

Article

Convergence of Agricultural Labour Productivity in the EU: Evidence from Farms by Economic Size

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Abstract

The study analyzes agricultural labour productivity in the context of the economic dimension of sustainability and the idea of European Union (EU) cohesion. This idea constitutes a central principle of European integration. The basis for implementing the concept of cohesion in European agriculture is the convergence of labour productivity levels. Convergence in this area forms the foundation of economic sustainability and serves as a prerequisite for the social dimension of sustainability, while often also being an underlying factor in environmental sustainability. The analysis concerns the productivity of labour in farms by the economic size, both at the national and regional levels, based on Farm Accountancy Data Network (FADN) data for the years 2007–2022. The β and σ -convergence methods were used. The results indicate that processes of labour productivity convergence occur in EU agriculture. This phenomenon was manifested by a decline in the heterogeneity of labour productivity levels among agricultural holdings. The fastest reduction in regional diversity was observed among the group of the largest economically farms (GE6). However, the dispersion of labour productivity levels remains considerable, and the rate of convergence continues to be slow. The convergence of labour productivity in agriculture will not accelerate without widespread and comprehensive structural changes in the sector, extending beyond mere changes in land use patterns.

Keywords: sustainability; economic dimension; convergence; FADN; economic size; farms

1. Introduction

1.1. Labour Productivity and Its Role in the Concept of Sustainable Development of Agriculture and the Idea of EU Cohesion

In this study, we analyze agricultural labour productivity across different groups of farms classified by economic size, in the context of the economic dimension of sustainability and the idea of EU cohesion. Among various contemporary approaches to socio-economic development, the concept of sustainable agricultural development occupies a central place. Research within this concept escapes clear disciplinary boundaries, as sustainable agriculture is inherently an interplay of natural, social, economic, political, and geographical phenomena and factors [1]. The sustainable development of agriculture is based on the synergy of three fundamental dimensions: environmental, economic, and social [2–5]. The literature presents numerous studies that address agricultural sustainability at various levels. Although most analyses focus primarily on the environmental

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dimension, some also examine the social and economic dimensions individually or all three simultaneously. A comprehensive review of the literature in this field was conducted, among others, by Sulewski et al. [3]. As the authors' findings on the relationships between the three dimensions of farm sustainability indicate, in practice, it is difficult to achieve the paradigm of sustainable development across all dimensions simultaneously, although it remains desirable. Nowadays, this represents one of the greatest challenges for the Common Agricultural Policy (CAP). It is worth emphasizing that the primary objectives of the CAP in the 1960s were to maintain and ensure food supplies and an adequate standard of living for producers. These objectives were therefore aimed at addressing socio-economic issues. The first measures addressing environmental sustainability were introduced by the McSharry reform in 1992 and were systematically expanded as the CAP evolved.

As previously indicated, this manuscript concentrates on the economic dimension of sustainable development. Dillon et al. [6] emphasize that to achieve other goals, farms must be profitable, although this must be achieved with respect for the natural environment. The economic dimension of sustainability is crucial for ensuring the long-term profitability of enterprises by promoting efficient resource use, resilience to market fluctuations, and innovation in response to global challenges [2]. A strong economic base enhances the socio-economic resilience of farms—and, more broadly, of the entire agricultural sector—and enables adaptation to climate change [4]. One of the elements of the economic dimension is the productivity of labour resources, which is closely linked to the social dimension of sustainability. Socially sustainable development includes, among other aspects, ensuring employment, decent working conditions, and satisfactory income. These issues appear even more critical in a sector such as agriculture, where outputs are strongly dependent on weather conditions. From an economic perspective, higher labour productivity directly affects farm income generation capacity and thus constitutes a key determinant of farmers' economic welfare. In this sense, labour productivity is closely linked to the economic dimension of sustainability, as it reflects the efficiency of resource use and the ability of farms to remain economically viable in the long term. It may therefore be concluded that without economic sustainability, achieving social sustainability is not possible. Moreover, as Sanyaolu and Sadowski [5] highlight, adequate economic strength of farms and management efficiency (including the efficient use of mineral fertilizers and plant protection products enabled by input-saving technologies such as precision agriculture or Agriculture 4.0) are often prerequisites for the environmental dimension of sustainable development.

A central principle of European integration is the idea of cohesion. All European Union (EU) policies should promote cohesion by reducing disparities in citizens' prosperity. This also applies to the Common Agricultural Policy, which is the second largest in terms of budget after the cohesion policy in the EU. CAP is a deliberate strategy aimed at fostering harmonious agricultural development while also promoting economic, social, and territorial cohesion [7]. However, the objective of the Common Agricultural Policy is not to standardize agriculture. Moreover, its diversity is regarded as a competitive advantage in the global market. The primary objective of CAP should be the reduction of disparities in farmers' welfare. Achieving this goal necessitates a convergence in the level of labour productivity in agriculture, particularly with regard to the profitability of labour inputs.

In a broader perspective, the efficient use of productive resources is currently one of the key factors determining international and global competitiveness. The efficient use of labour resources, that is, achieving high productivity, is an issue of particular importance in this regard. Maintaining it at an adequate level entails a reduction of costs, an augmentation of the supply of less expensive goods and services, stimulation of the market, and an increase in the purchasing power, wealth, and competitiveness of societies. This

phenomenon is relevant to all sectors of the economy, including agriculture. The issue of agricultural labour productivity assumes particular importance in the context of integration processes. It needs to be emphasized that, as it remains low in numerous EU countries, it constitutes a substantial impediment to economic advancement and income parity. Furthermore, changes in labour productivity have a substantial impact on the dynamics and costs of integration at the European and global levels, as well as on the degree of reduction of significant differences in the level of socioeconomic development between EU countries [8]. The reduction of territorial disparities between member countries and regions has been identified as a fundamental objective of integration processes [7].

Despite the wealth of literature on labour productivity in the European Union, most existing studies analyze differences in productivity at the national level. Much less attention has been paid to differences between farms of varying economic size. Meanwhile, farm size is a key factor determining resource efficiency, technology adoption, income generation, and resilience to market and environmental shocks. Consequently, ignoring structural differences between groups of farms can obscure important differences in productivity and welfare and lead to misleading conclusions about the effectiveness of the Common Agricultural Policy in promoting cohesion. Therefore, a more detailed analysis that explicitly considers the economic size of farms seems necessary.

1.2. The Concept of Convergence

Scientific research often addresses issues related to assessing the effectiveness of convergence achieved by countries or regions associated with various groupings. Convergence is defined as a tendency for differences in the level of development between countries or regions to decrease, while divergence signifies the opposite process. The extant research on these phenomena primarily focused on verifying the hypothesis of convergence of GDP per capita or labour productivity [9–22]. Concurrently, emphasis is placed on the notion that the degree of convergence is contingent upon the homogeneity of the group under investigation. Therefore, convergence processes are evident in developed countries (or groups of countries), while polarization tendencies are apparent on a global scale. A narrowed scope of the results of the aforementioned studies, focusing exclusively on the European Union, reveals positive trends in the equalization of income levels among its member states. Concurrently, it has been observed that the decline in income dispersion between the EU-15 and the EU-13 (the group of old and new member states) is more pronounced than that identified within the Community as a whole. In this context, a positive correlation can be observed between European integration and economic convergence. Note also that the strength of this process remains indeterminate due to the utilization of disparate convergence analysis methodologies and temporal perspectives in extant empirical studies.

Convergence in the agricultural sector across countries worldwide has also been extensively examined in the literature. For instance, Suhariyanto and Thirtle [23] investigate convergence processes in the agricultural sectors of eighteen Asian countries, from 1965 to 1996. McErlean and Wu [24] focus on the case of Chinese administrative regions and test the agricultural labour productivity convergence hypothesis for the period 1985–2000, while Ghosh [25] and Kumar et al. [26] point to regional disparities in agricultural development across Indian states. Furthermore, a study by Gutierrez [27] explores convergence in United States agriculture, whereas Rezitis [28] conducts a comparative analysis of the United States and the European Union. With regard to the European Union, this issue has also been addressed, among others, by Alexiadis [29], Galanopoulos [30], Cuerva [31], Barráth and Fertő [32], Hamulczuk [33], and Calejari et al. [34].

Numerous studies also address the issue of labour productivity in the EU agriculture. These include the works of Swinnen and Vranken [35], Gołaś and Kozera [36],

Kołodziejczak [37], Góral and Rembisz [38], Jaroszewska and Pietrzykowski [39], Parzonko [40], Adamowicz and Szepulak [41], Ball et al. [42], Kisielińska [43]. When narrowing the focus to papers concerning labour productivity where inference is based on convergence models, several noteworthy publications can also be found [8,44–49]. For example, Grzelak and Brelik [44], by examining income changes between Polish FADN regions in 2004–2008, identified both β and σ -convergence. Jaroszewska and Rembisz [46] analyzed changes in the level of differentiation of labour productivity in agriculture in EU countries between 1998 and 2015. The results indicated that convergence processes in labour productivity in EU agriculture were observed after 2011. The tendency to reduce the differences between EU countries in terms of labour productivity was also proved by Baer-Nawrocka and Markiewicz [45] and Nowak [48]. However, it was pointed out that there is still a high level of spatial disparities and a slow pace of eliminating these differences. The rise in labour productivity within the EU can be attributed mainly to a decline in employment in new EU Member States (EU-13), with a comparatively lesser impact from an increase in value added. Consequently, a convergence of labour productivity in the Community's agriculture emerged, although its pace was regarded as poor. The European Commission's 2023 report [50] emphasizes that in the coming years, there will be further convergence of labour productivity levels in EU agriculture, mainly due to the increase in labour productivity in the Member States that joined the EU after 2004 (EU-13). At the same time, it is argued that differences in this respect between countries will continue to persist.

Although numerous studies have examined convergence in the EU agriculture, little is known about convergence processes in different types of farms operating within the same policy and market environment. In particular, the question of whether labour productivity gaps between farms of different economic sizes and within these groups are narrowing over time remains insufficiently explored. This represents an important research gap, as persistent disparities in these areas may limit improvements in farmers' welfare, in general, as a social group.

To address this gap, the main aim of this study is to assess whether productivity differences between and within farm groups classified by economic size in the European Union decrease over time at both national and regional levels. Accordingly, the study tests the hypothesis that agricultural labour productivity exhibits convergence across all economic size classes of farms. By providing a more disaggregated perspective, the paper contributes to a better understanding of structural inequalities in EU agriculture and offers evidence relevant for the design of cohesion-oriented agricultural policies. This is particularly significant in that the convergence of labour productivity is a fundamental condition for achieving economic and social cohesion in EU agriculture. Cohesion, in turn, is essential for reducing disparities in the standard of living and overall well-being of the agricultural population.

This paper includes the following sections: an introduction that comprises a review of the extant literature on the subjects discussed and the objectives of the study, followed by the presentation of the research material and methods used. Subsequent to this introduction, the results of the study on the analysis of labour productivity at the level of countries and FADN regions are presented so as to consider farm groups established based on their economic size. The paper concludes with a summary of the main findings.

2. Materials and Methods

2.1. Data

The study relied on FADN data (Farm Accountancy Data Network) for the period 2007–2022. FADN, as a European system for collecting accounting data from agricultural holdings, is mandatory for all EU countries and covers approximately 85,000 farms.

Holdings covered by the FADN, of which the sample is representative, include only commercial farms that produce 90% of the SO (Standard Output) in a given region or country. It is defined as the 5-year mean value of the yield of a specific agricultural activity (crop or livestock) obtained from 1 hectare or 1 animal per year, under average production conditions for the region. The number of farms covered by the FADN is determined by the cumulative summation of the SO values of individual farms (from the largest to the smallest) until the SO value attains 90%. To safeguard the confidentiality and personal information of agricultural producers, each sample of farms must comprise a minimum of 15 farms. Standard Output (SO) serves as a foundation for the Community typology of agricultural holdings, with the classification system being based on economic size and the type of farming practiced. Another level of stratification of agricultural holdings is their regional location [51–53]. It should be underlined that the FADN is the only instrument that provides harmonized micro-economic data for farms in the EU. Derived from national surveys, the data is not only used to evaluate the income of agricultural holdings, but also to assess the overall achievements and impacts of the Common Agricultural Policy. Moreover, the quality of FADN data in farm economic sustainability assessment is also widely acknowledged in the literature [54]. It is worth noting that from 2025 onwards, the FADN system has been transformed into the Farm Sustainability Data Network (FSDN). In addition to the variables assessing the production and economic situation of agricultural holdings, environmental and social variables have been introduced in order to enable the monitoring of the level of sustainability of agriculture in the European Union. Focusing on the economic dimension of sustainability, it should be noted that various economic and financial categories can be used to assess labour productivity depending on the data source and the purpose of the analysis. We use Gross Farm Income (GFI) per AWU (Annual Work Unit) to ascertain labour productivity. In line with the FADN methodology, Gross Farm Income (under the symbol SE410 in FADN) is calculated as the output minus intermediate consumption plus the balance of current subsidies and taxes (excluding subsidies for investments).

The analysis covered 25 EU member states and their FADN regions (Table S1 in Supplementary Materials). Cyprus, Malta, and Croatia were excluded from the analysis. The share of farms from Cyprus and Malta in the total number of EU farms covered by the FADN system is marginal, amounting to 0.3% and 0.05%, respectively. Farms in these countries are, on average, characterized by a very small agricultural area (one-third of the farms included in the FADN system in these countries are classified as very small or small). Due to statistical confidentiality, data for certain groups of farms in these countries were often unavailable. Moreover, the specific nature of agricultural production in Cyprus and Malta—focused mainly on permanent crops and horticulture—differs significantly from the average structure of farms in other continental EU countries. Croatia was excluded from the study because it joined the European Union in 2013, nearly halfway through the analyzed period. As discussed later in this article, a key assumption underlying the treatment of EU Member States as a single convergence club was the inclusion of countries fully covered by the Common Agricultural Policy framework.

The number of FADN regions initially amounted to 141, but it varied across years and economic size classes. The exclusion of certain regions from the analysis resulted from the rules previously mentioned—the principle of statistical confidentiality and the requirement that the sample include farms accounting for at least 90% of the Standard Output. In some cases, regions did not meet these criteria, and data for them were therefore not published in the FADN database and could not be included in the analysis.

2.2. Methods

The study on the assessment of labour productivity in agriculture and the structure of farms by economic size relied on selected descriptive statistics supported by tabular and graphical presentation of data. This approach enabled the estimation of the magnitude of spatial variation within the area concerned.

The β and σ -convergence methods were employed to ascertain the extent of regional diversity in labour productivity across distinct farm groups based on economic size. The first of these, β -convergence, posits that entities exhibiting a lower initial level of the examined feature (variable), e.g., countries at a lower initial income level, demonstrate a higher growth rate than more developed countries. This phenomenon results in the progressive equalization of per capita income within the analyzed group of economies. The analysis of β -convergence can be categorized into two distinct classifications: unconditional (absolute) or conditional. Absolute convergence posits that all entities, such as economies, are progressing toward a uniform level of per capita income. Conversely, the concept of β conditional convergence asserts that each economy endeavours to attain its distinct level of prosperity, contingent on its inherent characteristics. A positive β coefficient is indicative of accelerated development in less prosperous economies and is interpreted as the annual rate of convergence. The second method of examining these aspects, known as σ -convergence, is employed to ascertain the extent of variation in a variable (feature). To illustrate, it can be used to determine per capita income in a given group of economies (e.g., countries or regions). The hypothesis of σ -convergence is typically tested by employing measures such as standard deviation or variance. The reduction in σ -convergence in the time horizon studied suggests that the disproportions in the levels of the variable under examination (e.g., economic development at the country level) tend to decline [55,56].

The relationship between the above-mentioned types of convergence was presented in an accessible way by Sala-i-Martin [10]. Based on the course of the log of GDP of two economies, A and B, over time, he explained how β -convergence is or is not related to σ -convergence. He prepared three simulations: Panel A, Panel B, and Panel C (Figure 1). In all cases, at the initial analysis period, economy A was richer than economy B. In Panel A, the growth rate of economy A was smaller than the growth rate of economy B—it means that β -convergence was occurring. Dispersion between economies A and B decreased over time; thus, σ -convergence also took place. In Panel B, the growth rate of economy A was greater than the growth rate of economy B. As a result, we noticed a lack of β -convergence. The distance between economies A and B at time $t + T$ increased; therefore, there was also a lack of σ -convergence. An interesting example is shown in Panel C. In this case, the growth rate of the poor economy (B) was so much higher than the growth rate of economy A that, in period $t + T$, economy B became richer. We can observe β -convergence, but the lack of a reduction in the dispersion between economies A and B in the period $t + T$ indicates a lack of σ -convergence.

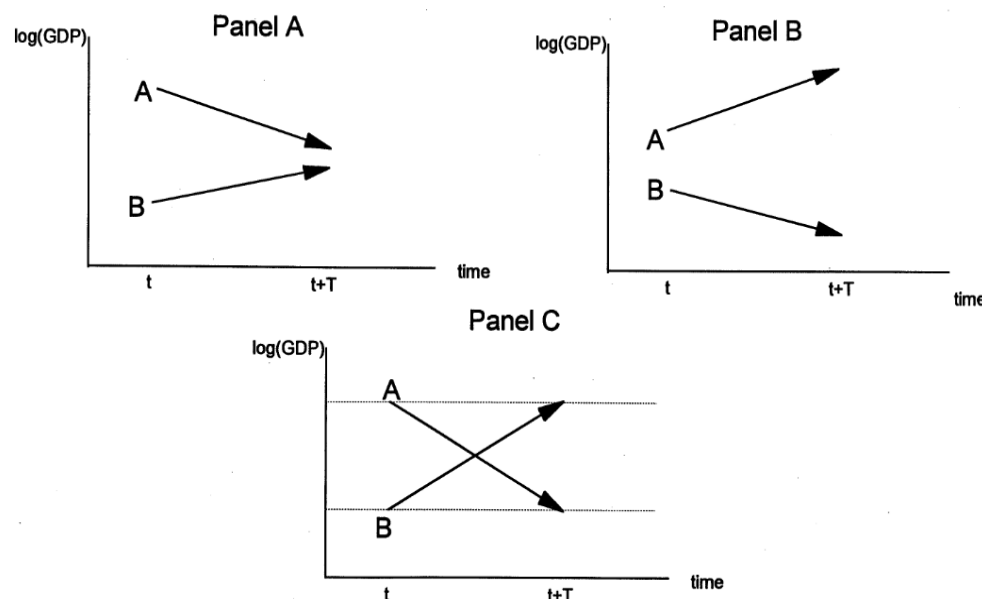


Figure 1. The relations between β and σ -convergence. Source: [10].

As previously mentioned, when defining the concept of β -convergence, attention is drawn to its two variants: unconditional (absolute) and conditional. Conditional β -convergence assumes that a negative correlation between the GDP per capita growth rate and its initial level occurs if, within a given group of economies, certain parameters take on similar values. Economies that differ in such parameters—for instance, the propensity to save—will converge toward different steady states. Therefore, this assumption is weaker compared to the verification of the unconditional β -convergence hypothesis. However, the hypotheses of unconditional and conditional β -convergence coincide in situations where all economies converge toward the same equilibrium state. In the context of conditional convergence, particular attention is given to a specific case known as club convergence. This phenomenon refers to the existence of multiple locally stable equilibrium states toward which economies with similar structural characteristics tend to converge. As a result, clusters of economies emerge, each characterized by distinct steady states. Within these clusters, income disparities tend to diminish; however, no convergence is observed between clusters. Moreover, club convergence may lead to the polarization of regions [55,56]. Determining the composition of convergence clubs presents certain methodological challenges for researchers. The literature identifies two principal approaches to testing conditional β -convergence. The first involves incorporating a vector of control variables into the regression equation to account for the determinants of the steady state, with different models employing different sets of variables. The second approach examines convergence within groups of economies for which the assumption of a similar steady state appears justified [55]. The group of EU countries included in the study is subject to the Common Agricultural Policy, under which identical instruments and rules apply to all member states. Therefore, it has been assumed that these countries constitute a single convergence club.

In this publication, the β -convergence hypothesis for labour productivity was verified in its unconditional variant by estimating the following equation [57]:

$$\frac{1}{T} \ln \frac{y_T}{y_0} = \alpha_0 + \alpha_1 \ln y_0$$

where

y_T : value of the analyzed variable in the final period;

y_0 : value of the analyzed variable in the initial period;

T : number of periods.

Subsequently, employing the established parameter α_1 , the β -convergence coefficient was determined through the use of the following formula [57]:

$$\beta = -\frac{1}{T} \ln(1 + \alpha_1 T)$$

In turn, the following formula was used to verify the σ -convergence hypothesis [55]:

$$\sigma_t = \sqrt{\sum_{i=1}^n (\ln y_{it} - \ln \bar{y})^2}$$

where

i : region index;

y_{it} : value of the analyzed variable in the i -th region in period t ;

$\bar{y}_t$: mean value of the analyzed variable in period t .

As Young et al. [58] have emphasized, β -convergence is a necessary condition for σ -convergence to occur, but it is not sufficient on its own.

3. Results and Discussion

3.1. Labour Productivity on All FADN Farms

Table 1 presents data on Gross Farm Income per AWU in EU countries from 2007 to 2022. In 2022, the average labour productivity in agriculture in the European Union was EUR 39,600 per AWU. In the agricultural sector of the EU-15 countries, the value of the indicator under analysis was more than double that of the countries that joined the EU in 2004–2013 (EUR 50,200 per AWU and EUR 23,500 per AWU, respectively). The highest labour productivity in agriculture was recorded in Denmark (EUR 177,800 per AWU), Luxembourg (EUR 129,400), and the Netherlands (EUR 110,200 per AWU). Among the recently acceded member states, higher values than the EU-25 average for the analyzed variable were recorded in Estonia, the Czech Republic, Hungary, and Slovakia. The remaining countries, particularly Romania, Poland, Slovenia, and Latvia, exhibited notably smaller labour productivity in agriculture. The reasons why Romania and Poland recorded some of the lowest values of the indicator among all EU countries can be found in the still high percentage of people employed in the agricultural sector [59].

Table 1. Gross Farm Income per full-time employee in EU countries in 2007–2022 (EUR).

Countries	2007	2011	2015	2019	2022	2022 (2007 = 100)	Change Between 2007 and 2022
Belgium (BE)	54,418	52,189	51,005	67,190	87,708	161.2	33,291
Bulgaria (BG)	3894	8517	12,110	18,758	33,171	851.7	29,276
Czech Republic (CZ)	17,333	24,842	26,569	33,985	47,581	274.5	30,248
Denmark (DK)	82,157	110,221	90,433	119,603	177,805	216.4	95,649
Germany (DE)	47,149	49,097	50,520	62,457	87,820	186.3	40,671
Estonia (EE)	16,630	23,265	26,959	39,345	67,266	404.5	50,636
Ireland (IE)	30,407	31,099	30,825	32,860	53,977	177.5	23,570
Greece (EL)	15,563	15,528	15,374	15,908	20,639	132.6	5076
Spain (ES)	25,871	22,811	29,024	34,277	38,122	147.4	12,250
France (FR)	47,771	52,936	50,182	52,824	71,584	149.8	23,813
Italy (IT)	27,722	27,876	34,919	36,269	41,519	149.8	13,797
Latvia (LV)	10,538	11,386	15,520	20,877	27,408	260.1	16,870

Lithuania (LT)	11,176	12,652	13,833	17,348	33,708	301.6	22,532
Luxembourg (LU)	65,989	70,029	75,797	97,742	129,367	196.0	63,378
Hungary (HU)	18,426	23,799	22,366	30,969	41,298	224.1	22,871
Netherlands (NL)	60,707	64,721	72,665	85,035	110,214	181.5	49,506
Austria (AT)	32,960	34,013	30,357	43,873	63,389	192.3	30,428
Poland (PL)	8834	9894	9417	13,530	22,120	250.4	13,286
Portugal (PT)	9912	11,541	14,813	16,579	22,957	231.6	13,045
Romania (RO)	2739	6081	5364	12,686	16,143	589.4	13,404
Slovenia (SL)	7533	9833	9902	15,064	26,241	348.3	18,708
Slovakia (SK)	16,388	18,749	22,225	28,938	43,278	264.1	26,890
Finland (FI)	42,103	45,163	48,264	56,746	79,710	189.3	37,608
Sweden (SE)	47,994	51,635	53,216	57,907	92,845	193.5	44,851
United Kingdom (UK) *	51,259	58,103	46,870	51,518	–	–	–
EU-25	19,791	22,251	22,454	30,446	39,613	200.2	19,822
EU-15	31,513	32,696	35,333	39,766	50,164	159.2	18,651
EU-10	5782	8876	8608	15,547	23,523	406.8	17,741
Weighted coefficient of variation (%)	108.4	110.4	99.0	89.5	97.7	–	–

Note: * The analyses did not include data for the United Kingdom from 2021. Source: Own calculations and compilation based on the FADN database.

Concurrently, an examination of the shifts in labour productivity within the agricultural sector of EU countries reveals that the majority of new member states exhibited higher increases in the index (in absolute terms) than their initial level (value) at the commencement of the analysis period. While numerous EU-15 nations exhibited comparable or higher absolute increases in income per person employed in agriculture, when evaluated against the initial level, these increases were less substantial than those observed in the EU-10 countries. As a result of the changes under consideration, the diversity of labour productivity in EU countries decreased in 2022 compared to 2007. This assertion is corroborated by an examination of the relative dispersion of the analyzed variable within the collective of all EU member states, expressed as the coefficient of variation. Despite maintaining a high level in 2022, the coefficient of variation underwent a decrease during the period under review. This finding suggests a positive shift in reducing territorial disparities in the compensation of agricultural labour. These effects are consistent with the narrative of fostering cohesion in the domain of welfare, articulated through the concept of remuneration for labour.

3.2. Labour Productivity on Farms by Economic Size Class

3.2.1. Farm Structure

In comparative analyses of agricultural farms in different countries, due to the wide variety of farm types and types of crops and livestock raised, one of the basic elements is the use of a single measure. This measure is defined as the economic size of farms. As previously stated, it is determined using the Standard Output (SO), which is then allocated to a specific economic size class of farms (Table 2).

Table 2. Classification of farms by economic size in the FADN methodology (EUR).

Symbol	Name	Economic Size (EUR)
GE1	extremely small	2000 *–8000
GE2	small	8000–25,000
GE3	medium-small	25,000–50,000
GE4	medium-large	50,000–100,000
GE5	large	100,000–500,000
GE6	extremely large	>500,000

Note: * The minimum threshold of EUR 2000 applied in accordance with EU Regulation 2015/220 only to Bulgaria and Romania. Since 2016 in Bulgaria and since 2018 in Romania, the minimum threshold has been EUR 4000. Source: FADN 2025.

Figure 2a illustrates the changes in the composition of agricultural holdings within the European Union during the period from 2007 to 2022, which have been categorized into six distinct groups based on their economic size (GE1–GE6). In 2007, farms classified as extremely small and small (GE1 and GE2, respectively) constituted approximately 70% of all farms, in which GE1 accounted for nearly 45%. In subsequent years, there was a steady decrease in their share, and in 2022, farms in these two groups accounted for approximately 52%, with the majority (34%) being farms in GE2. Concurrently, a discernible surge in farms was observed in GE5–GE6. In 2022, farms from these two largest groups accounted for a total of over 19%, compared to less than 11% in 2007. In this context, it is imperative to accentuate that large and extremely large farms generate over 75% of the total output of all farms covered by the FADN within the European Union (Figure 2b). Concurrently, the contribution of extremely small and small farms to total output diminished considerably, amounting to less than 8% in the most recent year examined, in contrast to 18% in 2007. Medium-sized farms (GE3–GE4) maintain a relatively stable, albeit moderate, share in total SO. This data substantiates the assertion that, despite their limited representation, the largest farms play a pivotal role in generating economic value within the EU agricultural sector. This phenomenon can be attributed to their superior scale of production, which is strongly influenced by large amounts of productive inputs and the level of production intensity. Additionally, they enjoy enhanced access to technology and abundant investment opportunities. Concurrently, it is noteworthy that the structure of farms grouped by economic size and the proportion of farms from each group in total output exhibits considerable variation across EU countries (Figure 3). In the Benelux countries, France, Germany, and Denmark, large and extremely large farms (GE5 and GE6) account for the greatest share of total farms (between 60% and 80%). At the same time, these farms contribute approximately 90% to the total output of all FADN farms within these nations. Among the new member states, the percentage of farms in these groups exceeding the EU average was recorded only in Slovakia, the Czech Republic, and Estonia, where large and extremely large farms generate 80–90% of total output. In contrast, the majority of EU-10 countries exhibit a more fragmented agricultural structure, which consequently leads to a more dispersed total output. This phenomenon is especially evident in countries such as Romania, Slovenia, and Poland. A significantly smaller percentage of the economically largest farms can be found in countries such as Lithuania, Latvia, Hungary, and Bulgaria. However, these farms generate a relatively higher share of total output compared to farms in Romania, Slovakia, and Poland, reaching 65–79%.

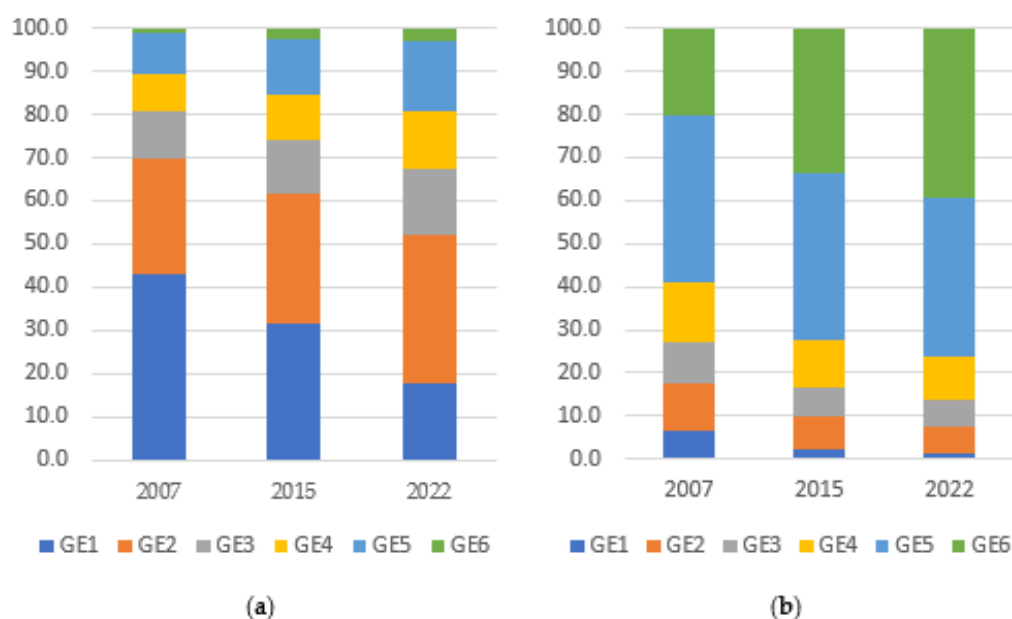


Figure 2. (a) Structure of farms grouped by economic size in the EU between 2007 and 2022. (b) Contribution of farms grouped by economic size to total output in the EU from 2007 to 2022. Source: own calculations and compilation based on the FADN database.

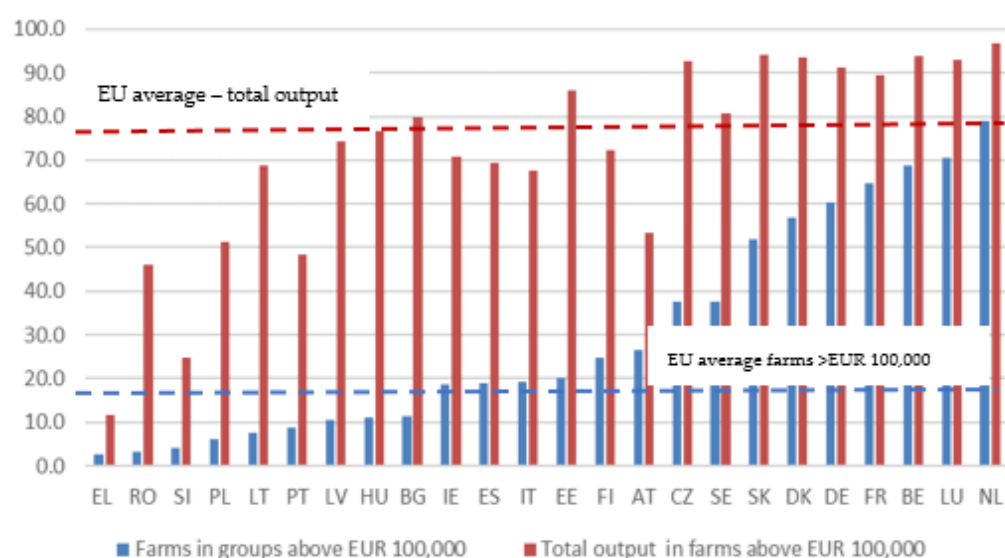


Figure 3. Farms and total output in the economic group of farms above EUR 100,000 (GE5 and GE6) in EU countries (share in the total number and total output of FADN farms) (%). Source: own calculations and compilation based on the FADN database.

The data presented in Figure 4 demonstrates that in the years under consideration, there was a decline in the proportion of the smallest farms (from the GE1–GE2 groups). The most significant changes in GE1 farms were observed in Bulgaria (−53 percentage points) and Romania (−36 percentage points). Apart from the ongoing structural changes in the farm sectors of these countries, this decline was also influenced by the increase in the minimum economic size threshold for farms included in the FADN sample, which was raised from EUR 2000 to EUR 4000 (in Bulgaria in 2016 and in Romania in 2018). A similar trend is also evident in Italy, Spain, Estonia, and Ireland. Concurrently, the most substantial increases in the proportion of farms in groups GE5 and GE6 are witnessed in these very countries, as well as in France, Austria, the Czech Republic, Slovakia, and

Latvia. Increases in the largest farm groups are also evident in other EU countries. Notably, exceptions to this trend were observed in countries such as the Netherlands and Denmark, where a decline in the number of farms in the GE5 group was accompanied by the largest relative increase in the GE6 group. These changes signify ongoing transformations in the economic structure of farms, increasing the role of medium-sized and large holdings.

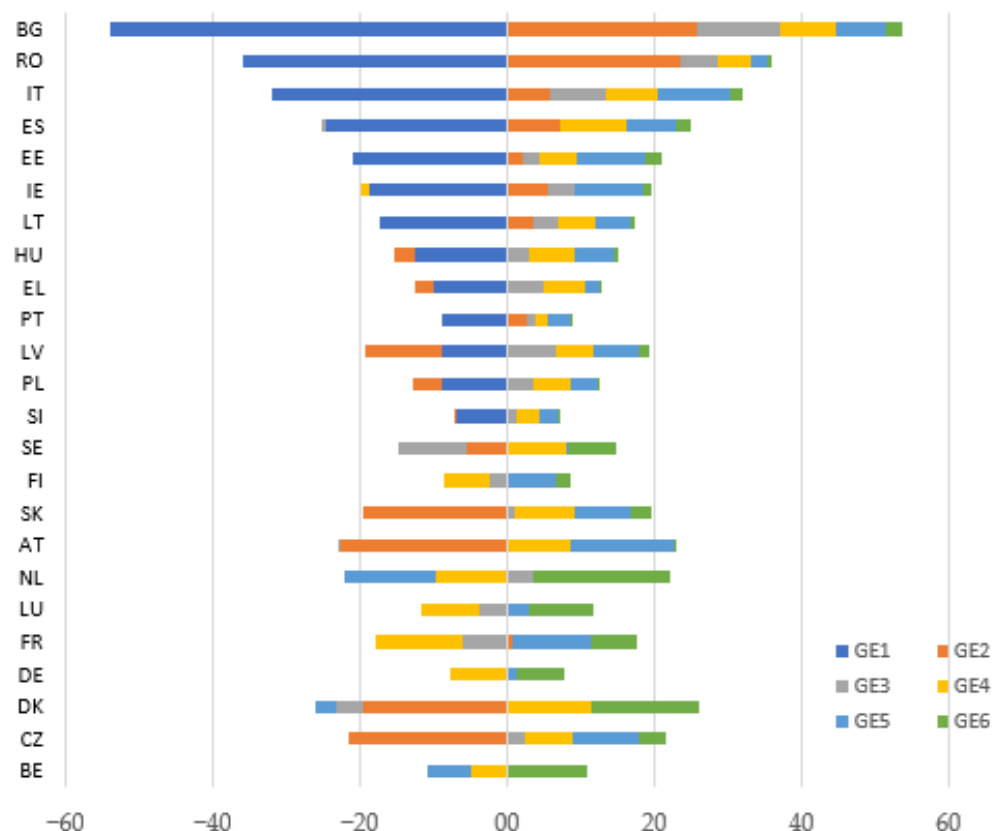


Figure 4. Changes in the structure of FADN farms grouped by economic size in EU countries from 2007 to 2022 (in percentage points). Source: own calculations and compilation based on the FADN database.

An analysis of GFI/AWU in economic groups of farms reveals a discernible increase in the level of GFI/AWU with growing economic size (Figure 5). The lowest values from 2007 to 2022 were observed in the smallest farms (GE1), where the average GFI/AWU level was recorded at barely EUR 4400, and the highest in the GE6 group, with an average of EUR 57,200. Concurrently, all farm groups exhibited low or moderate variability in terms of labour productivity. The coefficient of variation ranged from approximately 9–10% in groups GE2–GE4 to just over 20% in group GE6 (which is an open class interval).

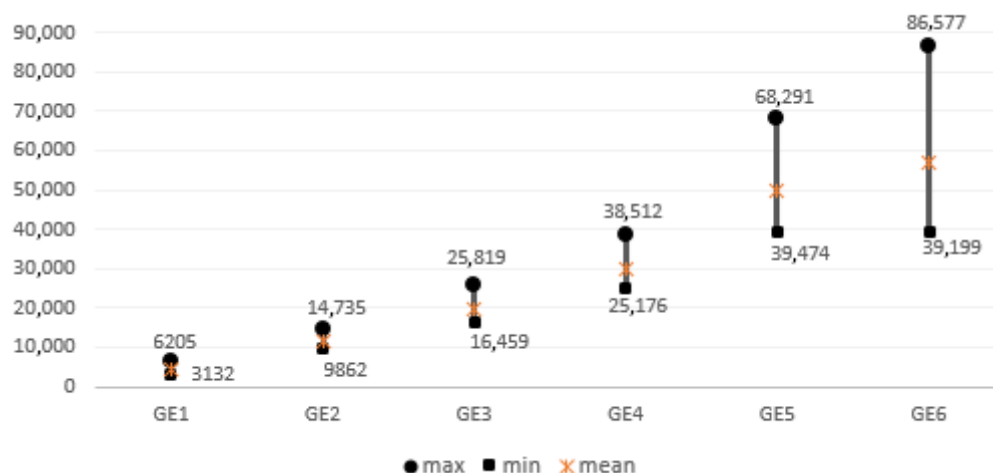


Figure 5. GFI/AWU in EU farms grouped by economic size in 2007–2022 (EUR, maximum, minimum, and mean values). Source: own calculations and compilation based on the FADN database.

Bojnec and Fertő [60] emphasize the importance of comparative analysis of production structures in agriculture for both scientific research and agricultural policy. Indeed, the transformation of these structures, aimed at increasing the importance of larger production units, determines rural markets for productive inputs and the competitiveness of farms on an international scale. The findings of numerous studies conducted by various authors have demonstrated that, in conjunction with technological advancements, improving the agrarian structure is imperative for achieving growth in labour and land productivity, as well as more efficient utilization of inputs within the agricultural sector (e.g., [61–65]). Changes in this area are also significant at the microeconomic level. An increase in the size of an agricultural holding is associated with numerous benefits resulting from economies of scale. It is also important to note that only economically large farms have the capacity to make investments, including those that do not receive external financial support. The advent of technological progress, particularly that pertaining to the substitution of labour with capital, has been demonstrated to precipitate production growth while also driving labour and land productivity. This, in turn, is imperative for the attainment of higher incomes. It has been confirmed that small farms are significantly less likely to engage in modernization investments. Moreover, these investments are typically rendered infeasible without subsidies. In turn, as posited by Gołębiewska [66], Grontkowska [67], Poczta et al. [68], Kirchweiger, Kantelhardt [69], Kryszak et al. [70], it is impossible to achieve higher assets-to-labour rates and higher incomes without investment. Convergent conclusions can be drawn from the research of other authors. For instance, Wicki [64] examined the variability of productive input efficiency and investment levels depending on the economic size of agricultural holdings. He concluded that the economically smallest farms exhibited low efficiency in all aspects under consideration and demonstrated inferior growth dynamics. Concurrently, he underscores that these agricultural holdings do not generate adequate surpluses to support their families, facilitate investments, and enhance production efficiency. In his research on the impact of the economic size of EU farms on their development potential, Sobczyński [71] showed that the self-financed replacement ratio, fixed asset replacement ratio, and gross and net value of investments were interdependent and increased with farm size. Sass [72] analyzed the productivity of inputs in farms of varying economic sizes. His study's findings indicate that the highest productivity levels of inputs, including labour and total factor productivity (TFP), were attained by large and extremely large farms.

As Kryszak et al. [70] have emphasized, in the context of growing global food demand, the long-term profitability of the largest farms may be crucial for the competitiveness of European agriculture on the global market.

3.2.2. A Regional Analysis

The dynamic analyses conducted thus far have revealed certain trends and directions of change in labour productivity across all agricultural holdings encompassed by the FADN in EU countries. In the subsequent stage of the study, an attempt was made to answer the question of whether there is a process of equalization of interregional disparities in labour productivity in individual economic size groups of farms. To estimate and illustrate the above phenomenon, this study employed the β -convergence and σ -convergence coefficients. The analysis was based on data from FADN agricultural regions.

The results of the estimation of absolute β -convergence for income per unit of labour input (GFI/AWU) in farms from individual economic groups are summarized in Table 3. In all cases that were analyzed, the α_1 parameter (which reflects the slope of the regression line) reached negative values, and the condition of parameter significance was met. Except for farms achieving an economic size of between EUR 25,000 and EUR 50,000 (GE3), the R^2 determination coefficients (values above 0.5) were also satisfactory.

Table 3. Estimation results for absolute β -convergence in terms of agricultural labour productivity of farms (grouped by economic size) in European Union regions from 2007 to 2022.

Symbol	Groups EUR	α_0	p -Value (α_0)	α_1	p -Value (α_1)	R^2	β	β —Convergence
GE1	2000–8000	0.316	0.000	−0.034	0.000	0.624	0.048	YES
GE2	8000–25,000	0.425	0.000	−0.043	0.000	0.672	0.068	YES
GE3	25,000–50,000	0.454	0.000	−0.044	0.000	0.484	0.071	YES
GE4	50,000–100,000	0.430	0.000	−0.040	0.000	0.534	0.060	YES
GE5	100,000–500,000	0.495	0.000	−0.044	0.000	0.576	0.071	YES
GE6	>500,000	0.559	0.000	−0.048	0.000	0.767	0.086	YES

Source: own calculations and compilation based on the FADN database.

In the group of medium-sized farms (GE3), the coefficient of determination was close to 0.5. However, as the condition of parameter significance was met, it was assumed that there is a process of β -convergence between regions in terms of agricultural labour profitability. The best fit of the regression model, with the β coefficient equal to 0.086, was found in the group of the largest agricultural holdings (77%). This result indicates that in the years 2007–2022, the annual rate of β -convergence in the analyzed group of regions, with respect to labour productivity in the economically largest farms (GE6), was the highest and amounted to 8.6%. Based on the β coefficient, it is possible to estimate the half-life factor according to the formula $HL_{1/2} = \ln 2 / \beta$, which indicates the time required to reduce differences in the level of the analyzed phenomenon by half [8]. A β -convergence rate of 8.6% per year implies that reducing half of the labour productivity gap in the group of the economically strongest farms takes approximately eight years.

A comparatively elevated rate of change (7.1%), though accompanied by a diminished R^2 index, was also identified as a hallmark of farms within the GE3 and GE5 groups. Conversely, the lowest rate of change in the area considered was documented in the group of the smallest farms (GE1).

Table 4 presents the estimation results for the σ -convergence model for all farm groups identified based on their economic size. As demonstrated by the data presented, the assumptions of a negative slope of the α_1 parameter were met in all cases, its significance was satisfactory, and the coefficient of determination was above 0.5. For the largest

farms, the percentage of the variable explained by the regression models exceeded 80%, and for the farms from the GE4 group, it was very close to that level, testifying to the high quality of the models. It can therefore be concluded that regional σ -convergence in labour productivity was observed across all economic groups of farms.

Table 4. Estimation results for regression models structured for the σ -convergence coefficients in European Union regions from 2007 to 2022, with farms grouped by economic size.

Groups		α_0	p -Value (α_0)	α_1	p -Value (α_1)	R^2	σ —Convergence
Symbol	EUR						
GE1	2000–8000	0.745	0.000	−0.014	0.001	0.541	YES
GE2	8000–25,000	0.643	0.000	−0.013	0.000	0.661	YES
GE3	25,000–50,000	0.471	0.000	−0.009	0.000	0.698	YES
GE4	50,000–100,000	0.454	0.000	−0.011	0.000	0.789	YES
GE5	100,000–500,000	0.518	0.000	−0.012	0.000	0.681	YES
GE6	>500,000	0.681	0.000	−0.021	0.000	0.806	YES

Source: own calculations and compilation based on the FADN database.

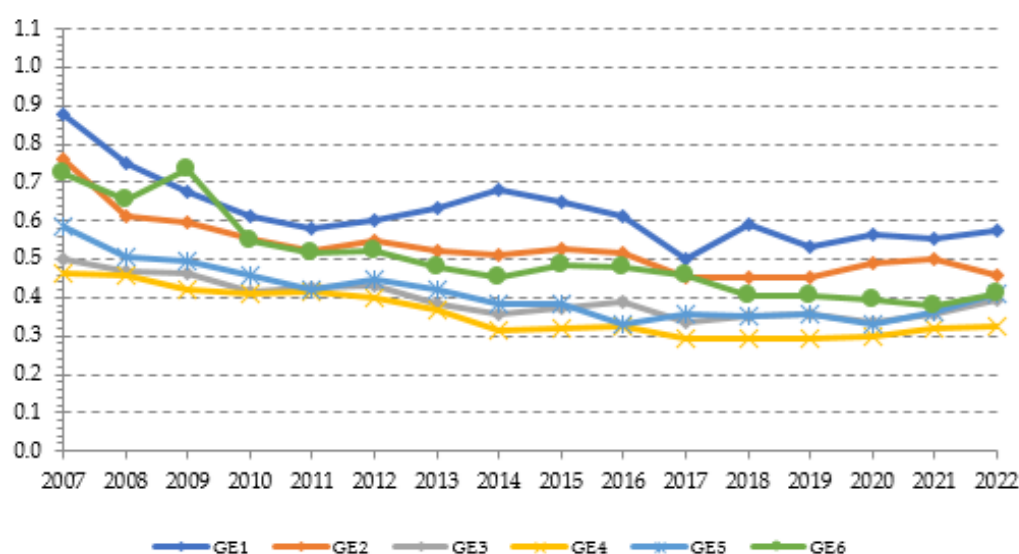
The parameters presented in Table 4 refer exclusively to the statistical verification of the estimated models. Hence, they provide grounds for advancing a hypothesis that σ -convergence exists or does not exist.

A comprehensive array of data concerning the evolution of σ -convergence coefficients from 2007 to 2022 is shown in Table 5 and Figure 6. As evidenced by the data presented, in 2007, there were more pronounced differences in the degree of dispersion in labour productivity between the analyzed groups of agricultural holdings compared to 2022. The σ -convergence coefficients ranged from 0.88 in GE1 to 0.46 in GE4, indicating a difference of 0.42. In the final year of the analysis, the observed difference was 0.24. A downward trend in σ -convergence coefficients is evident among all groups of farms classified according to economic size. The most significant decline was observed in the group of extremely large farms (GE6), where the coefficient went down from 0.72 to 0.41 between 2007 and 2022 (a drop by 43%). The above indicates that this group of farms exhibited the most rapid decline in interregional disparities in labour productivity. The smallest regional differences in labour productivity were observed in medium-sized farms (GE4), which, in addition to having the lowest initial σ -convergence coefficient, also saw a decline by nearly 30% during the period under examination. Conversely, the most pronounced disparities in labour productivity between EU regions were observed within the smallest farms (groups GE1 and GE2). However, as previously mentioned, just as in other groups, these holdings also experienced a decrease in disparities across FADN regions. The faster pace of labour productivity convergence observed in large agricultural holdings can be attributed to their better access to capital and output markets, which enables them to adopt new technologies and to use labour resources more efficiently through economies of scale. This, in turn, fosters faster development and promotes convergence in labour efficiency among farms in this group. In contrast, smaller holdings face financial and structural constraints that limit such opportunities, resulting in a slower pace of labour productivity convergence.

Table 5. Changes in σ -convergence coefficients within European Union regions in farms grouped by economic size from 2007 to 2022.

Group	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Change 2022/2007 (%)
GE1	0.88	0.75	0.68	0.61	0.58	0.60	0.63	0.68	0.65	0.61	0.50	0.59	0.53	0.57	0.55	0.57	−34.9
GE2	0.76	0.61	0.60	0.55	0.52	0.55	0.52	0.51	0.53	0.52	0.45	0.45	0.45	0.49	0.50	0.46	−39.7
GE3	0.50	0.47	0.46	0.42	0.43	0.43	0.38	0.36	0.37	0.39	0.34	0.35	0.35	0.34	0.36	0.39	−21.8
GE4	0.46	0.46	0.42	0.41	0.41	0.40	0.37	0.31	0.32	0.32	0.29	0.29	0.29	0.30	0.32	0.33	−29.5
GE5	0.59	0.51	0.49	0.46	0.42	0.45	0.42	0.38	0.38	0.33	0.35	0.35	0.36	0.33	0.36	0.41	−30.3
GE6	0.72	0.65	0.73	0.55	0.52	0.52	0.48	0.46	0.48	0.48	0.46	0.41	0.40	0.40	0.38	0.41	−43.0

Source: own calculations and compilation based on the FADN database.

**Figure 6.** σ -convergence coefficients within European Union regions in farms grouped by economic size from 2007 to 2022. Source: own compilation based on Table 5.

4. Conclusions

The main aim of this study was to assess whether productivity differences between and within farm groups classified by economic size in the European Union decrease over time. The paper contributes to a better understanding of structural inequalities in EU agriculture and offers evidence relevant for the design of cohesion-oriented agricultural policies. The notion of fostering cohesion within the agricultural sector entails promoting its development in a manner that results in the equitable distribution of welfare among individuals engaged in agricultural pursuits. In other words, this entails achieving comparable incomes from farm endeavours. This assumption applies irrespective of the prevailing natural, economic, and social conditions in a given country or region. This idea constitutes a central principle of European integration. The implementation of cohesion in European agriculture relies on the convergence of labour productivity levels. Convergence in this area forms the foundation of economic sustainability, as well as a prerequisite for the social dimension of sustainability, and is often an underlying factor in the environmental dimension of sustainable development.

Our research indicates that the EU agriculture witnessed convergence in labour productivity from 2007 to 2022. This phenomenon was manifested by a decline in the heterogeneity of labour productivity levels among agricultural holdings. The GFI/AWU ratio

exhibited an increase in all EU countries, with the most rapid shifts being observed in the new member states. Notwithstanding this fact, the dispersion of labour productivity levels between EU countries remains substantial, especially between the EU-15 and EU-10.

These findings are in line with previous studies by other authors and suggest the continuation of ongoing processes. Filling the identified research gap, we conducted an analysis of convergence processes occurring across different groups of farms classified by economic size. The results from the β -convergence and σ -convergence estimates yielded similar conclusions, which indicate that a convergence process is occurring within all economic groups of farms. The most significant disparities in labour productivity across regions are evident among extremely small and small farms (GE1 and GE2). Concurrently, as observed in other farm groups, these farms exhibited a pronounced decline in σ -convergence coefficients. The relatively lowest values of labour productivity standard deviation were observed in farms classified as GE3 and GE4. At the same time, the curves depicting the σ -convergence coefficients ascertained for labour productivity within these farm groups exhibited the most moderate trend. This finding suggests a relative stabilization of regional diversity among farms of this size. Conversely, the fastest decline in regional diversity was observed among the group of the biggest farms economically, designated as GE6.

Differences in the economic concentration of farms largely explain the disparities in income dispersion in European agriculture. Comparative analyses clearly demonstrate that an increasing share of large, economically strong farms fosters convergence in terms of labour income productivity. Numerous studies demonstrate that economic strength reflects capital investment, management quality, an appropriate production structure, and market linkages. Therefore, policy measures should aim to build the economic strength (size) of farms, as this constitutes the primary condition for convergence in labour productivity and, consequently, income convergence among those employed in agriculture. Although the analysis concentrates on European agriculture, the mechanisms linking farm economic size, structural transformation, and income convergence may be of general relevance to agricultural development in other regions of the world.

The guiding idea behind this study was to examine whether the changes in labour productivity in EU agriculture are consistent with the narrative and objectives articulated by Community policymakers. The responses to inquiries regarding income inequality among nations and regions, along with tendencies toward its diminution or augmentation, in conjunction with cognitive principles, have the potential to furnish rationales for economic policy, particularly within the framework of ongoing integration processes. As demonstrated by the findings of the research, one of the primary overarching objectives of European integration—namely, the reduction of disparities in agricultural labour productivity between nations and regions—is actually being pursued. However, the dispersion of labour productivity levels remains substantial, and the rate of convergence is slow. The design of agricultural support, both in the initial period of the Common Agricultural Policy (i.e., before the MacSharry reform in 1992), when was concentrated on socio-economic issues, and later, when it became linked to agri-environmental measures, has been and continues to be a factor fostering convergence processes among farms with high levels of production and/or large areas of agricultural land. Greater access to financial capital, including funds provided under the CAP, enables the adoption of innovative and increasingly similar production technologies, as well as adjustments to production techniques, to achieve the highest possible labour productivity. This partly explains the faster pace of convergence observed among the largest farms in economic terms. At the same time, however, this may also generate inequalities between this group of farms and other groups based on economic size. Finally, in practice, results in the exit of many farms that have not been included in the convergence process.

It is imperative to recognize that the convergence of labour productivity in agriculture will not accelerate without widespread and comprehensive structural changes in the field, which must extend beyond mere alterations in land use patterns. In order to accelerate labour productivity convergence among the smallest group of farms, it is essential, among other measures, to develop agricultural advisory services and to promote cooperation within producer groups and cooperatives. The weak pace of labour productivity convergence is associated, among other factors, with the marginalization of peripheral rural areas and the resulting depopulation processes. Moreover, the lack of modernization dynamics in part of the farm sector limits its capacity to adapt to climate change and market crises, thereby reducing the resilience of the agricultural sector as a whole. In the context of the agricultural sector in most new member states, which have historically enjoyed cost and price advantages, structural change processes (including rational land concentration) and rationalization of employment have emerged as pivotal factors in enhancing the competitive position of the agricultural sector. These processes have been instrumental in facilitating the attainment of improved agricultural incomes. The presence of ample labour resources, resulting in low wages, coupled with the persistent price convergence processes within the EU, may potentially culminate in the extinction of cost advantages. In this context, in order to increase the competitiveness of the agricultural sector in many countries in this group, it is necessary to improve the relationship between productive inputs and increase their efficiency. The economic size of farms constitutes a key factor in determining how efficiently they operate. Indeed, the economic size of a farm directly correlates with the capacity to adopt technological progress, achieve economies of scale, and attain higher resource productivity and production efficiency. Consequently, there is an imperative for additional support for structural changes in agriculture that would enable a more dynamic convergence of labour productivity between EU countries.

Future research could focus on a comparative assessment of labour productivity across economic groups of farms in EU Member States. At the same time, this constitutes certain limitations in the studies presented by the authors. The application of identical support instruments across all EU regions led the authors to examine the issue from an unconditional perspective. However, considering the structural and historical characteristics of agriculture in EU countries, it would be interesting to analyze the conditional convergence framework—within a priori defined clubs, namely the EU-13 (10) and EU-15—in accordance with the second approach to conditioning. This could help provide deeper insights into structural differences in the pace of labour productivity equalization between these groups of countries, as well as the role of the CAP and rural development programmes in shaping farm structures. In future research, it would also be interesting to look at the role of subsidies granted to agricultural producers and their role in convergence processes.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18052479/s1>, Table S1: Data scope.

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