,859| 623,401,129|
| Country Min.    | Brunei Darussalam | Brunei Darussalam | Brunei Darussalam |
| Country Max.    | USA       | China     | China     |
| Coefficient of Variation | 2.748 | 3.031 | 3.637 |
| N.              | 147       |           |           |
| Unit            | Thousand International $ |

The σ-convergence trend was evaluated by examining the CV values for all the three periods. The CV presented an increasing trend within the whole period, thus denoting that the dispersion of value among the countries was getting higher over time. This fact provided hints that, as far as the agricultural value is concerned, the hypothesis for σ-convergence in the period 1980–2016 should be rejected. This finding was also supported by the fact that the range of values between the first and the last country had increased from $156bn to $623bn in the considered period.

Finally, the results of the β-convergence test are presented in Table 2. As can be seen from the non-statistically significant F-statistic estimations and the value of the adjusted R² coefficients, the models had a poor explanatory power. Moreover, although the convergence coefficients yielded a negative sign for both periods, the lack of any statistical significance of the estimations led to the rejection of the β-convergence hypothesis in the considered period. It should be noted that the explanatory value of the second model was slightly improved from the initial one, taking into account the value of the F-statistic and the beta coefficient, but still the lack of any statistical significance denoted that a real convergence process is yet to take place. The overall results testify that no kind of convergence has occurred in the last four decades in the agricultural generated value.
Table 2. The results of the regression analysis of the TGPV indicator for the two periods of the study

| Fitting Statistics and Coefficients | 1980–1992 | 1992–2016 |
|-------------------------------------|-----------|-----------|
| F                                   | 0.95      | 1.45      |
| Adj R²                              | 0.01      | 0.01      |
| B                                   | –0.01     | –0.22     |
| A                                   | 0.42 **   | 0.80 ***  |

Statistical significance: (*** ) at the 0.01 level, (**) at the 0.05 level.

3.2. Testing the Energy Efficiency Convergence Hypothesis

The descriptive statistics of the EE indicator for the years 1992 and 2016 are given in Table 3. The mean annual efficiency had increased from about 4 kWh/CO₂ Ggto to 5 kWh/CO₂ (25%) between the starting and final year of analysis. This finding provided hints that the efficiency of the agricultural sector had substantially increased in the given period. Energy performance had also improved for both the least and worst performers of the initial year of analysis. The best performer for both the years was Iceland whereas the worst performer for 1992 was Mongolia and for 2012 Turkmenistan.

Table 3. The descriptive statistics and the CV values of the energy efficiency (EE) indicator for the years 1992, 2012.

| Statistic                  | 1992  | 2012  |
|----------------------------|-------|-------|
| Mean                      | 4.184 | 5.011 |
| St. Dev.                  | 6.858 | 7.695 |
| Min.                      | 0.668 | 0.986 |
| Max.                      | 35.878| 36.545|
| Country Min.              | Mongolia | Turkmenistan |
| Country Max.              | Iceland | Iceland |
| Coefficient of Variation  | 1.640 | 1.536 |
| N.                        | 63    |       |
| Unit                      | million kWh/CO₂ equivalent gigagrams |

Moreover, by examining the CV values of the two years, a decreasing trend between the years 1992–2012 was observed. This trend signified that an σ-convergence process was taking place across the countries of the globe as the gaps among countries were gradually being reduced. In addition, the results of the β-convergence hypothesis test are presented in Table 4. The F-Statistic was significant at the <0.10 significance level, and thus, the model had a better explanatory power than the respective of the TGPV indicator. The estimated convergence coefficient had a negative sign and yielded statistical significance at the <0.10 level. Therefore, the β-convergence hypothesis was also confirmed for the present dataset. The findings of the present analysis signified that the shift to a more liberalized market has enhanced the ability of countries to perform on higher environmental standards. Nevertheless, it should be noted that the rather small dataset for the EE analysis and the fact that statistical significance was only found at the <0.10 level made the findings rather questionable and therefore additional research is considered as essential in order to draw safer conclusions on this issue.

Table 4. The results of the regression analysis of the EE indicator.

| Fitting Statistics and Coefficients | 1980–1992 |
|-------------------------------------|-----------|
| F                                   | 3.63 *    |
| Adj R²                              | 0.04      |
| B                                   | –0.11 *   |
| A                                   | 0.28 ***  |

Statistical significance: (*** ) at the 0.01 level (*) at the 0.1 level.
3.3. Testing the Crops Productivity Convergence Hypothesis

The descriptive statistics for the CP indicator for all the five groups of agricultural products are presented in Table 5. For all crop types the land productivity increased through time, except for the fruits, where the trend followed a u-shaped curve. For cereals, the mean CP increased from 17 t hg/ha to about 30 t hg/ha. In addition, the range increased in the same period, as the best performer increased its CP from 57 t hg/ha to about 84 t hg/ha in the 1980–2016 period, whilst the CP for the worst performer has increased only from 3.8 t hg/ha to 4.4 t hg/ha. For the years 1980 and 1992 Netherlands was the best performer and it was replaced by New Zealand in 2016. On the other hand, Namibia presented the weakest CP figures for all the considered periods. The trends of the CP of coarse grains crop was similar to those of cereals as the evolution of both the annual mean and the range presented almost equal trends. A striking difference was found on the best performers of the two crops. More precisely, the best performers in this type of crop were Italy, USA, and Oman for the respective years of analysis. On the other side, Botswana was the worst performer in 1980 followed by Namibia in the next two years.

Table 5. Descriptive statistics of the crop productivity (CP) indicator for the years 1980, 1992, 2012.

| Year | Statistic | Crops (hg/ha) |
|------|-----------|---------------|
|      |           | Cereals       | Coarse Grains | Pulses | Fruits | Vegetables |
| 1980 | Mean      | 17,864        | 17,220        | 9,440  | 137,811| 119,364    |
|      | St. Dev.  | 12,193        | 12,824        | 7,294  | 111,662| 82,958     |
|      | Min.      | 37,68         | 23,45         | 1333   | 28,089 | 12,107     |
|      | Max.      | 56,892        | 51,567        | 35,714 | 708,804| 609,713    |
|      | Country Min. | Namibia   | 7,376         | 19,053 | 30,000 | 40,000     |
|      | Country Max. | The Netherlands | 83,988     | 149,609 | 56,480 | 360,737    |
| 1992 | Mean      | 21,378        | 20,977        | 10,852 | 103,083| 132,164    |
|      | St. Dev.  | 15,838        | 17,520        | 9,195  | 58,347 | 91,526     |
|      | Min.      | 1,590         | 1,434         | 1,000  | 31,053 | 10,149     |
|      | Max.      | 74,592        | 70,808        | 47,958 | 360,598| 636,981    |
|      | Country Min. | Namibia   | 1,590         | 1,434  | 1,000  | 31,053     |
|      | Country Max. | The Netherlands | 74,592      | 70,808 | 47,958 | 360,598    |
| 2016 | Mean      | 29,982        | 32,573        | 13,472 | 124,638| 165,756    |
|      | St. Dev.  | 19,557        | 25,487        | 9,621  | 69,700 | 109,940    |
|      | Min.      | 4,428         | 3986          | 2,744  | 19,033 | 19,646     |
|      | Max.      | 83,838        | 149,609       | 56,480 | 360,737| 629,002    |
|      | Country Min. | Namibia   | 4,428         | 3986   | 2,744  | 19,033     |
|      | Country Max. | New Zealand | 83,838       | 149,609| 56,480 | 360,737    |

Regarding pulses, the annual mean CP increased from 9.4 k hg/ha to 13.4 k hg/ha. The range also increased as the best performer had an increase of about 21 k hg/ha, whilst the weakest country presented only a 1.4 k hg/ha increase. The best performers were all European countries, namely Switzerland, Netherlands, and Ireland. In addition, for the first two years of analysis Ghana had shown the weakest records whereas in 2016 the weakest records were found for Cabo Verde. As far as fruits crop is concerned, the annual mean CP dropped from about 138 k hg/ha to 103 k hg/ha between the years 1980 and 1992 and it recovered to about 125 k hg/ha in the final year of analysis. The same trend was also observed for the range of the min/max values. Similar to the pulses, the European countries of Denmark, Switzerland, and Netherlands were the best performers for the years 1980, 1992, and 2016, respectively. On the other side, French Guiana presented the weakest performance in the initial years of analysis before being replaced by Mauritania for the next two years. Finally, a steady increase of the annual mean CP was observed for the vegetables. What was different in this type of cultivation was the evolution of the range of the distribution which showed a rather stable picture. Moreover, differences were also observed in the group of the best performers as the Middle East country of Kuwait surpassed the performance of Ireland in the years 1992 and 2016. The group of the weakest countries was composed by Tonga, Brunei Darussalam, and New Caledonia.
In addition, the results of the $\sigma$-convergence analysis for all crop types are presented in Figure 1. The evolution of the CV values presented a rather mixed picture regarding the trend and the magnitude of dispersion of the different crops. More analytically, in 1980 the highest value dispersion was found for the fruits, in 1992 for the pulses, and in 2016 for the coarse grains. In addition, the evolution of the CV value for the cereals, coarse grains, and pulses presented similar characteristics, as it was described by an inversed u-shaped curve. More precisely, the CP for cereals and pulses showed a divergence trend during the 1980–1992 time period, followed by a strong $\sigma$-convergence trend in the following period. The convergence trend had, as a result, the CV of the last year of analysis to lie below its initial value. The same trend was also observed on the coarse grains CP indicator, with the difference lying at the fact that the $\sigma$-convergence of the second period did not end up at a CV value lower than that of 1980. On the other side, the CP of the fruits and vegetables presented a different trend from the other three crops. The CP of these two groups of products had presented an $\sigma$-convergence trend since the first period of analysis. For the fruits crops the most remarkable convergence was found in the first period when the CV value had been reduced by over 30%, whilst for the vegetables the $\sigma$-convergence was higher at the second period of analysis.

![Figure 1](image_url). The CV values of the CP indicator for the years 1980, 1992 and 2016.

Finally, the results of the $\beta$-convergence test for the CP indicator of the five crops are presented in Table 6. For all the crops and periods, the estimation of the convergence coefficient was negative but there were striking differences in the statistical significance of the estimations. For the cereals, in the first period no sign of $\beta$-convergence was found, as the estimation of the beta coefficient lacked statistical significance. On the other hand, the statistically significant estimation of the beta coefficient ($<0.01$) for the model of the second period denoted that productivity in cereals started to converge after 1992. The same held true for the coarse grains and vegetables production, as the beta coefficient turned from statistically insignificant in the first period to significant in the second period.

| Period      | F     | Adj R² | $\beta$ | $\alpha$ | Estimations          |
|-------------|-------|--------|---------|----------|----------------------|
|             |       |        |         |          | Cereals | Coarse Grains | Pulses | Fruits | Vegetables |
| 1980–1992   | 0.09  | 0.08   | -0.02   | 0.29     | 49.88 *** | 0.58 | 0.30 | 0.47 | 3.01 * |
|             | 0.01  | 0.05   | -0.05   | 0.56     | 123.97 ***| 0.33 | 0.28 ***| -0.59 ***| -0.08 |
| 1993–2016   | 23.08 ***| 0.16 | -0.36 ***| 4.04 ***| 7.99 *** | 0.06 | -0.33 ***| -0.12 | 3.48 * |
|             | 0.01  | 0.02   | -0.12   | 2.67 *** | 2.35     | 0.02 | 0.16 * | 2.09 ** | 10.09 ***|
|             | 4.02 ***| 0.29 | -0.29 ***| 3.73 ***| 2.09 ** | 0.06 | -0.29 ***| 3.73 ***|

Table 6. The results of the regression analysis of the CP indicator for the two periods of the study.

Statistical significance: (*** at the 0.01 level, (**) at the 0.05 level, (*) at the 0.1 level.
The opposite picture was observed in the CP indicator of the pulses. The estimations of the beta coefficient—significant in the first period and insignificant in the second—denoted that the convergence trend of the first period had stopped in the second one. Finally, for the fruits crop, the β-convergence presented similar characteristics with the σ-convergence. This was because the strong convergence pace of the first period, as denoted from the estimation of beta coefficient at the 0.01 significance level, was succeeded by a more modest convergence trend in the second period.

4. Discussion

The results of the paper have a particular interest for the ongoing debate around the future of agricultural sustainability and the relevant global policies. More precisely, the lack of any type of convergence regarding the generated value across the countries around the globe has shown that the liberalization of the market has not resulted in any substantial improvements regarding the competitive position of the weakest countries. On the other hand, a convergence of both σ and β type has been found for the energy efficiency of the countries. That is, liberalization may not have helped the weaker countries to start coping with the competition in terms of value, but it resulted in improvements in their energy efficiency and subsequently helped them to become more sustainable in environmental terms.

In addition, the policy changes of the early nineties have substantially improved the position of the weakest countries when the productivity of various agricultural products is concerned. More precisely, it was only after 1992 when the σ-divergence trends in the productivity of crops such as cereals, coarse grains and pulses were reversed to a path of convergence. Moreover, for the first two, the early nineties were also the starting point for a β-convergence process to evolve. The policies also had a positive effect on the productivity of vegetable cultivations, whilst it seems that they have slowed down a strong convergence process for the fruits productivity. Although contradicting, the different trends of value generation and productivity of most of the considered crops still may leave a room for a more optimistic view of the future since the productivity gains of the weakest countries provide hints that they are in a process of learning and adjusting the best practices of the stronger countries to their own particularities. Therefore, it may be the mix of crops that should be readjusted in order for the weakest countries to start capitalizing their productivity gains towards the generation of more added value from agriculture. The implementation of the new standardized global agricultural policy framework has verified that improvement of generated value, especially for weak countries, can be achieved with additional actions for increasing entrepreneurial performance and improving market access, even though there are not any more policy measures creating barriers to it.

Finally, as the comparison with past similar papers is concerned, it should be mentioned that since this paper had a quite differentiated methodological structure and geographical focus from the past similar studies, any results comparisons should be treated with caution. To this end, the value generation and the energy efficiency indicators cannot establish a basis for comparisons with past results. This should be only made on the basis of the productivity indicators. In geographical terms, the paper focus coincides with this of Coelli and Rao [11]. Given that a convergence trend was found for most of the crops assessed in the present paper, the results verify the findings of Coelli and Rao [11], who have indicated an improved performance of Asian and African countries. Moreover, an indirect comparison could be made with some papers employing the developed–developing countries assessment framework. To this end, the paper verifies the findings of Suhariyanto and Thirtle [12] who have observed that some groups of African countries systematically performed better than the Asian ones. Finally, it does not verify the findings of Csaki and Jambor [18] who have observed a lack of convergence between the developed countries of Europe and the less developed countries of former USSR in terms of land productivity.

5. Conclusions

The present study has mostly emerged as a response to the challenge of backing policy making with scientific methods and findings. As the analysis in the introduction section has shown, there is an
adequate number of studies testing the convergence hypothesis in the agricultural sector. Most of the studies have focused on groups of countries and tested the convergence hypothesis on the productivity indicator. Moreover, in general, the years of analysis have not been set up in a way to account for any remarkable policy interventions or any other phenomena that would bring about any structural changes in the agricultural sector. By acknowledging that these limitations render the evaluation of policies effectiveness and their real global impact rather understudied, the present paper followed a different methodological pathway that may pave the way for more detailed research of agricultural convergence on a global scale.

More precisely, the lack of data, especially for less developed countries, which renders the application of TFP difficult, was here confronted by estimating different kind of indicators, which still may provide valuable information for the overall performance of countries. Therefore, three different dimensions of agricultural performance, namely value generation, energy efficiency, and land productivity, have been used as the basis of the analysis. Moreover, research focused on different types of crops after acknowledging that policy interventions do not affect the various crops markets in the same way. In addition, in order for the research to have a strict policy evaluation orientation, the paper focused on a certain benchmark time point, this of the Uruguay Round and the CAP reform, which was used in order to drive the analysis in two distinct time periods. Given the fact that in the early 1990s, strategic and radical changes started taking place on both European and global levels, the division of this time period into two sub-periods is essential. The major difference between them is that developed countries, until 1992, were implementing agricultural policies characterized by increased protectionism, expressed by applying distorting trade measures and coupled subsidy schemes to specific cultivations [31]. The continuous CAP reforms, in collaboration with the Uruguay Round agreement, mitigated, in the following years, the negative impact of the previous policies and established homogenous policy approaches for both developed and developing countries. Therefore, the significance of assessing the convergence of the crop production sector by using common indicators, which are being used to assess policy performance too, is a novel approach tailored to the new status of agricultural production and trade. When convergence occurs, it signifies that horizontal policy approach is able to improve the performance of the sector. When it does not, there is a signal that further, perhaps more tailored to specific needs, action is required for the same target to be achieved.

Finally, the present paper is not free of weak points both in the methodology, but also in the data used to extract the results. More precisely, the paper has shed light only on a part of the dimensions that shape the overall performance of the agricultural sector. Therefore, the effect of the policies on the capital and labor productivity as well as on other environmental outputs of the sector, is not examined by the present study. Moreover, it should be noted that this paper relied on regression analysis to test the convergence hypothesis. This methodological setting provides insights of the average global trends but is not effective in highlighting the particularities of individual countries or group of countries. Therefore, the paper could be considered as a starting point for a more detailed analysis at the country level, as it allows the assessment of performance of individual countries on par with the general global trend. In addition, more detailed examination of the convergence trends, using the club convergence hypothesis [22] as the basis for analysis could shed more light on the dynamics of global agriculture, and across different types of countries such as the developed, developing, and the less developed ones. Moreover, analysis should also focus on other production processes, mainly animal production, which were not considered by the present paper. Finally, additional policy frameworks should be used as benchmarks for future studies. Considering the complexity of the sector, these policies should not only stem from the agricultural sector but also from wider domains, such as energy, environment, and finance, as they clearly have an effect on the performance of agriculture.

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References
1. World Bank. Agriculture, Value Added (% of GDP). Available online: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS (accessed on 5 January 2018).
2. Awokuse, T.O.; Xie, R. Does agriculture really matter for economic growth in developing countries? Can. J. Agric. Econ. Revue Can. D’Agrocon. 2015, 63, 77–99. [CrossRef]
3. Divanbeigi, R.; Paustian, N.; Loayza, N. Structural Transformation of the Agricultural Sector: A Primer; World Bank Policy Research Working Paper; World Bank: Washington, DC, USA, 2016.
4. Pretty, J.; Brett, C.; Gee, D.; Hine, R.; Mason, J.; Rayment, M.; Van Der Bijl, G.; Dobbs, T. Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture. J. Environ. Plan. Manag. 2001, 44, 263–283. [CrossRef]
5. Tilman, D. Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. Proc. Natl. Acad. Sci. USA 1999, 96, 5995–6000. [CrossRef] [PubMed]
6. Food and Agriculture Organization of the United Nations—FAO. The Role of Agriculture in the Development of LDCs and Their Integration into the World Economy; FAO: Rome, Italy, 2001.
7. Food and Agriculture Organization of the United Nations—FAO. Building a Common Vision for Sustainable Food and Agriculture. Available online: http://www.fao.org/3/a-i3940e.pdf (accessed on 14 May 2019).
8. World Trade Organization—WTO. Agreement on Agriculture. Available online: https://www.wto.org/english/docs_e/legal_e/14-ag_01_e.htm (accessed on 10 May 2019).
9. European Commission. The Common Agricultural Policy at a Glance. Available online: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en (accessed on 12 May 2019).
10. Henke, R.; Benos, T.; De Filippis, F.; Giua, M.; Pierangeli, F.; D’Andrea, M.R.P. The New Common Agricultural Policy: How do Member States Respond to Flexibility? J. Common Mark. Stud. 2018, 56, 403–419. [CrossRef]
11. Coelli, T.J.; Rao, D.P. Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980–2000. Agric. Econ. 2005, 32, 115–134. [CrossRef]
12. Suhariyanto, K.; Thirtle, C. Asian agricultural productivity and convergence. J. Agric. Econ. 2001, 52, 96–110. [CrossRef]
13. Galanopoulos, K.; Surry, Y.; Mattas, K. Agricultural productivity growth in the Euro-Med region: Is there evidence of convergence? Outlook Agric. 2001, 40, 29–37. [CrossRef]
14. Rezitis, A.N. Agricultural productivity and convergence: Europe and the United States. Appl. Econ. 2010, 42, 1029–1044. [CrossRef]
15. Poudel, B.N.; Paudel, K.P.; Zilberman, D. Agricultural productivity convergence: Myth or reality? J. Agric. Appl. Econ. 2011, 43, 143–156. [CrossRef]
16. Barath, L.; Fertó, I. Productivity and convergence in European agriculture. J. Agric. Econ. 2017, 68, 228–248. [CrossRef]
17. Kijek, A.; Kijek, T.; Nowak, A.; Skrzypek, A. Productivity and its convergence in agriculture in new and old European Union member states. Agric. Econ. 2019, 65, 1–9. [CrossRef]
18. Csaki, C.; Jambor, A. Convergence or divergence—Transition in agriculture of Central and Eastern Europe and Commonwealth of Independent States revisited. Agric. Econ. 2019, 65, 160–174. [CrossRef]
19. EU Regulation (EU) No 1307/2013 of the European Parliament and of the Council. Establishing Rules for Direct Payments to Farmers Under Support Schemes within the Framework of the Common Agricultural Policy and Repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32013R1307&from=EN (accessed on 13 July 2019).
20. Kennedy, P.L.; Koo, W.W.; Marchant, M.A. Key issues and challenges for the 1999 World Trade Organization agriculture round. Am. J. Agric. Econ. 1999, 81, 1134–1141. [CrossRef]
21. European Commission. CAP Indicators. Available online: https://agri.data.ec.europa.eu/extensions/DataPortal/cmei_indicators.html (accessed on 13 July 2019).
22. Artelaris, P.; Kallioras, D.; Petrakos, G. Regional inequalities and convergence clubs in the European Union new member-states. East. J. Eur. Stud. 2010, 1, 113.
23. Barro, R.; Sala-i-Martin, X. Convergence. *J. Political Econ.* 1992, 100, 223–251. [CrossRef]
24. Krugman, P.R. Increasing Returns and Economic Geography. *J. Political Econ.* 1991, 99, 183–199. [CrossRef]
25. Dalggaard, C.J.; Vastrup, J. On the measurement of σ-convergence. *Econ. Lett.* 2001, 70, 283–287. [CrossRef]
26. Barro, R.J.; Sala-i-Martin, X. *Economic Growth*; McGraw Hill: Boston, MA, USA, 1999.
27. Sala-i-Martin, X. The Classical Approach to Convergence Analysis. *Econ. J.* 1996, 106, 1019–1036. [CrossRef]
28. Vlontzos, G.; Niavis, S.; Pardalos, P. Testing for Environmental Kuznets Curve in the EU Agricultural Sector through an Eco-(in)Efficiency Index. *Energies* 2017, 10, 1992. [CrossRef]
29. Yan, Q.; Yin, J.; Baležentis, T.; Makutenienë, D.; Štreimikiene, D. Energy-related GHG emission in agriculture of the European countries: An application of the Generalized Divisia Index. *J. Clean. Prod.* 2017, 164, 686–694. [CrossRef]
30. Faostat. Available online: http://www.fao.org/faostat/en/ (accessed on 27 February 2019).
31. Vlontzos, G.; Niavis, S. Assessing the evolution of technical efficiency of agriculture in EU countries: Is there a role for the Agenda 2000? In *Agricultural Cooperative Management and Policy*, Zopounidis, C., Kalogeras, N., Mattas, K., Van Dijk, G., Baourakis, G., Eds.; Springer International Publishing: Cham, Switzerland, 2014; pp. 339–351.

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