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Changes in Agricultural Productivity in New and Old Member States of the European Union

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Abstract:

Purpose: *This paper aimed at evaluating changes in agricultural productivity in the group of new (NMS) and old (OMS) member states of the European Union.*
Design/Methodology/Approach: *The analysis covered the years 2007-2016. The calculations made use of unit data from farms participating in FADN (Farm Accountancy Data Network). Surveys were carried out based on the Malmquist productivity index and partial indicators of land, workforce and capital productivity.*
Findings: *The outcome pointed to increased total productivity of agriculture in NMS (9.5%), resulting from positive technological changes and improvement in technical efficiency. A small decrease in productivity was noted in a group of EU-15 countries, which was due to a decrease in technical efficiency. Despite the growth in total productivity, the value of partial productivity indicators in NMS remained at a much lower level than in OMS.*
Practical Implications: *Identification of the determinants of growth in agricultural productivity is the precondition to make up differences occurring between member states in this respect.*
Originality/Value: *This study contributes to reference literature concerning productivity of agriculture for a number of reasons. First, the scope of the survey is extensive, as it covers a group of 27 EU member states split into new and old members. The second aspect of the survey is taking into account both changes in total factor productivity and in productivity of respective production factors. Thirdly, the Malmquist index adopted for the needs of the survey made it possible to identify the sources of change in total factor productivity.*

Keywords: *productivity, agriculture, farms, European Union countries.*

JEL Codes: *O13, O47, Q12.*

Article Type: *Research Paper.*

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1. Introduction

Since 2004 thirteen new states have acceded to the European Union (EU), causing a number of changes in agriculture. The effect of accession to the EU on agriculture can be measured in many areas such as production, trade, income, structure of farms, as well as productivity (Csaki and Jambor, 2013). Many scientific papers have studied the problems of changes in agriculture in the above-mentioned areas, in particular, trade (Jambor, 2014; Carraresi and Banterle, 2015; Bojnec and Fertő, 2015).

Particular significance is assigned to surveys concerning agricultural productivity. Improvement in the productivity of this sector is a condition for permanent economic growth (O'Donnell, 2010). Leimane *et al.* (2017) emphasize that growth of productivity is an indicator of competitiveness, as well as a possible way to achieve economic growth. In addition, a change in productivity is a key aspect of structural changes and competitiveness. This is even more important in agriculture since it is linked with food supply (Dakpo *et al.*, 2019; Gumidullaeva, 2018).

Productivity is defined as the relation of output to inputs, and thus, gives information about the efficacy of factor input. Productivity is not only determined by the ability to use efficiently inputs in the production of outputs but also by the technology in use and economies of scale (Čechura *et al.*, 2014). Many different measures of productivity exist and their choice depends on the objective of assessment and on the availability of data. Productivity in agriculture can be calculated as partial productivity referring to a single production factor or as total productivity.

The main advantage of partial productivity measures is the ease of calculation and interpretation, but they can sometimes provide a misleading indication of overall productivity when considered in isolation from other indicators (Csaba *et al.*, 2014; Burkaltseva *et al.*, 2017; Srinita, 2017).

The most often applied complex productivity indicator is the total productivity of production factors. Total factor productivity (TFP) is a key measure of the economic performance of agriculture. TFP measured at the sector level provides the most comprehensive measure of the sector performance (Bokusheva and Čechura, 2017). It indicates how efficiently the agricultural sector uses the resources that are available to turn inputs into outputs. TFP growth reveals the joint effects of many factors, including new technologies, efficiency gains, economies of scale, managerial skill and changes in the organisation of production (European Commission, 2017).

From a review of literature it follows that productivity in agriculture is often evaluated using non-parametric methods. Non-parametric analyses mainly involve Data Envelopment Analysis (DEA) for determining technical efficiency. This method primarily makes use of the Malmquist productivity index. In addition, non-parametric methods often utilise the Tornqvist-Theil index. Both were based on an assumption that a growth in outputs is generated by a growth in inputs. The fundamental difference between them is technological changes that have not been taken into account by the Tornqvist-Theil index (Melfou *et al.*, 2007).

Surveys regarding changes in the total productivity of agriculture most frequently referred either to a selected group of farms, e.g. dairy farms (Čechura *et al.*, 2014; Madau *et al.*, 2017; Bokusheva and Čechura, 2017), or to selected countries (Latruffe and Desjeux, 2016; Leimane *et al.*, 2017; Zaman and Meunier, 2017; Duguleana and Duguleana, 2016), or the analysis covered the previous study period (Coelli and Rao, 2005).

Baráth and Fertő (2014) indicate that no studies have been carried out concerning the comparison of TFP in agriculture between old and new member states, especially after 2007. This paper attempts to fill this gap, thus, it aims to assess changes in total and partial productivity of agriculture in the member states of the European Union, considering their division into old (OMS) and new (NMS) member states, as well as indicating the sources of such changes.

2. Methodology

Changes in productivity of the agricultural sector were measured using a non-parametric method based on the Malmquist productivity index. In setting the Malmquist indices an output-oriented approach was applied. The calculations were performed for one output and three variable inputs:

- output Y_1 – Total output - total of output of crops and crop products, livestock and livestock products and of other output (EUR),
- input X_1 – Total Utilised Agricultural Area (ha),
- input X_2 – Total labour input (AWU - annual work unit = full-time person equivalents)
- input X_3 – Total fixed assets (EUR).

The Malmquist indices as well as decomposition and total factor productivity (TFP) were calculated according the formula proposed by Caves et al. (1982):

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \quad (1)$$

where: x^t (x^{t+1}) stands for the input vector in time t $(t+1)$ and y^t (y^{t+1}) is the respective output vector for vector x^t (x^{t+1}), whereas D^t (D^{t+1}) is an input-oriented distance function referring to production technology.

Improvement (change) in observed productivity expressed as the Malmquist index can be an output of progress in the production technology used (technical progress) and/or technical efficiency. Thus, the above-presented index can be decomposed as follows:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \quad (2)$$

The first bracket measures the change in technical efficiency between periods *t* and *t+1* (shift towards production capacity limit). The square bracket expresses technical progress, indicating the geometric centre of the shift in technology in periods *t* and *t+1* at input level x^t and x^{t+1}.

Although the Malmquist index can be decomposed into changes in technical efficiency and changed in production technology in many ways (Coelli and Rao, 2005), this paper adopted decomposition as proposed by Färe *et al.* (1994):

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = TECHCHxPEFFCHxSCH \quad (3)$$

TECHCH stands for technological changes, *PEFFCH* expresses changes in production efficiency changes, whereas *SCH* refers to changes of scale. The change in scale efficiency is measured by means of distances of the observed input-output vectors in relation to variable returns to scale (VRS) and constant returns to scale (CRS).

Thus, the presented Malmquist index makes it possible to see not only how the change in parameters (inputs and outputs) in two different periods of time affects the total factor productivity of agriculture (Kagan, 2008). In addition, this index differentiates between sources of growth in productivity. Indices with the value above one indicate growth in productivity of respective countries, below one – deterioration in productivity. In turn, those that equal one show that no changes have occurred. The Malmquist indices were calculated using DEAP software version 2.1 available on the websites of the Centre for Efficiency and Productivity Analysis (CEPA).

In addition, surveys were extended by partial productivity analysis. They relate production to respective production factors involved in the process, i.e. land, workforce and capital. Partial productivity indices were calculated as follows:

Land productivity = Total output/Total Utilised Agricultural Area (4)
Labour productivity = Total output/Total labour input (5)
Capital productivity = Total output/Total fixed assets (6)

The study included the latest data collected over a decade (2007-2016). The calculations made use of unit data from farms participating in FADN (Farm Accountancy Data Network). Year 2007 was adopted as the starting year of the observation, which was a result of availability of data concerning countries that joined the European Union in that year (Bulgaria and Romania). With regard to the lack of data for the years 2007-2012 in FADN, Croatia, which joined the EU in 2013, was not included in the surveys. The adopted 10-year period allowed evaluating changes in the conditions of membership for new member states of the European Union.

According to the assumptions of this study, the community was split into two groups:

- member states of the ‘old’ EU, referred to as OMS or EU-15;
- ‘new’ member states that joined the European Union after 2004, referred to as NMS or EU-12.

3. Results and Discussion

Table 1 presents descriptive statistics for the analysed variables. All variables were characterised by significant variability, which testifies to a considerable differentiation of agriculture in respective EU member states. Each variable taken into account in the surveys was characterised by higher variability in NMS than in EU-15.

Table 1. *Descriptive statistics of variables in 2007-2016*

Specification	Y_1	X_1	X_2	X_3
UE-15				
Mean	164463.8	61.1	1.7	722445.8
Standard error	33410.9	10.2	0.1	165086.5
Standard deviation	129400.2	39.7	0.4	639377.1
Minimum	22825.0	9.1	1.1	84490.4
Maximum	446741.4	158.3	2.7	2148215.0
Coefficient of variation	78.7	65.0	23.5	88.5
NMS				
Mean	103775.4	93.9	3.2	193511.3
Standard error	44448.6	43.9	1.1	52578.81
Standard deviation	153974.5	152.3	3.7	182138.3
Minimum	11901.9	2.8	1.4	27792.1
Maximum	531708..2	536.8	14.2	589847.6
Coefficient of variation	148.4	162.1	117.3	94.1

Source: *Own elaboration.*

Table 2 presents the geometric mean for the total factor productivity (TFP) index covering years 2007-2016 including decomposition into technological changes and changes in technical efficiency. Grabowski and Self (2007) emphasize the particular significance of technological changes in agriculture indicating that improvements in agricultural technology have a significant positive effect on long-term national growth. They are directly connected with the implementation of progress – in the first place agricultural sciences but also management.

Thus, the possibility of evaluating the effect of changes in technology on total factor productivity of agriculture in the analysed period is very valuable. In addition, in the case of a decrease in productivity, identification of the principal source of such decrease is of key importance to developing future strategies aiming to improve productivity (Dakpo *et al.*, 2019; Marwa *et al.*, 2017).

Table 2. *Estimation of total factor productivity (TFP)change and its components in 2007-2016*

Country	Technical-efficiency change	Technical change	Pure efficiency change	Scale-efficiency change	TFP change
UE-15					
Belgium	0.792	1.100	0.865	0.915	0.871
Denmark	0.936	1.038	0.936	1.000	0.971
Germany	0.930	1.091	1.054	0.883	1.015
Greece	0.949	1.031	0.946	1.003	0.978
Spain	1.068	1.106	1.000	1.068	1.182
France	0.922	0.928	0.929	0.992	0.856
Ireland	0.985	1.125	1.010	0.975	1.108
Italy	1.129	0.925	1.000	1.129	1.044
Luxembourg	0.860	1.050	0.911	0.944	0.903
Netherlands	0.902	0.971	0.903	0.999	0.875
Austria	0.881	1.020	0.934	0.943	0.898
Portugal	0.893	1.079	0.872	1.025	0.963
Finland	0.880	1.129	0.878	1.002	0.994
Sweden	1.058	1.098	1.040	1.018	1.161
United Kingdom	1.000	1.026	1.000	1.000	1.026
UE-15 (mean)	0.942	1.046	0.950	0.991	0.985
NMS					
Bulgaria	1.024	1.056	1.101	0.93	1.081
Cyprus	0.949	0.946	1.000	0.949	0.898
Czech Republic	1.001	1.023	0.922	1.085	1.023
Estonia	1.030	1.022	1.088	0.947	1.053
Hungary	1.009	1.037	1.063	0.950	1.046
Latvia	0.995	1.209	1.037	0.959	1.202

Malta	0.825	1.146	0.850	0.971	0.946
Lithuania	1.310	1.046	1.279	1.024	1.370
Poland	1.046	1.031	1.017	1.028	1.078
Romania	1.073	1.083	1.000	1.073	1.162
Slovakia	0.964	1.064	0.856	1.126	1.026
Slovenia	1.236	1.100	1.172	1.054	1.359
NMS (mean)	1.032	1.062	1.025	1.006	1.095
UE-27 (mean)	0.981	1.053	0.983	0.998	1.032

Source: *Own elaboration.*

The analysis of indices determined for 27 member states of the EU points to a small (3.2%) growth in total factor productivity of agriculture in the analysed period. It is noticeable that technological changes contributed to that growth (the index value was 1.053). Technical efficiency on an EU scale adversely affected changes in productivity; the index level was 0.981. Analysing the level of TFP index in the group of new and old member states, it should be pointed out that in the first of the above-mentioned groups in 2007-2016 agricultural productivity increased by 9.5%, whereas the other group noted a 1.5% decrease in productivity.

The growth in productivity in new member states was a result of both technological changes (index 1.062) and improved technical efficiency (by 3.2%). In the whole EU, the leader in improvement of agricultural productivity due to changes in production technology was Latvia (1.209). Differences in the Malmquist index value between new member states were relatively high. In countries such as Cyprus and Malta, the index was lower than 1, which corresponds to a decrease in productivity.

On the other hand, in other countries from that group a growth in total factor productivity was observed and the index ranged from 1.026 in Slovakia to 1.370 in Lithuania. Decomposition of changes in productivity into pure technical efficiency change and scale efficiency change shows growth in pure technical efficiency (2.5%) and 0.6% growth in scale efficiency in the group of new member states. The growth in TFP, higher than or equal to average growth in the group of member states under discussion, was recorded in six countries (Bulgaria, Latvia, Lithuania, Poland, Romania, and Slovenia).

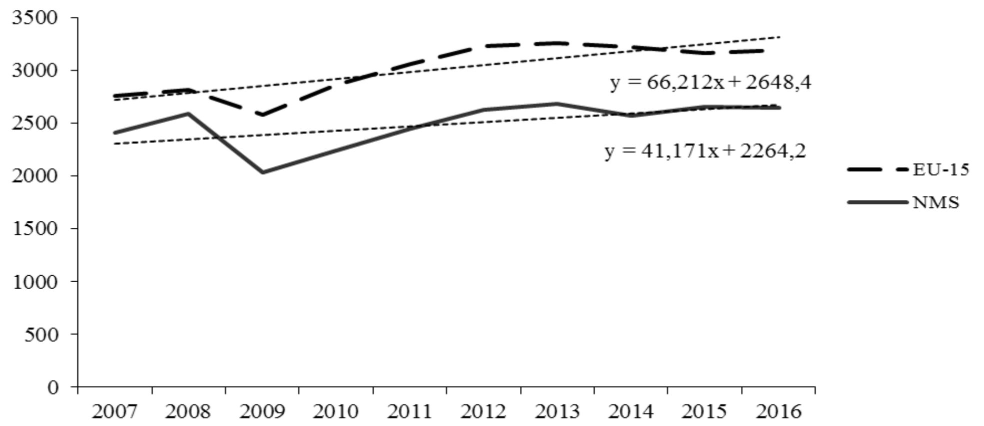
Among member states of the so-called ‘old 15’, a decrease in total factor productivity was noted, which was due to a decrease in technical efficiency. The technological changes index was above 1, while pure efficiency and scale-efficiency indices were below 1. Growth in total factor productivity in the analysed period was recorded in 6 countries only – Germany, Spain, Ireland, Italy, Sweden and the United Kingdom. In most of the above-mentioned countries the growth was a consequence of technological progress; only in Italy did the technological changes index suggest that such changes adversely affected the TFP.

In addition, in Spain, Italy and Sweden technical efficiency increased, and in the United Kingdom the technical efficiency index amounted to 1. It is worth noting that in the majority of old member states in 2007-2016 positive technological changes occurred in agriculture (except in France, Italy, Netherlands), whereas technical efficiency deteriorated. This means that those countries, having exhausted the options of simple improvement in production efficiency, will be required to implement technological progress. In turn, new member states make use of both improved utilization of existing resources and gradual implementation of high technologies (Floriańczyk, 2008). Slower growth in the total factor productivity of agriculture in developed countries is also mentioned in the studies by the European Commission (2012).

Figures 1 to 3 illustrate partial productivity indices referring to production factors involved in farms, i.e. land, workforce and capital. Data in Figure 1 indicates higher land productivity in the analysed period for EU-15 member states. The lowest values of land productivity indicators were noted in 2009 for both surveyed groups of EU member states (Figure 1). This followed from increased land input (EU-15 +4.0%, NMS +7.7%) with a simultaneous decrease in the output production value (EU-15 -7.4%, NMS -13.0%).

On the other hand, the best relations between production value and the area of cropland in use occurred in 2013. The trend lines presented on the chart indicate an upward trend in land productivity. Based on the comparative analysis of equations describing the trend lines, it can be stated that in EU-15 member states the rate of growth in land productivity was higher.

Figure 1. *Land productivity (EUR/ha) of Old Members States and New Member States in 2007-2016*



As regards workforce productivity, the index showed higher levels in the member states of the 'old' EU (Figure 2). This was caused by lower workforce input and higher production level than in NMS. Lower workforce productivity in NMS was mainly due to insufficient application of high technologies that require a large involvement of capital, which necessitated the use of additional workforce resources. Analogous to land productivity, workforce productivity achieved the lowest level for both surveyed groups in 2009. It is significant that changes noted in the value of that indicator, both in EU-15 and in NMS, point to an upward trend in workforce productivity.

Figure 2. *Labour productivity (EUR/AWU) of Old Members States and New Member States in 2007-2016*

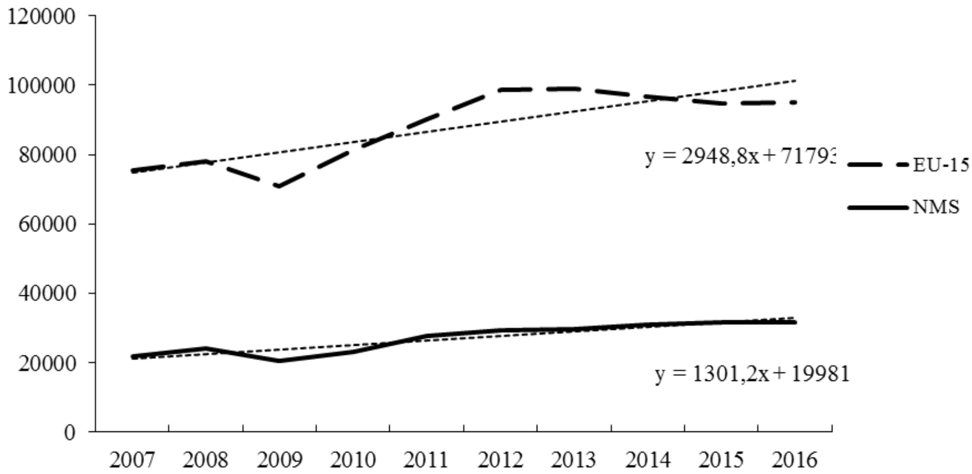
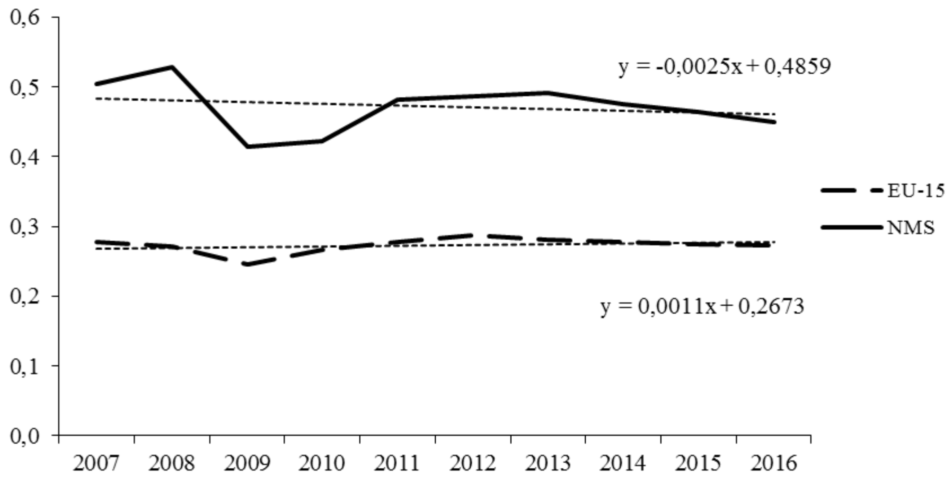


Figure 3 presents the level of capital productivity indicators for EU-15 and NMS. As indicated by the estimated trend lines, capital productivity in both groups has not been subject to significant changes throughout the analysed period. The relation between production value and fixed assets was higher for NMS. This is a consequence of a lower level of capital involved in technical equipment of farms.

Figure 3. *Capital productivity (EUR/EUR) of Old Members States and New Member States in 2007-2016*



The workforce productivity dynamics in agriculture for NMS amounted to 145% and was higher than in EU-15 (126%). At the same time, land productivity indicators improved, but their growth throughout the analysed period was not as high as for workforce productivity. In this case, the land productivity dynamics for EU-15 was higher than for NMS (116% compared to 110%).

For both surveyed groups, capital productivity throughout the analysed period was relatively constant. This means that the factor connected with capital productivity had no effect on the change in total factor productivity.

Table 3. *Mean and dynamics of productivity indexes in 2007–2016*

Specification	Productivity index of		
	land	labour	capital
EU-15			
Dynamics (2016/2007)	116	126	98
Mean	3013	88011	0.27
NMS			
Dynamics (2016/2007)	110	145	89
Mean	2491	27137	0.47

Source: *Own elaboration.*

4. Conclusion

The presented study evaluates changes in agricultural productivity for 27 EU member states in 2007-2016. To this end, the Malmquist productivity index was used including decomposition into technological changes and technical efficiency changes. The analysis was also carried out based on partial productivity indicators expressing relations between production value and production factors, i.e. land, workforce and capital. This study contributes to reference literature concerning productivity of agriculture for a number of reasons.

First, the scope of the survey is extensive, as it covers a group of 27 EU member states split into new and old members. The second aspect of the survey is taking into account both changes in total factor productivity and in productivity of respective production factors. Thirdly, the Malmquist index adopted for the needs of the survey made it possible to identify the sources of change in total factor productivity.

The outcome of the survey showed growth in total factor productivity of agriculture in 2006-2017 for NMS (9.5%), resulting from positive technological changes and improvement in technical efficiency. In the analysed period, leaders in improving agricultural productivity among new EU members were Lithuania and Slovenia in which the growth in productivity exceeded 30%. In 9 out of 12 surveyed new member states the growth in TFP was higher than its average growth in 27 member states of the European Union. Productivity decreased only in Cyprus and Malta.

A small decrease in productivity was noted in a group of EU-15 countries, which was due to a decrease in technical efficiency. In most old member states a decrease in total factor productivity was observed despite the occurrence of positive technological change. This phenomenon can be explained by the period of adaptation of the implemented new technologies that is initially accompanied by a decrease in productivity.

From the analysis involving partial productivity indicators it follows that the resulting growth in total factor productivity in NMS was principally a reflection of improvement in workforce productivity. The workforce productivity level in EU-15 in the analysed period was significantly higher.

This means that NMS should aim at better utilisation of their human resources through introducing modern labour-saving production technologies. In addition, a significant decrease in partial productivity indicators was noted in 2009 in both surveyed groups. This was cause by a decrease in the value of production generated in that year, which was induced by global economic downturn.

Further surveys concerning agricultural productivity in EU member states should take into account additional factors which determine the level of productivity and the rate of their changes. It would also be justified to undertake surveys with reference to more uniform groups of farms selected with regard to their production potential or production specialisation.

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