TOTAL FACTOR PRODUCTIVITY CONVERGENCE IN THE EU AGRICULTURE

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Abstract
Productivity is considered to be an important factor underlying the economic growth. The progressive integration processes in Europe, the EU enlargement and covering the new EU Member States (NMS) with the structural funds should promote the equalization of the efficiency of agriculture among the countries. In this context, the subject of the paper is an attempt to answer the question whether the convergence processes occur in the EU agriculture in terms of productivity. More specifically, the subject of the studies is total factor productivity (TFP) and unconditional convergence. TFP for the individual EU countries has been estimated using the DEA method and Malmquist indices. Sigma-, beta- and stochastic convergence was analysed. For the assessment of the convergence process, methods based both on cross-sectional data and on panel data have been applied. The results show that we are dealing with the convergence processes, in particular in case of NMS.
Keywords
productivity, agriculture, convergence, European Union

Introduction

Productivity is commonly considered as a major source of the economic growth (Barro, Sala-i-Martin 2003) as it expresses the changes in the efficiency of production processes, which, in turn, are a basis for the competitiveness of the economies, sectors or economic entities. In the free market, these entities, which have competitive advantages, are able to grow faster than others. We may argue in a similar way, taking the regions or countries as a basis.

Currently, we are dealing with the enormous stratification of the socio-economic development of the countries in the world and in the European Union itself. The differentiation among the countries takes place also in case of individual sectors, including agriculture (Baráth, Fertő 2014). There are attempts to find answers to the question about the reasons for such enormous stratification in the theories of economic growth. This leads to asking a question whether the economic reality around us is dominated by convergence or divergence processes. Stating the occurrence of the convergence phenomenon confirms the validity of the assumptions made by Solow and neoclassical theory, while rejecting this statement evidences the correctness of the endogenous growth theory (Solow 1956, Romer 1988, Krugman 1991).

The purpose of this article was to assess the changes in total productivity in agriculture of the European Union countries in 1993-2012. During that period, the EU was enlarged by the Central and Eastern Europe countries, commercial and administrative barriers were removed which led to releasing the movement of production factors. At the same time, the new Member States were covered by the Cohesion Funds and structural funds whose aim was to compensate for the disparities in the socio-economic development (nominal convergence). Hence, the expected effect is real convergence leading to reducing the diversification of productivity among the countries or consisting in catching up with the more developed countries by the less developed countries. The lack of barriers to the movement of production

factors and harmonisation of the agricultural policy should also result in the occurrence of similar directions of changes with regard to TFP.
These arguments directly relate to the analysed types of convergence: sigma-convergence, beta-convergence and stochastic convergence. The methods based on cross-sectional data and panel data have been applied to assess TFP convergence. Convergence for the entire EU, the group of old (OMS) and new Member States (NMS) has been analysed. Attention was also paid to the issue of whether we are dealing with the changes in productivity convergence over time. Total factor productivity has been estimated using the non-parametric DEA method (Data Envelope Analysis) in the input-oriented version. The changes in TFP in the individual countries have been expressed in the form of Malmquist indices. The basis for the calculations was the annual data from the FAOSTAT database.

1. Productivity and its convergence – literature review

We define real economic convergence as the process of convergence of the analysed economies over time. When writing about convergence, we may find quite different concepts and measurement methods in the literature. For example, Islam (2003) distinguishes seven concepts of division of the real convergence phenomenon: (a) convergence within one economy and convergence among economies, (b) convergence of growth rates and convergence of income levels, (c) beta- and sigma-convergence, (d) absolute and conditional convergence, (e) global and local convergence, (f) income and TFP convergence, (g) deterministic and stochastic convergence. Additionally, there are various estimation techniques, which can be based on cross-sectional data, time series or panel data. As a result, it is difficult to compare the obtained study results.
In this paper, we analyse absolute convergence of TFP among the countries. Total factor productivity is a synthetic way to assess the changes in the efficiency of production processes, taking place under the influence of technological progress. It expresses the changes in productivity of all production factors at the same time (Färe et al. 1994, Solow 1956). Convergence in absolute (unconditional) terms involves the economies' striving for the same and steady-state of productivity level. The essence of conditional convergence is an assumption that individual economies may have their own steady-state productivity level, dependent on certain fixed factors specific to them (such as technological progress, investment and employment rates) (Barro, Sala-i-Martin 2003).
Beta-convergence means, broadly speaking, catching up with, initially, the richer areas (countries, regions) by the poorer ones. If it is the only explanatory variable, a hypothesis about the presence of unconditional convergence is tested. If the model includes additional growth factors, then a hypothesis about conditional convergence is tested. Criticism of beta-convergence (Quah 1993) led to defining the concept of sigma-convergence. It assumes the reduction of inequalities among the countries over time. It turns out that the results of studying these two types of convergence may be in contradiction to each other. Formally, beta-convergence is a necessary condition, but not sufficient to the occurrence of the sigma type. This means that if the poor regions are developing faster than the rich ones, the inequalities among them are not necessarily reduced (Sala-i-Martin 1996).
One of the reasons for inconsistencies in conclusions for beta- and sigma-convergence may be a phenomenon, which in the literature of the subject is called leapfrogging. The development of the poorer areas is so fast that we are dealing not only with the catch-up but even with the overrun effect, which explains the increase in inequalities among the analysed areas. To test this effect, we may use an approach called gamma-convergence. It consists in assessing the changes in the ranking of the analysed objects (Boyle, McCarthy 1997).

A relatively new approach to convergence is a stochastic approach based on an analysis of time series. In this aspect, convergence takes place when productivity in a given region proceeds similarly as productivity in other regions. Stochastic convergence does not mean catching up processes but reducing the differences among the regions in the infinitely long period. One of the measurement methods under the concept of stochastic convergence is an approach based on co-integration of time series. Co-integration proves that time series are striving to the long-run equilibrium, while the deviations from the long-term path are stationary. Therefore, if the variables characterised by data series from different locations are co-integrated, then it is said that stochastic convergence takes place between the analysed regions (Bernard, Durlauf 1996).

The dispute about the occurrence of convergence and its conditions takes place mainly between the neoclassical school and the school of endogenous growth, and relates to the role of production factors, which in the first aspect are exogenous, and in the endogenous growth model are generated by the analysed system. The occurrence of convergence is a manifestation of the flow of innovation among the individual countries or regions assuming the identical and exogenous technologies and similar preferences. The factors conducive to convergence may include (Solow 1996, Kusideł 2013):

- law of diminishing returns, where the same amount of capital invested in the economy with lower initial capital level gives a higher return than in the economy with higher initial capital level,
- ability to imitate existing technologies, which is much cheaper than developing new ones,
- structural transformations and segmentation of the economy (in sectors with the low level of innovation there is a greater probability of convergence),
- mobility of production factors and international exchange promoting the equalisation of salaries and income.

The factors which are not conducive to convergence are (Romer 1988, Krugman 1991, Kusideł 2013):

- law of increasing returns – physical capital expanded by human capital and knowledge does not need to provide diminishing returns,
- uneven distribution of natural resources which hinders convergence,
- the starting position of a given region tends to become the established position (quality of human capital and institutions),
- structural transformations and segmentation of the economy (in sectors with the high level of innovation and technical advancement concentration is more likely than convergence),
- international exchange does not necessarily lead to the effective flow of production factors as the underdeveloped countries receive relatively obsolete technologies and the placement of modern resources is related to the maintenance of the rights thereto by leaders.

The literature review provides fairly diversified conclusions on convergence of agricultural sectors among the EU or global countries. This results from different concepts of productivity measurement, different time interval or various convergence indicators. Coelli and Rao (2005), using FAO data, compared agricultural TFP for 93 countries between 1980 and 2000. They applied a Malmquist index and DEA methods and found some evidence of catch-up between low and high performing countries. Suhariyanto and Thirtle (2001), using tests based on cross-sectional data and on panel data, did not prove the occurrence of TFP convergence among the Asian countries in 1965-1996. Rezitis (2010) indicated the existence of beta-convergence between the USA and the selected European countries in the absence of sigma-convergence in 1973-1993. At the same time, he demonstrated the occurrence of long-term (stochastic) convergence. Alexiadis (2010), on a sample from the years 1995-2004 and using

the data at the level of NUTS 2, demonstrated the occurrence of the so-called club convergence of labour productivity among the EU countries. Baráth and Fertő (2014) applying panel unit root tests, found TFP convergence between the OMS and NMS in 2000-2010. The analysis was based on DEA method and Lowe TFP indexes.

2. Data and methods

The FAOSTAT data from 1993-2012 were used as the basis for estimating productivity in agriculture in the EU countries. The annual data at the national level (24 countries) were aggregated and covered output (net production value expressed in real USD and adjusted by purchasing power parity) and five inputs expressed in physical units (land, labour, fertilisers, machinery, animal stock). Due to the missing data, Belgium was not included and due to the non-typical observations, Malta was eliminated from the studies.

The changes in TFP in the individual countries *j* have been expressed in the form of Malmquist indices. To estimate them, the non-parametric DEA method with an input-oriented approach has been applied. DEA is a linear programming method for the assessment of the efficiency of Decision Making Units (DMU_j; j = 1,..., n). Input orientation means minimising m of inputs x_{ij} (i = 1,..., m) in order to obtain specific s outputs u_{rj} (r = 1,..., s) (Coelii, 1996).

The Malmquist index M_i^{t+1} is the relative measure of productivity, which is based on a comparison of the relationship of inputs with the outputs of a given object over time *t* and *t*+1. M_i^{t+1} means productivity of the most recent production point (x^{t+1}, u^{t+1}) using period *t*+1 technology relative to earlier production point (x^t, u^t) using period t technology (Caves et al. 1982, Fare et al. 1994). In the literature, the decomposed form of the Malmquist index is often used, which allows its division into the relative efficiency change ΔEFF and technological progress $\Delta TECH$ between the period *t* and *t*+1:

$$M_i^{t+1}(x^t, u^t, x^{t+1}, u^{t+1}) = \frac{D_i^{t+1}(x^{t+1}, u^{t+1})}{D_i^t(x^t, u^t)} \sqrt{\left[\frac{D_i^t(x^{t+1}, u^{t+1})}{D_i^{t+1}(x^{t+1}, u^{t+1})} \times \frac{D_i^t(x^t, u^t)}{D_i^{t+1}(x^t, u^t)}\right]} = \Delta EFF + \Delta TECH\,, \qquad 1)$$

where D_i are the functions of distance of inputs, other designations as above.

The increase in the value of the Malmquist productivity index is possible even if one of the components shows a decline, but this decline must be compensated for with the increase in the other component. For the Malmquist productivity index value greater than 1, it is assumed that in the analysed period, from *t* to *t*+1, there was an increase in productivity. The index value below 1 indicates a decrease in productivity while the value equal to 1 means that productivity remains at the same level.

To assess convergence, several indicators (concepts) based both on cross-sectional and panel data have been applied. One of the concepts of convergence measurement is based on an assessment whether the diversification among objects takes place over time. It is called sigma-convergence (Barro, Sala-i-Martin 2003, Islam 2003). If we denote productivity of the object *i* (i = 1,..., N) over time *t* (t = 0,…, T) as $y_{i,t}$ and the average productivity index value among the objects as $\overline{y}_t$ then the indicator of sigma-convergence will be:

$$S_{yt} = \frac{\sqrt{\sum_{i=1}^{N} (\ln y_{i,t} - \ln \overline{y}_t)^2}}{(N-1)}\,. \qquad 2)$$

Convergence may be evidenced by the negative slope of the fitted trend function, e.g.: linear or simply a decrease in the size of the indicator over time.

The second measure of convergence used in the study is the so-called beta-convergence. Its assessment (unconditional version) is based on estimation of the following equation (Barro, Sala-i-Martin 2003):

$$\ln\left(\frac{y_{i,t_0+T}}{y_{i,t_0}}\right) = a + b\ln(y_{i,t_0}) + \varepsilon_{i,t_0,t_0+T}, \quad 3)$$

where: a, b – coefficients of equation, ε – random component.

In this equation, the changes in productivity between the last t_{0+T} and the initial period t_0 are the function of the initial level of productivity. The negative and statistically significant b coefficient evidences convergence of the regions. Bearing in mind that $b = -(1-e^{-\beta T})$ then the annual average convergence rate is calculated as $\beta = -\ln(1+b)/T$.

As it results from the studies (eg. Bernard 1996, Durlauf, Caselli et al. 1996), estimators of equations based on cross-sectional data may be inconsistent and biased. This results from the correlation of the random component of the model with the explanatory variables. Hence, currently beta-convergence is estimated most often, on a basis of panel data (Baltagi 2008). In this case, the equation takes the following form:

$$\ln\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = a + b\ln(y_{i,t-1}) + \eta_i + \nu_t + \varepsilon_{i,t}, \quad 4)$$

which may be noted alternatively as:

$$\ln(y_{i,t}) = a + (1+b)\ln(y_{i,t-1}) + \eta_i + \nu_t + \varepsilon_{i,t}, \quad 5)$$

where: a, b – coefficients of equation, η_i – individual effects for object i, ν_t – periodical effects for the year t, $\varepsilon_{i,t}$ – random component.

In this case, the speed of convergence is defined as $\beta = -\ln(1+b)$ because $b = -(1-e^{-\beta})$.

This model is dynamic and requires the application of relevant estimation models, which take account of the endogeneity of explanatory variables. In our paper, to estimate model 5, the one-step system estimator (SYS GMM) of Blundell and Bond (1988) was applied.

The third concept used in the studies is the so-called stochastic convergence. In the studies, it was assessed whether there was convergence in relation to the average value of the Malmquist productivity index ($\bar{y}_t$) in the entire EU or in a group of selected countries. If we assume that $D_{i,t} = \ln y_{i,t} - \ln \bar{y}_t$, the starting point for the assessment of convergence is the following equation (Bernard, Durlauf 1996, Rezitis 2010):

$$D_{i,t} = \gamma + (1-\gamma_1)D_{i,t-1} + \varepsilon_{i,t} \quad 6)$$

Convergence occurs when transformed variables are stationary, i.e. $1 > \gamma_1 > 0$. To assess stochastic convergence, three versions of the unit root panel tests were applied (Levin, Lin, Chu, 2002):

$$\text{LLC1: } \Delta D_{i,t} = \rho D_{i,t-1} + \sum_{j=1}^{p} \varphi_i \Delta D_{i,t-j} + \varepsilon_{i,t}; \text{ H}_0\text{: } \rho = 0, \text{ H}_1\text{: } \rho < 0, \quad 7)$$

$$\text{LLC2: } \Delta D_{i,t} = \rho D_{i,t-1} + \sum_{j=1}^{p} \varphi_i \Delta D_{i,t-j} + \alpha_{0i} + \varepsilon_{i,t}; \text{ H}_0\text{: } \rho = \alpha_{0i} = 0, \text{ H}_1\text{: } \rho < 0, \quad 8)$$

$$\text{LLC3: } \Delta D_{i,t} = \rho D_{i,t-1} + \sum_{j=1}^{p} \varphi_i \Delta D_{i,t-j} + \alpha_{0i} + \alpha_{1i} t + \varepsilon_{i,t}; \text{ H}_0\text{: } \rho = \alpha_{1i} = 0, \text{ H}_1\text{: } \rho < 0, \quad 9)$$

where ρ, φ, α are parameters. The null hypothesis implies the occurrence of the unit root in the variables panel, in turn, the alternative hypothesis – the absence of the unit root. The rejection of the null hypothesis is identical with the adoption of an assumption that we are dealing with stochastic convergence.

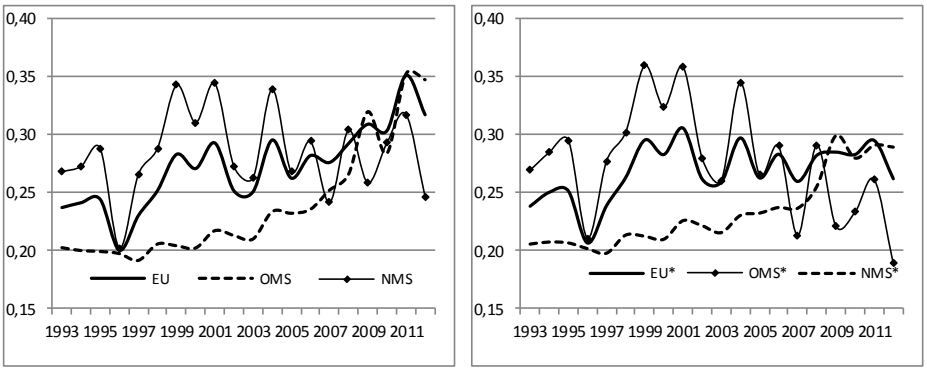
3. Results of the studies

The empirical studies have been carried out for three types of convergence and by all countries of the European Union (EU), the old EU countries (OMS), and the new EU members (NMS), the countries which joined the EU after 2004. Due to the fact that the results

of some analyses were strongly affected by outlying observations, for some types of convergence the results of estimates after eliminating such objects (Austria and Slovenia) were additionally presented. Those results were additionally marked with an asterisk, respectively: EU*, OMS*, NMS*.

3.1 Sigma-convergence

The manifestation of sigma-convergence is a reduction in the variation for a given category among the countries over time. Fig. 1 shows the evolution of standard deviations of productivity over time. We may easily notice that the dispersion of TFP represented by the Malmquist indices is not reduced in time. Indeed, we are dealing with a reverse situation. Total factor productivity in the EU and in the OMS is subject to divergence. Therefore, we are dealing with a significant increase in the diversification of productivity in these aggregates.



Source: own calculation

Fig. 1 Estimates of sigma-convergence in TFP of the EU agriculture

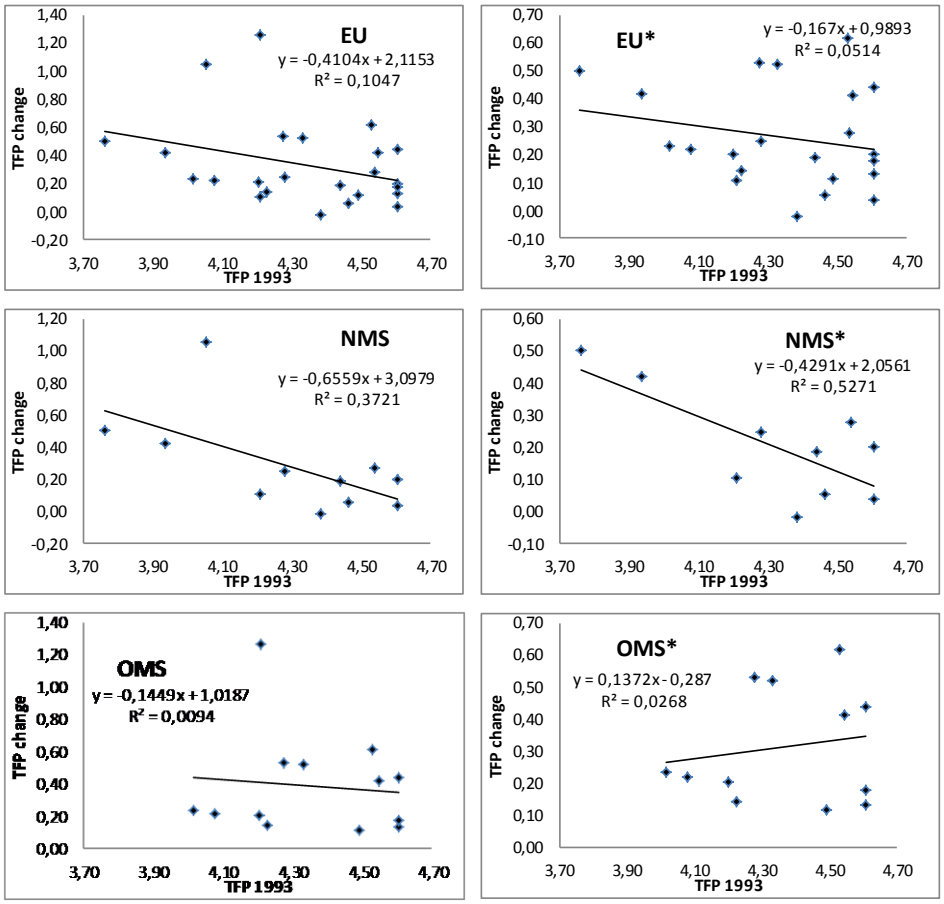
In case of the NMS, we are not dealing with convergence while the dispersion of productivity is not increasing, as well (Fig. 1 on the left). It is worth stressing that the changes in TFP in Slovenia are very rapid which influences the obtained results. Its removal from the data set changes the picture of sigma-convergence in the NMS (Fig. 1 on the right). Namely, as from 2000 we are dealing with a statistically significant negative trend in S_{yt} reflecting the reduction in the TFP variation among the NMS.

3.2 Beta-convergence

In the next step, it was attempted to assess whether the less developed countries are catching up with the better developed countries. First, an analysis was carried out based on cross-sectional data. Also in this case, the results may be significantly biased by non-typical observations, thus, the estimates for the full sample and after the exclusion of Austria and Slovenia were presented.

As it results from Fig. 2 and Table 1, the negative coefficients of the estimated regression models occur in case of the entire European Union and for the NMS group. However, in case of the EU and EU*, these relationships are not statistically significant at the level of significance $p = 0.1$. In case of the NMS, we can discuss catching up with the better developed countries by the less developed countries. In fact, for the NMS there are negative and statistically significant estimates of the coefficients b (Table 1). The estimated convergence

speed β for the NMS amounts to 0.028 and for the NMS* is 0.056. No beta-convergence was found among the group of the OMS an OMS*.



Source: own calculation

Fig. 2 Estimates of beta-convergence in agriculture of the European Union countries based on the cross-sectional data

Table 1 Estimates of beta-convergence based on the cross-sectional data and on panel data

Countries	(1+b)	b	Se	t / z	p- value	β
Cross-sectional framework						
EU	-	-0.410	0.256	-1.604	0.123	0.028
NMS	-	-0.656	0.284	-2.310	0.046	0.056
OMS	-	-0.145	0.448	-0.323	0.752	0.008
EU*	-	-0.167	0.160	-1.041	0.310	0.010
NMS*	-	-0.429	0.144	-2.986	0.017	0.030
OMS*	-	0.137	0.261	0.525	0.611	-0.007
Panel framework						
EU	0.642	-0.358	0.069	9.340	0.000	0.444
NMS	0.682	-0.318	0.050	13.718	0.000	0.382
OMS	0.845	-0.155	0.051	16.430	0.000	0.169

Source: own calculation

In the next step, beta-convergence was estimated based on panel models. It should be stressed that estimated panel models include time effects, which is equivalent to the transformation of the variables into the deviations from the group averages. This allows for omission of common time effects, resulting from one-way changes in productivity. The estimated models were characterized by the lack of second-order autocorrelation at the 5% significance level (Arellano-Bond test), and met the over-identifying conditions (Sargan test).
Estimates of panel models (Table 1) and the convergence speed coefficients β calculated on their basis are significantly different from those obtained based on cross-sectional data. Namely, according to the dynamic models, we are dealing with statistically significant TFP convergence of the agricultural sector across the EU and in the selected groups: NMS and OMS. The convergence speed from panel models is implausible as β coefficients are several times higher than their equivalents estimated based on cross-sectional framework. It seems that actual convergence of total factor productivity may be much lower.

3.3 Stochastic convergence

Stochastic convergence is another of its types, which refers to the concept of time series modelling. It comes down to analysing the stationarity of the variables adjusted by the averages for individual units of time. The studies estimated the test in two versions: without the auto-regression component and with one lag (Table 2).
In the unit root tests with constant and trend (LLC3), we may reject the null hypothesis stating the non-stationarity (and thus non-convergence) of TFP in the entire EU. Thus, it may be concluded that we are dealing with convergent changes in productivity in the individual countries around their trends.
Stronger confirmation of stochastic convergence takes place for the NMS. In their case, the null hypothesis about non-convergence has been rejected in eight out of nine cases. Thus, we may write that there is a long-term trend of convergence of productivity among the NMS. The reverse situation occurs in case of the group of the OMS. Only one test variant (LLC3, lag 1) in nine, confirmed its occurrence. It is worth stressing that these results are similar to the conclusions drawn from testing sigma-convergence and beta-convergence using the cross-sectional data.

Table 2 Testing for stochastic convergence – the Levin-Lin-Chu unit root test results

Countries	Model	Autoregressive lag: p=0			Autoregressive lag: p=1		
		ρ coeff.	Z-score	p-value	ρ coeff.	Z-score	p-value
EU	LLC1	-0.005	-0.415	0.339	0.015	1.331	0.908
EU	LLC2	-0.276	-4.668	0.000	-0.157	0.220	0.587
EU	LLC3	-0.745	-8.852	0.000	-0.760	-2.900	0.002
NMS	LLC1	-0.069	-2.609	0.005	-0.036	-1.471	0.071
NMS	LLC2	-0.397	-4.863	0.000	-0.234	-1.069	0.143
NMS	LLC3	-0.810	-6.949	0.000	-0.874	-3.253	0.001
OMS	LLC1	0.013	1.139	0.873	0.029	2.357	0.991
OMS	LLC2	-0.161	-0.723	0.235	-0.100	1.447	0.926
OMS	LLC3	-0.622	-4.334	0.000	-0.607	-1.010	0.156

Source: own calculation

Conclusions

The aim of the research was an analysis of TFP unconditional convergence in the European agriculture. It was expected that increase of regional integration should promote convergence. The study generally confirmed presumptions that countries initially characterized by low productivity are catching up with countries having a high productivity. The TFP indices for the EU countries have similar trends and panel unit root test results support the presence of long-run convergence among the EU countries (stochastic convergence). Similar conclusions were drawn by Baráth and Fertő (2014).

The strongest convergence takes place among the NMS which may result from the strong restructuring processes and the application of similar instruments to support agriculture and rural areas. Most of the tests did not confirm the occurrence of absolute convergence of TFP among the OMS. Even though there is beta- and stochastic convergence in the EU agriculture, the differences among countries do not disappear. The results for sigma-convergence indicate that there is no reduction inequality among the EU countries. We strongly confirmed an increase in the TFP variation among the OMS over time.

The extension of these studies could consist in assessing whether we are dealing with the changes over time of TFP convergence as already indicated partly by the results of sigma-convergence. Another modification of the study might be application of the Malmquist productivity index, with respect to the sequential instead of contemporaneous frontier technology. This may alter some conclusion drown as contemporaneous frontier might be unstable because of the dimensionality problems (Suhariyanto, Thirtle 2001). The lack of absolute convergence for some countries does not exclude the conditional convergence as countries may tend to their own steady-states. Therefore, another extension of the study might be including the conditional variables.

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