# Convergence Processes in the European Agriculture: Analysis of the Total Factor of Productivity

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*Abstract:* - The article explored labour productivity in agriculture and carried out a comparative analysis of the achieved level of labour productivity in the countries of the European Union. The efficiency of agricultural production needs to be measured to improve the productivity, competitiveness, and profitability of farms. The multifactorial total factor productivity (MFP) of agricultural production evaluates the main and additional sources of economic growth in the agricultural sector. Based on the analysis of beta convergence, we observe an increase in total factor productivity (TFP) in Slovakia and the countries of the European Union. Based on the obtained statistically significant regression analysis models, beta convergence and sigma divergence of the TFP of the agricultural sector in the EU and Slovakia were identified. Thus, the process of positive convergence was confirmed, which indicates the convergence of the economic development of Slovakia with highly developed countries and the reduction of disparities between countries. State support and investment in innovative technologies will stimulate the adoption of new technologies and at the same time ensure technological progress and improve the impact of agriculture on the environment. We also concluded that it is important to improve the skills of those working in the agricultural sector, and as a result, an increase in TFP is expected.

*Key-Words:* - agricultural productivity, labour productivity, total factor productivity, sigma-convergence, beta-convergence model, rural economic growth

Received: November 28, 2022. Revised: August 24, 2023. Accepted: September 9, 2023. Published: September 15, 2023.

## 1 Introduction

The main objectives of the work are to study the essence of agricultural productivity, a comparative analysis of the dynamics of the level of labour productivity, to substantiate the importance of increasing total agricultural productivity as a key factor in increasing farm incomes, national income and increasing the competitiveness of the agricultural sector. The study, [1], believes that the analysis of the productivity of factors of production is necessary because it is a tool for making decisions and introducing changes at the economic level.

The countries of the European Union, which is most agriculture-oriented, have begun to implement policies to increase agricultural productivity and implement the goals of the 2030 Agenda for Sustainable Development. Because increasing the efficiency and productivity of production in agriculture will reduce poverty, increase food security, and increase farm incomes, [2].

Also, the productive agricultural sector provides a structural transformation of the country's economy, leads to an increase in the welfare of the population, and improves the diet of consumers through a decrease in food prices, since low prices increase real incomes, [3], [4].

Analysis of the level of agricultural productivity is an information basis for management decisions aimed at increasing the profitability and competitiveness of the enterprise, organizational improvement of production and technology, pricing, and effective human resource management. The

ability to effectively utilization of production factors, mainly capital, and human resources, is also a measure of increased competitiveness, [5]. Productivity lies in the ability to efficiently use resources to produce products, the technology used, and economies of scale, [6]. According to the European Commission, from a long-term perspective, productivity is the most reliable factor in increasing competitiveness, [7]. Thanks to productivity growth, firms (industries, countries) can more efficiently use and redistribute limited factors of production for other purposes, which ensures a high national income, [2].

Increases in agricultural productivity are an essential condition for economic development. The studies, [8], [9], [10], [11], [12], emphasize that the growth of productivity is an indicator of competitiveness, as well as a possible way to achieve economic growth. In the study, [13], among many other authors, have made essential contributions towards developing a better understanding, measuring, and analysing agricultural productivity. The study, [14], pointed out that economic development goes hand in hand with TFP, and can increase only under, conditions of intensive agricultural expansion. Agricultural development is essential to economic growth, leading to the perception of expanding opportunity, [15]. The analysis of the productivity of production factors is particularly important as it is a useful management tool at any economic level, [1].

## 2 Literature Review of the Total Factor Agricultural Productivity (TFP)

Productivity is defined as the ratio of volume output to resource use, [16]. The following factors influence productivity growth:

- Changes in farm physical productivity.
- Changes in nominal prices for products produced by farms.
- Changes in labour productivity

At a fundamental level, productivity measures the amount of output produced in a country, industry, sector, or farm given a set of resources and inputs. Productivity can be measured for each subject separately or for the group, [2].

Productivity in agriculture is calculated as partial productivity related to one factor or as total productivity (multi-factor). Multi-factor or total factor productivity growth (MFP or TFP) is a change in production that is not the result of a change in all or several factors of production, which in agriculture are usually land, labour, and capital. The most comprehensive indicator of productivity is total factor productivity (TFP), which measures the efficiency with which producers combine resources to produce output. The total factor productivity is defined as the aggregated output-input ratio, [1]. According to a generic definition, productivity is the ability of production factors to produce output, [17]. Total factor productivity measures the ratio of total marketable output (plants and livestock) to inputs (land, labour, capital, and materials), but does not consider inputs and outputs that have no economic value to the producer. Following the methodology for assessing the factors of economic growth (growth accounting) TFP is calculated as the remainder of the difference between the growth rates of output and the sum of the growth rates of capital and labour, weighted by the corresponding elasticities. The TFP growth rate is calculated as the difference in the average growth rate of combined outputs and inputs. If total output grows faster than total input, then each unit of output is produced using fewer total inputs, and average cost productivity, or TFP, increases, [18]. Total Factor Productivity reveals how efficiently farmers are producing it and indicates how well they are conserving available resources to meet future needs, [19].

TFP, measured at the industry level, reflects the most complete measure of efficiency, [20]. TFP demonstrates the efficiency of the agricultural sector in using available resources to turn inputs into finished products. Many factors, such as new technologies, efficiency gains, economies of scale, managerial skills, and changes in the organization of production, have a complex influence on the growth of TFP, [21].

The total factor productivity index is the relation of total production to total expenditure on production, [22]. The index of TFP growth can be defined as the ratio between the change in production volumes over a period and the corresponding change of inputs to produce them. An increase in TFP reflects a gain in output that does not originate from an increase in input use. The productivity of the agricultural sector is quite differentiated in the respective member states of the EU, [23], [24]. Identification of the determinants of growth in agricultural productivity is the precondition to make up for differences in TFP between member states.

Data Envelopment Analysis (DEA) use for determining technical efficiency and use of the Malmquist productivity index. The Malmquist index shows how the change in parameters (inputs and

outputs) in two different periods affects the total factor productivity of agriculture and differentiates the sources of productivity growth, [25].

TFP gives a complete picture of performance and is linked to technical changes and economic performance. Increases in single-factor productivity measures such as output per worker or yield per hectare may simply be due to increases in the use of other inputs (capital per worker, fertilizer per hectare, etc.), that do not reduce costs or reflect changes in the underlying technology. However, a 1% increase in TFP at fixed is equivalent to a 1% decrease in the unit cost of production and represents a real welfare gain to society, [18].

TFP is influenced by several factors, such as the introduction of new technologies, better management of resource use and the choice of agricultural practices, economies of scale, and efficiency gains from trade. TFP will also be affected by long-term changes in environmental factors, such as changes in soil fertility, water quality, and climate, which can reduce TFP in the event of environmental degradation. TFP analysis is especially important as it is a useful management tool at any economic level, [19]. Performance evaluation creates the basis for continual improvement, so an accurate analysis of TFP growth is essential to develop appropriate policies to access its performance, [26].

Agricultural productivity growth is a key source of economic growth in the EU agricultural sector. Growth in agricultural productivity is associated with new research and development, growth in human capital, innovation, and improvements in technology. Technical change has been the main source of productivity growth, not efficiency change. The agricultural industry uses digital (information) technologies to create additional opportunities to increase productivity and diversify incomes. Multi-product performance metrics can be used to measure farm productivity growth that demonstrates the impact of new technologies, economies of scale, and management practices on productivity, [27].

Rising agricultural productivity affects the welfare and structural transformation of the economy, contributes to overall economic growth, and can reduce poverty; leads to the release of labour from agriculture to the manufacturing industry and other industries; reduces food prices and thus increases real incomes, [3], [4].

The development of the agricultural sector has brought numerous benefits to society. The growing availability of food has allowed people to overcome the problems associated with inappropriate levels of food security and thus improved the standard of living of the rural population, [28]. It is important to strive for cost-effective agriculture based on knowledge and innovation, with a focus on the well-being of farmers and increasing the potential for yields and a positive impact on the environment. In this context, the analysis of agricultural productivity is important for producers and the government, [29].

Climate change negatively affects agricultural productivity due to rising temperatures and changes in weather conditions, which makes it difficult to grow and develop crops and livestock, and for agricultural workers to endure the physical challenges, [19].

Thus, it is necessary to develop effective policy regulation focused on environmental TFP, which will have a significant impact on the reduction of greenhouse gas emissions, thereby significantly contributing to a sustainable and productive agricultural sector, [26].

# 3 Methodology

We performed an analysis of the regional disparities between Slovakia and EU countries based on the TFP using the Gini coefficient and the Theil index. The dynamics of the indices help to identify the processes of convergence or divergence and, as a result, the presence of regional disparities in TFP in the EU and Slovakia from 2007-2018. We verified the presence of convergence processes, or divergence using regression models.

The Gini coefficient, the best-known and most widely used measure of inequality, is a measure of statistical dispersion used to express the distribution of a set of values and is calculated as the mean of the absolute differences between all pairs of values for a given variable. It compares the distribution of a variable to theoretical perfect equality.

Regional disparities are measured using the unweighted Gini coefficient, which is calculated using the formula, [33]:

$$GINI = \frac{2}{N-1}\sum_{i=1}^{N-1}|F_i - Q_i| \quad (1)$$

where:

$$F_i = \frac{i}{N} \quad (2)$$

$$Q_i = \frac{\sum_{j=1}^{i} y_j}{\sum_{i=1}^{n} y_i} \quad (3)$$

N – is the number of regions;

$y_i$ – is the value of the variable y (e.g. GDP per capita, TFP) in country j when evaluated from the lowest ($y_1$) to the highest ($y_N$) among all countries.

The Gini coefficient ranges between 0 % and 100 % (perfect equality or inequality: y is the same in all countries or zero in all regions except one).

The Theil index measures total disparities between all countries (GDP, income, TFP, labour productivity). It divides total inequality into inequality due to differences within countries and inequality due to differences between countries.

The Theil index is calculated by the formula, [33]:

$$Theil = \frac{1}{N}\sum_{i=1}^{N}\frac{y_i}{\bar{y}} \times \ln\left(\frac{y_i}{\bar{y}}\right) \quad (4)$$

where:

N – is the number of regions/countries;

$y_i$ – is a variable in the i-th region (i.e. GDP per capita, household income, life expectancy, etc.);

$\bar{y}$ – is the average value of the variable over all regions.

The Theil index ranges from zero to $\ln n$ $\infty$, where zero is the same distribution, the higher the value, the higher the level of disparities, and the value of $\ln n$ represents perfect inequality.

Convergence refers to the convergence of the levels of development of countries or regions over time. The opposite process is called divergence. The concept of convergence is linked to the Solow model of economic growth, which refers to higher rates of economic growth in countries that are far from a steady state (a state in which the capital-labour ratio is constant) compared to countries that are closer to him. Therefore, lagging economies are gradually catching up with developed countries.

Sigma convergence is a gradual decrease in variation (inequality, differentiation) in the levels of economic development of countries or enterprises. Sigma convergence occurs when the value of the variance of the indicator under consideration decreases/increases over time for a group of countries (including compared to the average value), [31]. The standard deviation or coefficient of variation is the most used indicator for testing the convergence hypothesis. It is more advantageous to use a coefficient of variation which, unlike the standard deviation, will not depend on the spatiotemporal dimension.

This type of convergence means that the values obtained by the calculation according to the following formula (2) are constantly decreasing:

$$CV = \frac{\sigma}{\bar{Y}} - \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(y_{i,t}-\bar{y}_t\right)^2}}{\bar{y}_t} \times 100\% \quad (5)$$

where:

$\sigma$ – standard deviation;

$\bar{Y}$ – arithmetic mean of the indicator;

yi,t – level (value) of the indicator in the i-th region at time t;

yt – is the average level of the indicator in the group of the countries;

N – is the number of countries.

We confirm the hypothesis of the presence of sigma convergence if there is a downward trend in inequality across countries. The higher the values of the coefficient of variation, the greater the disparities between countries.

The term beta convergence was introduced by R. Barro and X. Sala-i-Martin, [30]. Beta convergence is the negative dependence of the rate of economic growth on the initial level of development of countries.

Poor regions (or countries) have a higher rate of economic growth than the rich, respectively. richer countries are growing more slowly, which in the long run should lead to a leveling off of regional levels of economic development.

Absolute convergence is understood as the convergence of the levels of development of regions over time, without this process being affected by other conditions.

For empirical verification of absolute beta convergence, a regression of the logarithm of the average baseline growth rate of the observed property and the logarithm of the initial level of the investigated property is compiled. The absolute beta convergence model can be quantified as follows:

$$\log\left(\frac{y_{it}}{y_{i,t-1}}\right) = \alpha_i - \left(1 - e^{-\beta}\right) \times \left[\log\left(y_{i,t-1}\right) - x_i(t-1)\right] + u_{it} \quad (6)$$

where:

$\alpha_i = x_i + \left(1 - e^{-\beta}\right)\log(\hat{y}_i^*)$ a $u_{it}$ – is a random error;

$y_{it}$, $y_{i,t-1}$ – the initial (final) amount of well-being (salary, income, etc.) in the i-th region;

t – year.

Regression analysis is used to model $\beta$-convergence. For absolute beta convergence, we can write a regression function in the form:

$$\ln\left(\frac{y_{i,t_1}}{y_{i,t_0}}\right) = \alpha + \beta\ln\left(y_{i,t_0}\right) + \varepsilon \quad (7)$$

If the coefficient $\beta$ is significant for the explanatory variable and has a negative sign, the hypothesis of absolute convergence is not rejected and regions with worse initial conditions will have a higher growth rate. In this way, the presence of a negative correlation between the rates of economic growth and the initial level of development of the regional economy is checked. With a positive coefficient, $\beta$-divergence is observed.

The convergence process is characterized by two indicators:

- the degree of convergence ($\beta$), which indicates how many fractions of a unit the gap between regions decreases over time. If

it has the opposite sign to the coefficient b, that is, if the coefficient b is negative, then the velocity is higher than zero;

- the time ($\tau$) needed for the regions to cross halfway to equilibrium.

These indicators can be calculated based on an estimate of the coefficient b, which can be expressed as follows:

$$b = -\frac{1-e^{-\beta T}}{T} \quad (8)$$

Then:

$$\beta = -\frac{\ln(1+bT)}{T} \quad (9)$$

$$\tau = \frac{\ln(2)}{\ln(1+\beta)} \quad (10)$$

The presence of convergence/divergence processes indicates whether regional disparities decreased or increased during the analysed period.

## 4 Practical Research Results

TFP is a key indicator of the effective implementation of the overall objectives of the CAP. To analyse the dynamics of productivity changes, the TFP is used, which also evaluates the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-Agri3). Thus, the TFP indicator is the main factor in the growth of agricultural production and farm incomes.

Productivity in the EU has increased over time. (Figure 1). TFP grew by 14.69% in 2018 compared to 2000, and by 8.93% in 2018 compared to 2008. In 2019 TFP decreased by 2.5%, which is related to the coronavirus and indicates the growth of problems in agriculture, which continued in 2020 and became the basis for increasing the danger of a world food crisis in 2022. In general, the behaviour of TFP is different in different periods – periods of growth alternate with decline. In Figure 1, we observe a drop in TFP growth after the financial and economic crisis in 2009-2012, as well as in 2015-2017, after the start of the implementation of the new CAP 2014-2019 program. In 2012-2015, there was an acceleration in the growth of TFP due to favourable climatic conditions for growing crops, which led to an increase in agricultural production. It follows from this that the growth of total output has a positive effect on TFP, but the associated increase in costs, on the contrary, hurts TFP, [31].

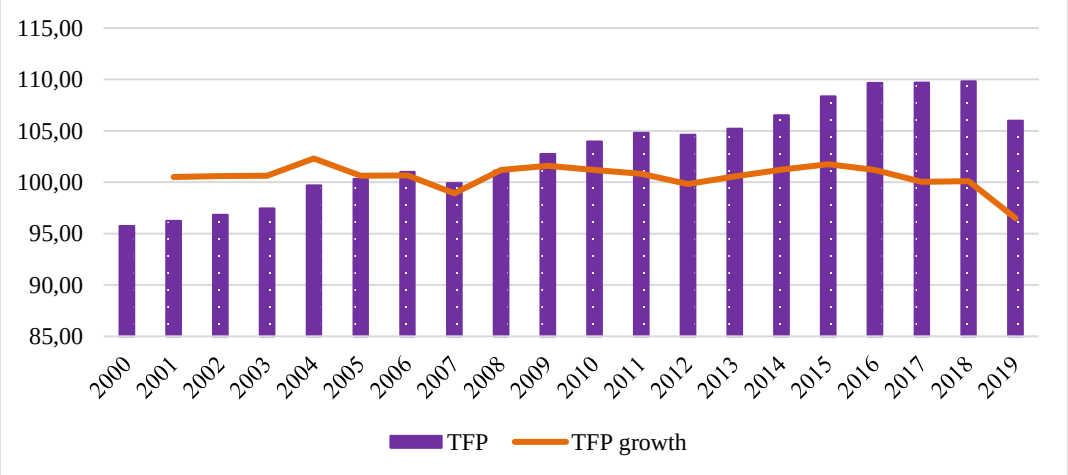


Fig. 1: Total factor productivity of EU-28 in 2000-2019 years (index)
*Source: Authors' calculations based on data from the Agri-food data portal*

The total TFP index has a growing trend, but TFP in EU countries is different. That demonstrates the results in Figure 2. Therefore, we are dealing with a significant increase in the diversification of productivity. The average level estimated for all European Union-28 countries only in the case of 18 countries, where the TFP index was the highest or equal, obtained a result higher of 109.81% compared to EU-28. In other countries, where TFP is lower than the EU-28 average level, this may be explained by the fact that implementation of technological progress in these countries not only requires structural transformations including optimization of work resources, but also quality changes, and especially an improvement in farmers' knowledge and qualifications.

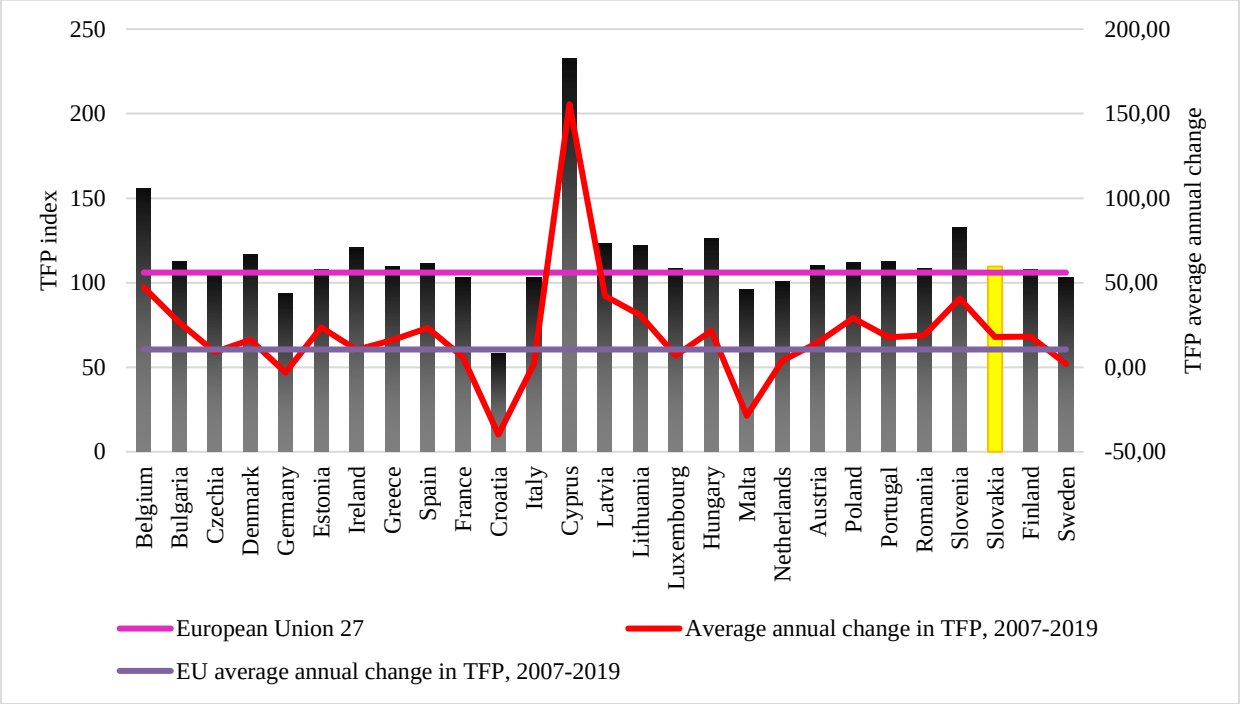


Fig. 2: Total factor productivity in EU's countries in 2007-2019 (index)
*Source: Authors' calculations based on data from the Agri-food data portal*

Figure 3 was built without Cyprus, Croatia, and Malta, as they have significantly broken away from the rest of the EU-27 countries. Average annual rates of TFP decline were in Croatia (–39.86%), Malta (– 28.75%) and Cyprus increased by 155.05%.

The results in Figure 3 show that Belgium (156), Slovenia (123.6), Hungary (126.3), and Latvia (123.7) are the four countries with the maximum total factor productivity and total factor productivity growth in 2007-2019. Belgium, Latvia, and Slovenia show a 47.1%, 42.2%, and 40.7 % average growth in total factor productivity change. It should be noticed that a productivity increase in the mentioned countries was affected to a great degree by technological changes. The lowest average rates for 2007-2019 were in Germany (–3.09%). Only in the Czech Republic, Germany, Greece, Estonia, France, Italy, the Netherlands, Austria, Finland, and Sweden were TFP lower than the European average. In Slovakia, the TFP was 109 compared to the average of EU-27 (113). After the transition of the economy, there had been a change in the structure of the agricultural sector which affected Slovakia and the Czech Republic, causing the TFP to lag in the EU average TFP growth.

There was a decrease in TFP in Germany, Malta, and Croatia. The most powerful agrarian countries

in Europe – Belgium, Latvia, and Estonia – respectively had the highest growth rates of TFP, the level of which exceeded the average European level.

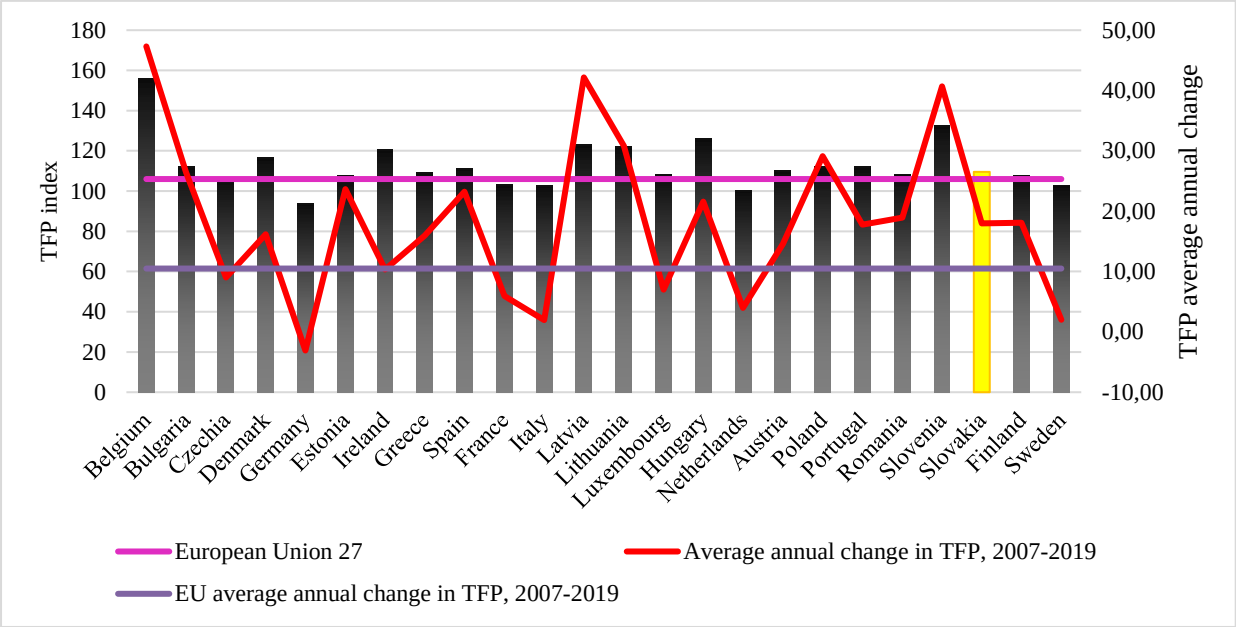


Fig. 3: Total factor productivity in EU's countries in 2007-2019 (index)
(without Malta, Cyprus, and Croatia)
*Source: Authors' calculations based on data from the Agri-food data portal*

The highest productivity increase during the examined period may be observed in agriculture, where the examined index reached 108.92 % (113.19 % without three countries that significantly differed from the average values) and annual average growth of 110.53% (118% without three countries) and was an effect of both production technology changes and technical efficiency, and natural conditions. Accordingly, such countries as Cyprus, Germany, and Malta exhibit the lowest total factor productivity in the agriculture sector.

A general indicator of labour performance that characterizes the efficiency of its production costs is labour productivity. A significant part of the difference in agricultural TFP is caused by changes in labour productivity. This relationship between total factor productivity and labour productivity is confirmed by the high correlation coefficient (0.9567).

To determine the factors that have the greatest influence on the TFP of individual countries we have estimated a linear regression model for the studied countries from the agricultural sector. The regression model describes the dependence between the total factor productivity and labour productivity in 2005-2018 years. The coefficient of determination is equal to 95.83%. The estimated model explains 91.53% of the variability of the dependent variable, and the model is high statistical significance. With 95% confidence, we can state, that if labour productivity increases by 1 unit, then we can expect total factor productivity to increase by 0.16. Considering the small dependence of TFP in rural areas on technologies, equipment, and natural conditions, the organization is quite a good result.

Compared to the base year 2005 in the EU-28, labour productivity in agriculture rose by 68.73% in 2019. At present, labour productivity in agriculture is an increase in all EU Member States. The highest productivity growth was in the years 2010 to 2012 after the financial crisis, and then since 2016, it has been growing slightly. Between 2013 and 2015, most EU regions saw a slight annual decline in productivity (Figure 4).

The growth of labour productivity in absolute terms, which to some extent is the result of a decrease in the number of employees in rural areas. During 2000-2020 the biggest drop was observed in Europe, the number of people working in agriculture decreased by 50 % from about 35 million, which represents a decrease of 18 million people, [32]. Regarding the price trend, then prices decreased annually by 1-7 % from 2013-2019 (World Bank

Commodity Price Data – Agricultural) and jumped by 5 and 22 percent in 2020-2021 due to the corona crisis. Annual fluctuations in labour productivity demonstrate its unstable dynamics, which to some extent reflects the influence of natural factors on labour productivity in agriculture. In general, some inconsistencies between the results of labour productivity growth and the state of the food market and farmers' incomes should be washed away. Despite the positive effects of increased labour productivity, and therefore agricultural production and more complete satisfaction of society's needs, the increase in supply puts downward pressure on prices. This has a negative impact on farmers' incomes if they are not balanced by the growing volume of sold products. Therefore, regulatory actions by the state to balance the food market by year and smooth out market shocks are extremely necessary.

In the EU countries, the level of labour productivity in agriculture is highly differentiated and lower than in other sectors of the economy, which is a negative reason for slow intensive growth. The current trend associated with low levels of labour productivity has a negative impact on sustainable economic growth, the creation of a competitive economy, and the improvement of the standard and quality of life.

As part of the agroecological transition and integration on a European and global scale, disparities in the level of socio-economic development of countries will be affected by changes in labour productivity. Increasing labour productivity is one of the decisive conditions for the development of agricultural production, the implementation of social transformations in rural regions, and the improvement of the material well-being of the population.

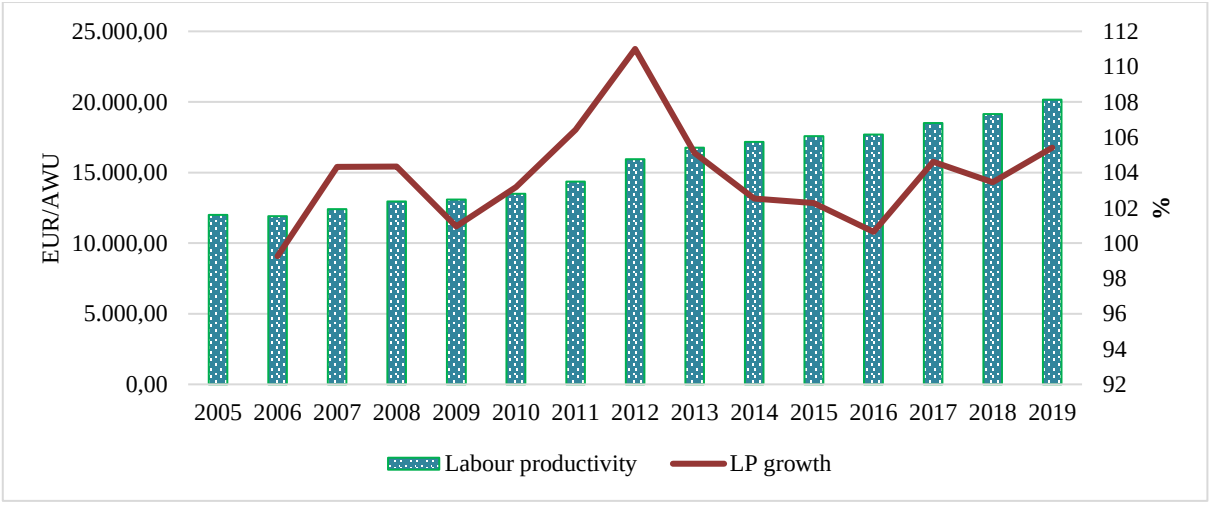


Fig. 4: Changes in labour productivity in EU-28 agriculture in 2005-2019
*Source: Authors' calculations based on data from the Agri-food data portal*

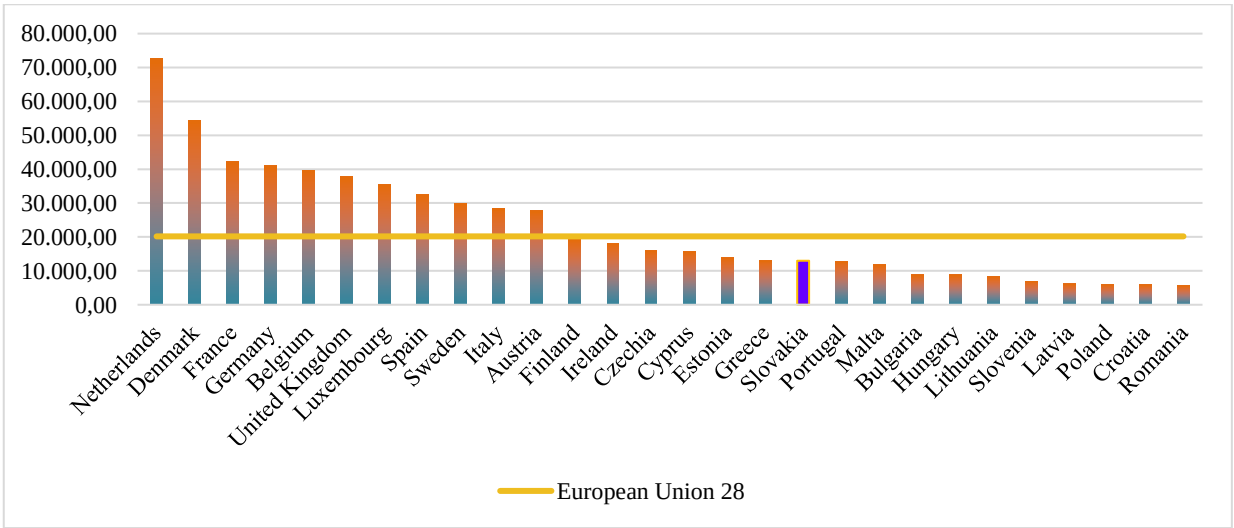


Fig. 5: Labour productivity in EU-28 countries in 2019, EUR/AWU
*Source: Authors' calculations based on data from the Agri-food data portal*

In Figure 5 agricultural labour productivity varies greatly across EU countries. The highest labour productivity in agriculture in 2019 was in the Netherlands, Denmark, France, Germany, and Belgium. In these countries, labour productivity is higher than the EU-28 average. And the lowest labour productivity in agriculture was in Latvia, Poland, Croatia, and Romania. That is, in the most agrarian-oriented countries of Europe, relatively low labour productivity was to some extent compensated by favourable natural conditions. At the same time, rather high rates of their growth prove that probably fewer positive changes in labour productivity have taken place in agriculture in most of the other new EU Member States, notably Estonia, Croatia, Slovenia, and Malta.

Slovakia also exhibits labour productivity which is lower than the EU-28 average. It was caused by the decrease in labour input in the agricultural sector. The constant decline in the number of employees in agriculture ranks Slovakia among the countries with the lowest share of agricultural workers in the total number of employees.

The gradual stabilization of the dynamics of labour productivity may be evidence of a certain exhaustion of the potential for increasing the volume of agricultural production in the existing conditions. This reinforces the need to find new opportunities for increasing labour productivity, not by reducing the number of people employed in the labour market, but by intensification and diversification of production.

Differences in labour productivity growth between regions are the result of many national and local factors, including labour market policies and institutions, as well as innovation and the use of new technologies. Despite clear progress in labour productivity, the level of agriculture in the new Member States is still significantly lower. This means that convergence processes are taking place in the field of labour productivity in EU agriculture.

Improving labour productivity in agriculture is a multifactorial task that includes institutional mechanisms that will strengthen the material and technical base, deepen specialization, and strengthen the concentration of agricultural production through the development of economic cross-sectoral ties, development of rural infrastructure, and development of adequate pricing policy. agricultural products, which will open opportunities to increase the level of real incomes of the personnel of agricultural enterprises and raise the prestige of agricultural labour.

Figure 6 shows the dynamics of the Gini coefficient (right scale) and the Theil index and coefficient of variation (left scale), which point out a significant increase in the difference between countries in terms of TFP in the period 2007-2018. We can see a reduction during the financial crisis on the stock market in 2008-2009. After this period, we can see a constant increase in these coefficients, which confirms the presence of divergence processes. Dynamics of indicators of the coefficient of variation of TFP in the period 2007-2018 Indicate a gradual process of increasing differences between the levels of development of countries (convergence). The main fluctuations in the coefficient of variation occur during the crisis period.

In 2014-2018 disparities between countries also increased, partly due to the implementation of the next phase of EU agricultural policy reform. The Gini coefficient, coefficient of variation, and Theil index clearly show that disparities between countries are getting bigger. This means that disparities in the EU are increasing, mainly due to the divergence of countries.

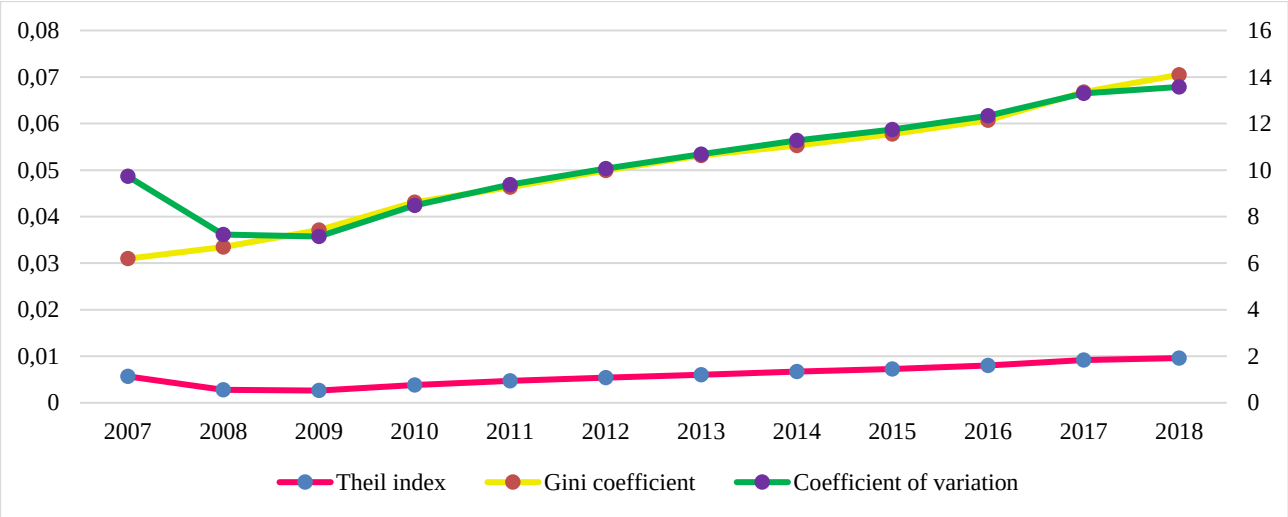


Fig. 6: Sigma-convergence between EU-28 countries in the years 2007-2018
*Source: Authors' calculations based on data from the Agri-food data portal*

The large correlation between the Gini coefficient, Theil index, and the coefficient of variation between 2007 and 2018 increases the validity of our assumption about the presence of sigma divergence processes between the EU countries. Thus, we can say that the sigma-convergence processes were gradually replaced by diversification processes since the countries began to develop according to their development trajectory and found their place in the EU's agriculture system.

Table 1. Summary of the estimation of the parameters of the beta-convergence model

| | *Coefficient* | *Std. Error* | *t-ratio* | *p-value* | *Statistical significance* |
|---|---|---|---|---|---|
| const | 4.06328 | 1.01761 | 3.993 | 0.0005 | *** (Very significant) |
| ln_TFP_2007 | −0.860789 | 0.222403 | −3.870 | 0.0007 | *** (Very significant) |

*Source: Authors' calculations based on data from the Agri-food data portal*

Based on the data obtained in Figure 6 and Table 1, the negative dependence of the studied indicators is manifested in all countries of the European Union. We confirmed the process of beta convergence in the EU countries, as evidenced by the negative and statically significant value of the beta coefficient (-86.08%) in the calculated econometric model based on regression analysis. significant, which confirms the absolute beta convergence (Table 1). The coefficient of determination is equal to 36.55%. Homoskedasticity is one of the classical conditions of the linear econometric model and is the requirement of finite and constant variance of random perturbations and residuals. Identifying homoscedasticity is necessary to evaluate, that parameter estimates by the econometric model did not lose some optimal properties. We used the Breusch-Pagan test and White's test to verify homoskedasticity, and we did not reject the null hypothesis, so the model is statistically significant and optimal. We can confirm catching up with the better-developed countries by the less developed countries.

The absolute beta convergence rate is 17.93% and is not constant over time. However, the rate of convergence is faster in the poorer and less economically developed regions of the EU. Within the EU, there is a process of beta convergence across EU regions, and the general trend of narrowing TFP differences continues. The time for passing half the distance to the convergence of the levels of regional development in terms of TFP is $\tau = 4.21$, and this is a fairly short period to achieve sustainable economic development of countries, [31].

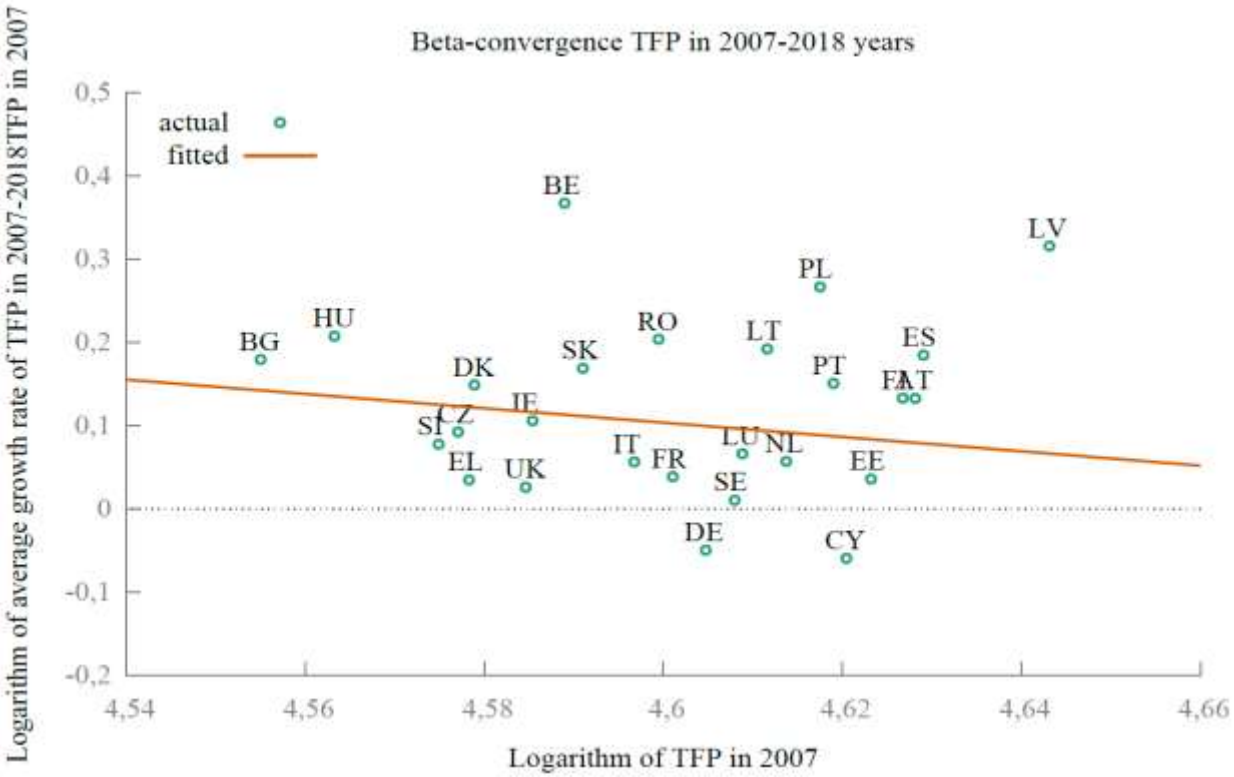


Fig. 7: Beta-convergence in the EU-28 in years 2007-2018
*Source: Authors' calculations based on data from the Agri-food data portal*

As can be seen in Figure 7, the change in the level of TFP in the years 2007-2018 allows the grouping of countries. The first group includes countries with a high level of development (France, Germany, Belgium, the Netherlands, and the United Kingdom). They did not significantly change the level of development but remained at the upper stages of development. These countries lie under the regression line. Slovak Republic is in the second group, which includes countries with a relatively lower level of development in comparison with the EU average (Latvia, Lithuania, Estonia, Poland, Hungary, Bulgaria), which developed at an accelerated pace. These countries are above the regression line. Thus, it can be assumed that these countries are using the catch-up development strategy within the framework of the convergence policy applied in the European Union, [31].

Based on this, we can say that Slovakia is convergent in the sense of absolute beta convergence. For Slovakia, this means strengthening the agrarian nature of the country's economy, primarily through improving the quality of agricultural development, especially labour productivity and total factor productivity. An increase in TFP is one of the decisive conditions for the development of agricultural production, the implementation of social transformations in rural areas, and the improvement of the environmental conditions, and material well-being of the population. The dynamics of positive changes in TFP in agriculture in Slovakia indicate significant reserves for its increase: an increase in the share of value added in the value of GDP; renewal of long-term funds, the introduction of energy-saving technologies, technical innovations; changes in environmental factors; improvement of the organization of production and institutional infrastructure. Important criteria for technical progress in the agricultural production of Slovakia are the efficient use of land and animal husbandry. Their rational use increases the efficiency of all factors of production. It is technological progress that increases the TFP and leads to savings in labour time and the growth of agricultural production while increasing the income of farmers.

The empirical assessment of economic convergence and growth carried out points to economic convergence of total factor productivity in the EU countries. Countries initially characterized by low productivity are catching up with countries having high productivity. Despite a significant disparity in TFP levels and growth rates among countries, agricultural productivity in the EU-28 countries has grown. In addition to technological progress, changing labour factors also contribute to inter-country disparities in TFP levels and growth, [31].

The TFP indices for the EU countries have positive increased trends and similar dynamics of the Gini index, Theil index, and Coefficient of Variation support the presence of long-run divergence among the EU countries. Absolute beta convergence in the EU countries continued continuously before, during, and after the financial crisis. The absolute beta convergence among the EU-28 countries is a consequence of the transformational processes of the agroecological transition in agriculture and requires state support for the further growth of TFP, farm incomes, improvement of the well-being of the population and the environment, and in general the economic development of agriculture and rural areas.

# 5 Discussion

A study, [34], based on unit root tests confirms the evidence for TFP convergence in developing countries. They found a trend towards TFP convergence with the average TFP of OECD countries. The study, [34], recommends that countries should take care to improve TFP by boosting R&D and improving technological progress to further accelerate productivity growth. The study, [35], also tests for absolute and conditional convergence of total factor productivity and real GDP per worker, using cross-section and cross-section, time-series data. The findings support both absolute and conditional β-convergence of total factor productivity in 83 countries.

In, [36], explored trade openness and foreign direct investment as the main determinants of TFP convergence across 91 emerging economies over the period 1960–2015. They concluded that a high degree of openness promotes the growth and convergence of TFPs, but policy action is needed to stimulate trade activity and FDI flows.

The article, [37], applies conditional quantile regression to a panel dataset of 17 OECD countries to examine relative factor endowments and technological advances, which are important drivers of convergence in agricultural productivity levels in developed countries. Capital deepening has been found to have an impact on the technological gap in different clusters of countries, but to increase the TFP of agriculture in countries with a large amount of land than in countries with a relatively large amount of labor. That is, differences in relative factor endowments within countries influence domestic technological progress through capital deepening and contribute to the growth of TFP in agriculture and the convergence of productivity across countries, [37].

The study, [38], examines the process of global TFP convergence in the EU-15 regions in 1985-2006 and finds that there is no overall process of TFP convergence, as the dispersion of estimated TFP levels has remained stable and constant over time. Spatial dependence has been proven to be a constant feature of the distribution of TFP over time, but technology and the IT revolution also affect regional disparities and convergence processes.

Thus, our conclusions about the presence of conversion processes in TFP between the countries of the European Union and Slovakia coincide with the studies of other scientific works.

# 6 Conclusion

Agriculture is a specific sector of the national economy, which, is extremely important for the economic development of the country as a whole, so an objective assessment of the productivity of this industry is an important economic task.

Several factors play a role in the development of TFP (climatic, capital, land, and labour). To develop effective measures of state regulation of the agricultural sector, it is necessary to investigate the causes and factors that cause changes in the level of agriculture and conduct an in-depth analysis of the use of production resources.

Labour productivity is the main driver of TFP growth in the EU. Changes in the agricultural labour force, jobs, and rural economic growth, are among the main policy directions under the CAP and the main drivers of TFP.

According to calculated regression models, we are dealing with statistically significant TFP beta-convergence and sigma-divergence of the agricultural sector across the EU. We can see an increase in TFP in analyse period in EU-28 countries and confirm a convergence process. However, the slowdown of this process may indicate the exhaustion of its potential, which will require excessive costs for its continuation. Therefore, it is possible to predict the onset of a period of divergence when countries will maintain differences in labour productivity levels and will use this difference to develop integration and trade.

Given the fact that the TFP is also affected by long-term changes in environmental factors, such as changes in soil fertility, water quality, and climate, the efforts for climate change mitigation could also lead to TFP growth.

To further increase the level of TFP there is a need for public support for investments in research and development to help enhance the technical

progress in agriculture. The final policy recommendations are to invest in innovation, in the development and retraining of farm management personnel. The introduction of new innovative technologies and their competent use increases the productivity of agriculture through the qualitative use of production factors.

*Acknowledgment:*
This publication is the result of the project implementation: „Scientific support of climate change adaptation in agriculture and mitigation of soil degradation" (ITMS2014+ 313011W580) supported by the Integrated Infrastructure Operational Programme funded by the European Regional Development Fund (ERDF).

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**Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)**

- Peter Bielik, Izabela Adamičková were engaged in the collection of literature and material for writing the theoretical part and made formal amendments to the article.
- Stefaniia Belinska (*corresponding author), Tatiana Bullová, and Natália Turčeková was responsible for formulating and setting the goals and objectives of the study. Was engaged in the collection and processing of data, the choice of methodology, and its description. Carried out the statistical data analysis using the chosen methodology and was engaged in the construction of graphs. Writing the practical part and conclusion. Engaged in the design and preparation of articles for publication.
- Zuzana Bajusová, and Yanina Belinska prepared and writing of the initial draft of the published work, wrote an abstract and introduction, and assisted in the analysis of graphs and structuring of the theoretical part.

**Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself**

This publication is the result of the project implementation: „Scientific support of climate change adaptation in agriculture and mitigation of soil degradation" (ITMS2014+ 313011W580) supported by the Integrated Infrastructure Operational Programme funded the by the European Regional Development Fund (ERDF).

**Conflict of Interest**

The authors have no conflict of interest to declare.