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THE ROLE OF TECHNOLOGICAL PROGRESS IN AGRICULTURAL OUTPUT GROWTH IN THE NMS UPON EUROPEAN UNION ACCESSION

Key words: EU, total factor productivity, technological change, land substitution, inputs productivity

ABSTRACT. It is very important to increase input productivity in agriculture. This not only enables feeding the growing population, but also reducing agricultural pressure on the environment. The aim of the study is to determine the importance of TFP in comparison to the significance of production inputs in the growth of agricultural output in new EU member states. The analysis covered 2000-2016. Data available from the USDA on agriculture of the studied countries was used. The method of Solow residuals was used in the study. It was found that, in the studied countries, agricultural output decreased after political transformation and, since 2004, a further decrease of agricultural production was observed in five out of nine countries. Only in the three Baltic states and Poland was there an increase in production. In all countries, except Poland, a decrease in production intensity was observed. The area of agricultural land in all countries except the Baltic states decreased similarly. In the analyzed period, the highest increase in factor productivity was achieved in Lithuania (72%), Estonia (57%) and Latvia (51%), while the lowest in Hungary (7%) and Poland (21%). In each of the analyzed countries, the increase in TFP resulted in either an increase in agricultural output or the decrease in agricultural output was smaller than the decrease in the amount of inputs used. Technological change plays a dominant role in achieving an increase in agricultural production and an increase in the productivity of other inputs.

INTRODUCTION

Growth in agricultural productivity is one of the most important factors in ensuring that there is and will be enough food for a growing world population. According to Keith Fuglie et al. [2012] real food prices have fallen at a rate of 1% per year since 1900, and the number of people in the World has increased from 1.7 to 7 billion over the same period. Only in the short term, after 2000, was there some slowdown in the decline of food prices,

which is not known to have continued in the long run. Thanks to technological progress, the pressure to convert land into agricultural land is lower, and greenhouse gas emissions from agriculture are also lower [Villoria 2019].

The increase in production in agriculture can be achieved by using more land for production, increasing the use of production inputs, and introducing technological progress. In the last 20 years, the increase was mainly due to technological progress, and its role increased in subsequent periods (see Figure 2). Agricultural economists studying the determinants of agricultural production growth indicate two most important growth factors: almost 70% of this growth results from increasing factor productivity, and only a smaller part from increasing the amount of production inputs. The dominance of technological changes in the increase in productivity results from spending on research and development in agriculture for many decades [Gardner 2002, Ruttan 2002, Alston et al. 2011, Wang et al. 2015]. It is also indicated that the increase in agricultural production in the USA after 1950 was significantly correlated with the increase in TFP, while there is no visible relationship between the level of use of production inputs and the volume of agricultural production [Fuglie et al. 2017]. For developing countries, there is a significant gap in land and labor productivity in agriculture, reaching several decades [USDA 2019]. For the countries of the former Eastern Bloc, such delay has been estimated to be almost 30 years.

The set of factors that determine the possibility and speed of progress transmission and then obtaining an increase in productivity in agriculture include economic and social factors, as well as those related to the area structure of farms [Piwowar 2017]. Farms with lower economic strength and small-scale production both face a barrier of lack of financial resources for introducing progress, and the availability of appropriate machinery and technology for small farms. In such farms, it is usually only biological progress which is neutral towards the scale of production, but not mechanization or organizational progress [Wicki 2016].

As the concentration of land on farms increases, the introduction of changes in technology becomes faster [Esposti 2011, Du et al. 2018]. As a result, large farms achieve higher factor productivity. In the first place, as a result of the mechanization of production processes, labor productivity increases, followed by land and capital productivity [Kusz, Misiak 2017, Parzonko 2018, Kisielińska 2019, Wicki 2019, Czyżewski et. al. 2020]. Productivity growth dynamics strongly depend not only on the area structure of farms in a given country and the profitability of production, but also on the price relations between individual inputs, as described by Yujiro Hayami and Vernon Ruttan [1969]. Therefore, the subsectors of agriculture in which no more expensive input, e.g. labor, is required and the production processes can be mechanized, there is higher profitability and faster development [Wicka, Wicki 2016].

Achieving higher productivity in agriculture requires the appropriate professional education of producers, because, in agriculture, it is necessary to deal with many issues in various fields, e.g. plant diseases and animal nutrition. A new production technique

is often associated with the introduction of complex changes, otherwise no increase in production is achieved [Wicki, Dudek 2019] especially the importance of certified seed. The following data have been used in research: inputs of artificial fertilizers per hectare, consumption of pesticides per hectare, certified seeds per hectare and average soil quality. All data were calculate for provinces level for each year in the period 2000-2017. The patterns of source of productivity were investigated using two methods: interpretation of estimated parameters in Cobb-Douglas production function and analysis of squared semipartial correlations. The results from both methods applied in the research are similar. The paper argues that the least ”pure impact” is connected with certified seeds, medium impact to chemical originated inputs (fertilizers and pesticides. A significant productivity gap may therefore be observed between countries or even individual regions in a given country [Kisielińska 2019]. In more developed countries, biotechnology currently plays the main role in creating productivity growth [Stevenson et al. 2013], in less developed ones, mechanization progress is still of key significance [Pawlak 2010].

An important role in inducing changes in agricultural productivity is played by the state policy regarding research on agriculture or investment support and the common agricultural policy in the EU. Long-term investments in agricultural research and policy and institutional reforms have enabled many developing and transition countries to improve their agricultural productivity [Fuglie, Rada 2013]. Some investment directions, focus on environmental protection, including the reduction of greenhouse gas emissions or the provision of other public goods by agriculture, may limit the dynamics of agricultural production growth [Daniłowska 2015, Lenerts et al. 2017]. Similarly, changes in agriculture can be slowed down by supporting small farms for social reasons or striving to reduce production surpluses, as well as supporting the development of production directions with lower productivity, e.g. traditional products or the production of certain biofuels [Rubins, Pilvere 2017, Wicki 2017].

The so-called new EU member states (NMS) were characterized by a lower level of agricultural development after the political transformation in the 1990s, although it was not identical in this group of countries. As part of the market economy, agriculture was modernized in these countries, and agricultural production, after an initial large decline, grew despite the reduction in input amounts [Takács 2014, Wicki 2018]. In some countries, up to 30% of agricultural land was excluded from use in the early 1990s.

It should be pointed out that the increase in agricultural productivity in the EU, especially in new member states, may depend on the most supported directions of agricultural policy in the EU, including those specifically planned in individual countries. Subsidies for agriculture and RDP measures significantly increase the level of investments in agriculture, including input-saving ones (e.g. labor-saving ones) [Mickiewicz, Pilvere 2017]. It was found for the entire EU that despite the high level of agricultural development in the EU-15 countries, TFP is still the basic factor influencing the size of agricultural output [Baráth, Fertő 2017]. In studies on single NMS concerning changes in agriculture after

accession in 2004, it was found that thanks to the TFP increase, agricultural production did not decrease significantly, although production inputs were significantly reduced [Takács 2013, Cechura et al. 2015, Nowak 2017] dairy and pork–and assesses the period after the accession of the Czech Republic to the EU (2004-2011). These results confirm the long-term analysis of USDA [2019], which have shown that, in developed countries, the level of inputs does not increase, and agricultural production increases only thanks to the increase in TFP. In addition, it was found that, in the long run, the change in overall productivity was, to a small extent, dependent on the current objectives of agricultural policy, the priorities of which changed in the following decades, and the impact of the weather was more pronounced [Fuglie et al. 2017]. Additionally, the achievement of higher productivity of agriculture as a whole, in a given country, takes place slowly because the system is very complex and not centrally coordinated, and the effects of implementation of innovative solutions are not always known [Broring 2008].

Total factor productivity in measuring changes in agricultural productivity is considered to be one of the better measures as it takes the total input of land, labor, capital and other materials involved in agricultural production and compares them to the total amount of crop and livestock production obtained. If total production increases faster than the inputs, TFP improves (input productivity increases). The TFP index differs from such measures of productivity as yield or value added per worker as it takes a wider range of inputs used for production into account. For this reason, it is often used, with various modifications, in productivity research at a country level [Moghaddasi, Pour 2016, Czyżewski, Majchrzak 2017, Jałowiecki 2018] as well as at a regional level [Rusielik 2014].

While productivity has been the major source of agricultural growth in developed countries for at least half a century, the acceleration of global TFP growth since 1990 came about largely because of improved productivity performance in developing countries and, to some extent, in the transition economies of the former Soviet Union and Eastern Europe [USDA 2019]. For this reason, it was decided to investigate the factors of changes in agricultural production in the former socialist bloc countries that joined the EU in and after 2004. The agriculture of these countries was covered by the CAP, so the conditions for agriculture did not differ significantly between countries. The main intention of the article is to define the importance of TFP for agricultural output growth in these countries.

MATERIAL AND METHODS

The aim of the study is to determine the significance of technological change (TFP) in comparison to the significance of production inputs in the sources of growth of agricultural output observed in 2000-2016 in the so-called new EU member states, i.e. in the pre-accession period and after accession. The research tasks are as follows:

1) determining the dynamics of agricultural output,
2) determining the change in the level of inputs,
3) determining the relative importance of land inputs, production intensity and TFP in generating an increase in the level of agricultural production.

The analysis covered the period 2000-2016. Nine of the twelve countries that joined the EU in 2004 and 2007 were included in the research. Slovenia, Malta and Cyprus were omitted as countries that before 1991 were not included in the former Eastern Bloc countries, and at the same time are characterized by significantly different agricultural conditions.

Source data for analysis was obtained from the United States Department of Agriculture (USDA) database, prepared on the basis of the data of FAO available at http://www.usda.gov. The latest available data was used, i.e. as of November 2019.

The study used the approach to determining TFP as proposed by Keith Fuglie [2015]. Total factor productivity (TFP) is defined as the ratio of change in total output to total inputs. If total output is Y and total inputs is X, TFP can be determined as follows:

$$TFP = Y/X \tag{1}$$

where: Y represents total production (output) and X represents total expenditures (input).

Changes in TFP over time can be determined by comparing the rate of change in total production with the rate of change in total input. Expressed as logarithms, the changes in equation (1) over time can be written as:

$$\frac{d\ln(TFP)}{dt} = \frac{d\ln(Y)}{dt} - \frac{d\ln(X)}{dt} \tag{2}$$

which states that the rate of change in TFP is the difference between the rate of change in aggregate output and aggregate input. It is also possible to focus on a particular input, for example land (which is designated as X_1), and all other inputs (X_j) decompose growth into the component due to land expansion (extensifiaction) and after further decompose yield growth into the share due to TFP and the share due to using other inputs more intensively per unit of land (intensification).

$$g(Y) = g(X1) + g(TFP) + \Sigma S_j\, g\left(\frac{X_j}{X_1}\right) \tag{3}$$

where: g – annual rate of growth in a variable and S_j is a share of the j-th input.

Figure 1 shows a graphical representation of the growth distribution described in equation (3). The height of the bars indicates the growth rate of real production. The increase in real production is first broken down into an increase resulting from an increase in the expansion of the use of agricultural land (extensification) and an increase related to intensification leading to an increase in yield per hectare (intensification).

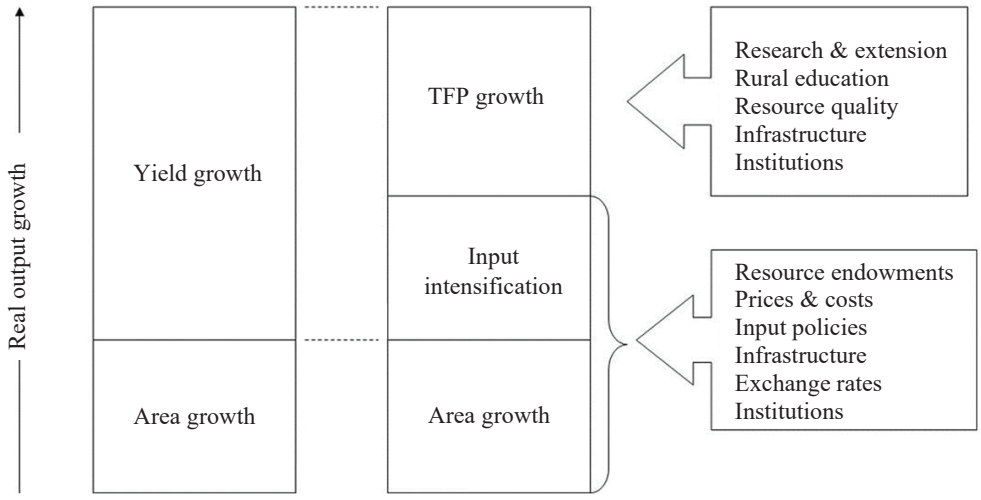

Figure 1. Agricultural growth comes from increasing the use of land and other resources and/or from raising the productivity of those resources

Source: [Fuglie, Rada 2013]

RESEARCH RESULTS AND DISCUSSION

Since the beginning of the 1970s, agricultural production in the World has increased by over 2% annually. In the following decades, in creating production growth, an increase in the importance of technological progress (TFP) was observed, and the importance of increasing the area of arable land and increasing production intensity decreased. In the years 1971-1990, the increase in TFP resulted from about 25% of the increase in factor productivity, and after 2000 this share increased to almost 78% (Figure 2).

The size of agricultural production between the analyzed countries differed significantly because the size of individual countries is different. In Poland, the value of agricultural output in 2016 was 22.4 billion (constant USD 2004-2006), USD 10.1 billion in Romania, USD 6.0 billion in Hungary, and USD 4.3 billion in the Czech Republic. In relatively small Baltic countries it was: USD 0.7 billion in Estonia, USD 1.1 billion in Latvia, and USD 2.4 billion in Lithuania. Changes in agricultural output in the analyzed countries

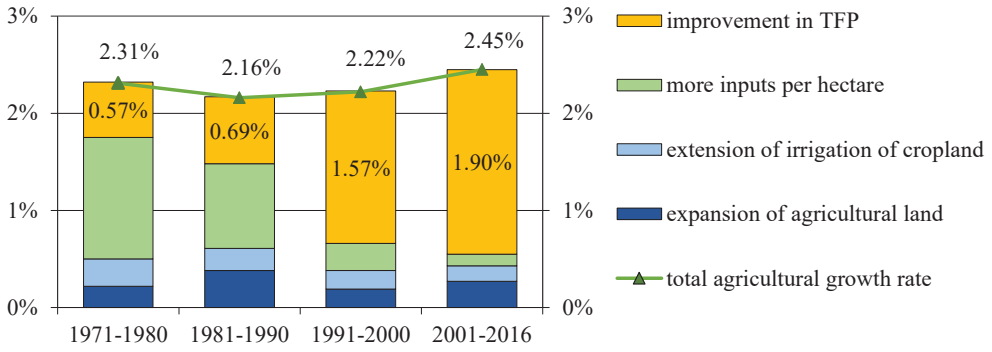

Figure 2. Sources of growth in global agricultural output
Source: [USDA 2019]

after 2000 were different. There was a marked increase in production in five countries, and only slight changes in the remaining four (Figure 3). After 2004, only in Poland and the Baltic countries an increase in production was observed, and in 2016 it was higher by 8% in Poland and by 25 to even 50% in Baltic countries. In the same period, in Bulgaria, the Czech Republic, Slovakia, Romania and Hungary, a decrease of several percent in real agricultural production was observed.

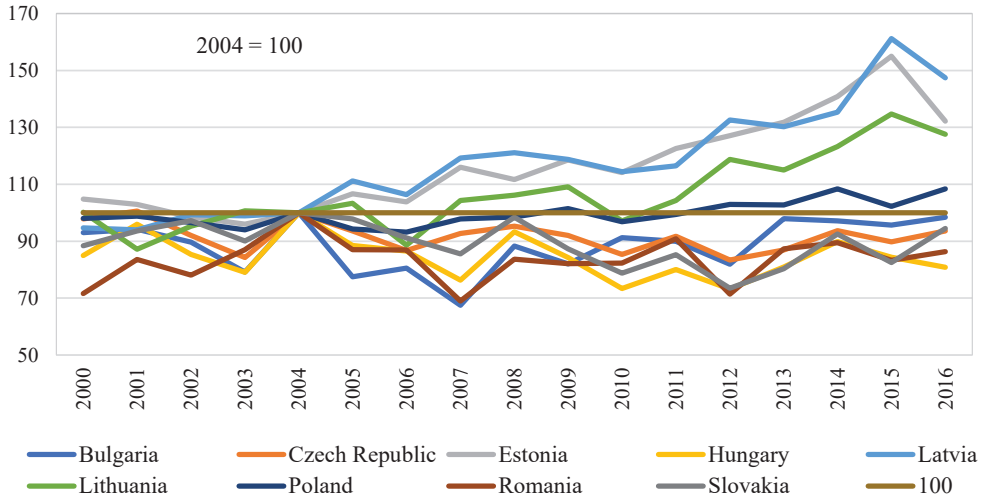

Figure 3. Total agricultural production between 2000 and 2016 (calculation based on prices in constant USD 2004-2006), 2004 = 100
Source: own calculations

The change in the volume of agricultural production resulted from both changes in agricultural land area and production intensity measured by the level of inputs. Figure 4 shows changes in the level of production inputs in agriculture in the studied countries. The level of outlays in agricultural production decreased more than the volume of production in agriculture. In the years 2000-2016, the highest decrease in outlays was observed in Lithuania – 25% and Estonia – more than 20%, and in other countries it was about 10%. Only in Latvia the outlays increased by 3% in this period. The area of agricultural land used for production only increased in Latvia by as much as 30%. In Estonia and Lithuania, an increase in the agricultural area has only been observed since 2004. This

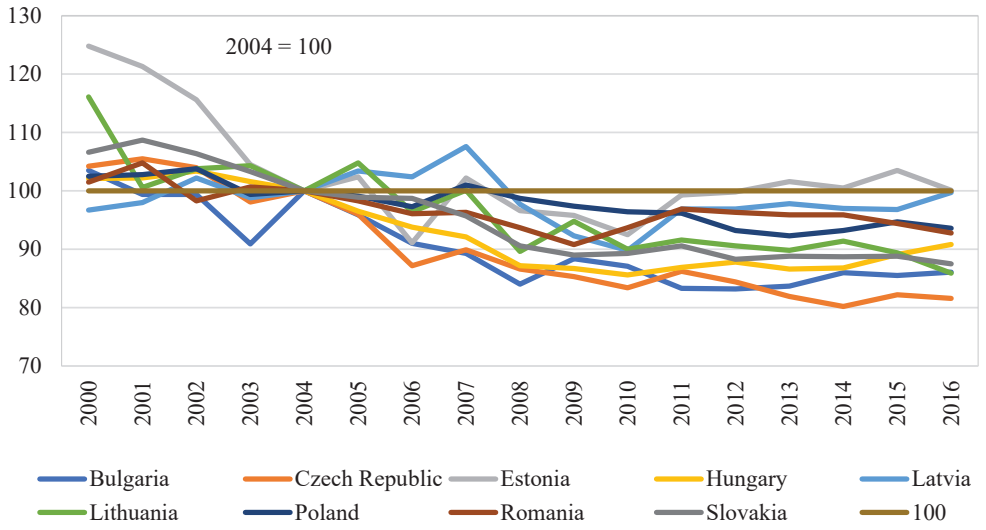

Figure 4. Aggregate inputs in agriculture between 2000 and 2016 (calculation based on prices in constant USD 20042006), 2004 = 100

Source: own calculations

was due to the recovery of agriculture after the collapse of large-scale Soviet farms. In other countries, there was a decline in the area of utilized agricultural land. The decrease was as high as 20% in the Czech Republic, Slovakia, Poland and Lithuania, and in other countries it was 10-15%.

Figure 5 shows the change in TFP in the analyzed period for agriculture in individual countries. In 2016, the total level of TFP in each of the analyzed countries was higher than in 2000. The cumulative increase was from 6% in Hungary to over 50% in the three Baltic countries. In other countries it ranged between 20 and 30%. During the period considered, some slowdown in TFP was observed in 2005-2012. A similar slowdown

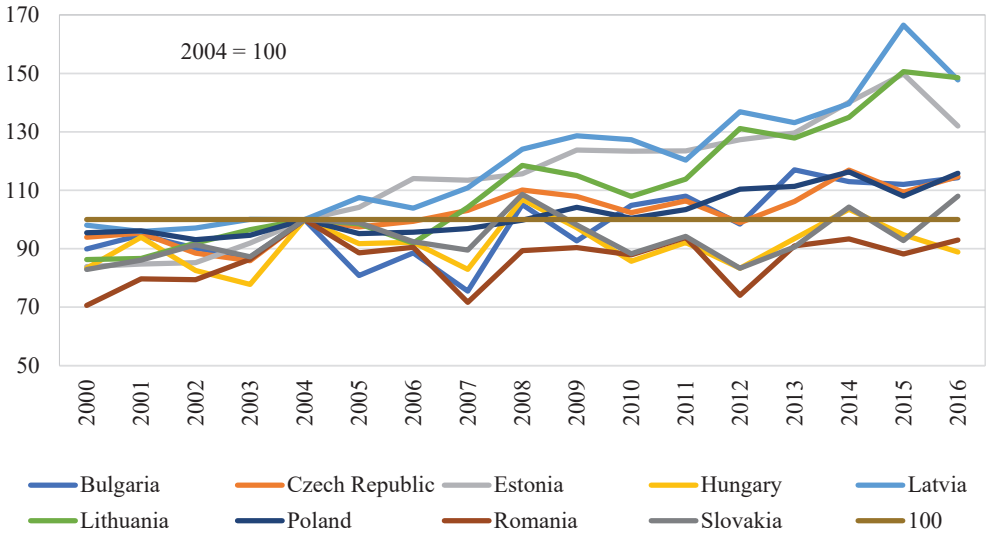

Figure 5. Total Factor Productivity in agriculture between 2000 and 2016, 2004 = 100
Source: own calculations

across the whole EU has also been reported in other studies [Baráth, Fertő 2017, Cechura et al. 2015]. In the period from 2004 in Romania, Slovakia and Hungary there was a slight decrease in TFP, and in the following years there was a stagnation in this regard. It should be emphasized that the dynamics of TFP changes does not mean that agriculture in a given country is characterized by a high level of productivity [Takács 2013], and NMS has lower agricultural productivity than that observed in the EU-15 countries, they are also diversified within the group.

In summary to the previous results, Figure 6 shows the structure of the impact of the most important factors on changes in agricultural output in the studied countries for the entire analyzed period (2000-2016). The change in production was decomposed into three factors: land area, level of intensity of production (inputs) and TFP. It can be seen that the total change of agricultural output resulted from the opposite influence of individual factors.

As mentioned above, there was a decline in agricultural output in the three analyzed countries (The Czech Republic, Slovakia and Hungary). In the entire study group, average annual growth of agricultural output ranged from -0.76% in Slovakia to 2.93% in Latvia. The change in agricultural production was lower than the change in inputs of other production factors. In most countries, except Poland, a decrease in the total intensity of agricultural production was observed. The rate of decline of inputs was not high on average, only in the three Baltic states was it above 1% per year. In each of the studied countries, the level of employment and animal stock decreased, while the level of fertilization and

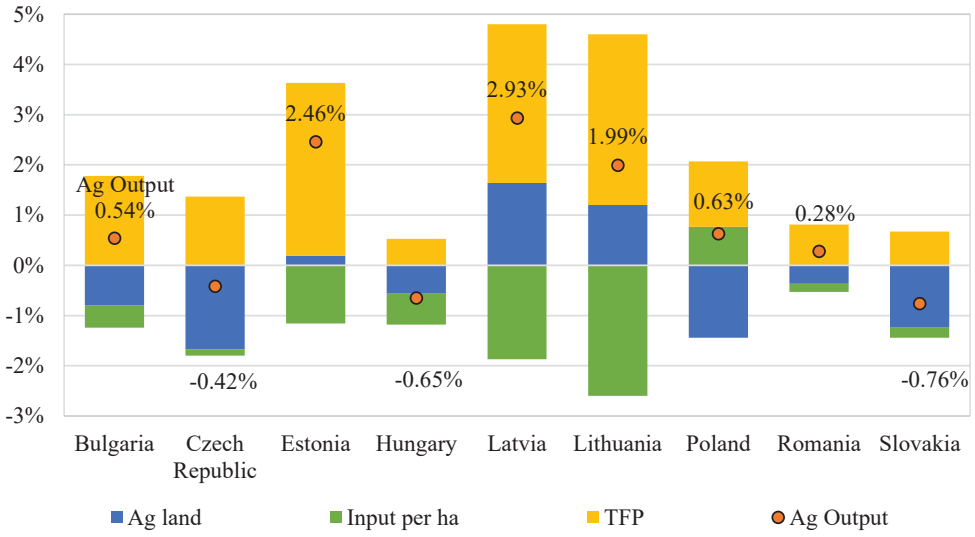

Figure 6. Sources of growth in global agricultural output in percent annually, 2000-2016
Source: own calculations

machine inputs increased. The area of agricultural land used for agricultural production decreased. Also, in this case, a reverse tendency was observed in the Baltic states.

In the years 2000-2016, the average annual growth of TFP was the highest in the Baltic states and amounted to over 3%. The change in TFP below 1% per year was observed in Slovakia, Romania and Hungary. In the remaining three countries, it ranged from 1.3% to 1.7%. This means that despite different dynamics, in each of the surveyed countries, there was a continuous increase in input efficiency.

The increase in factor productivity (TFP) did not fully compensate for the decrease in land inputs and the decrease in intensity in the Czech Republic, Slovakia and Hungary. The main reason for the decline in agricultural output in the first two countries was a reduction in the area of land used, and in Hungary, an additional reduction in production intensity. In Bulgaria, Poland and Romania, the average annual increase in TFP compensated for the decrease in land inputs and, as a result, an increase in agricultural production was observed. The situation was completely different in the Baltic states. Both TFP growth and an increase in the area of agricultural land used were observed there. The reduction in the intensity of production in these countries resulted from the substitution of labor with capital, which brought an additional effect in the form of a high increase in productivity.

In each of the analyzed countries, TFP increased, which means that agriculture is becoming more productive, production costs may decrease and, possibly, some of the

environmental impacts of agriculture can be avoided. The impact of the TFP change on the production volume in agriculture was large. On the other hand, the intensity of production decreased, primarily labor inputs and animal stock. There was a clear difference in land use. In all the Baltic countries, there was an increase in agricultural land area (from 0.2% per year in Estonia to 1.6% in Latvia), and in other countries, the area of agricultural land used decreased, even at a rate of more than 1% annually (in the Czech Republic, Slovakia and Poland).

In each of the studied countries, a different structure of the impact of the researched factors on changes in the size of agricultural output was observed. The observed differences resulted from a different initial state of agriculture after the period of economic transformation, including the depth of decline in agricultural production. An additional factor influencing the observed results could be the different area structure of farms in individual countries.

CONCLUSIONS

The role of technological progress in generating growth in global food production is constantly increasing. In the years 1971-1990, in the World, an annual average of 2.2% of increase in agricultural production was achieved, the share of technical progress in this increase was about 25%. After 2000, production dynamics remained at a similar level, but the contribution of the increase in factor productivity increased to over 70%. Currently, TFP is the most important factor in the growth of agricultural production.

The results obtained for the surveyed countries show that we observe a positive trend in TFP in agriculture in each of the surveyed countries. There are fluctuations in the dynamics of TFP, but, in total, in the years 2000-2016, the average annual growth rate ranged from 0.7% to even 3.4%. TFP is a significant source of agricultural production growth in each of the NMS. In most of the analyzed countries, the increase in TFP more than compensated for both the decrease in the area of agricultural land used in agricultural production and the decrease in the consumption of other production inputs. However, the obtained results do not fully confirm the assumption that the TFP increase in all NMS is high enough to maintain the agricultural production volume, while reducing the consumption of other factors. In the Czech Republic, Slovakia and Hungary the increase in TFP did not compensate for the significant decline in agricultural land and agricultural production decreased.

An optimal scale of production is not observed in these studies, but there is a supposition that part of the TFP increase results from changes in the area structure of farms related to the liquidation of smallest farms. In countries where such reserves related to changes in agrarian structure exist, the future change in agricultural productivity may be higher.

The increase in TFP shows that there was a significant factor productivity gap. Still, productivity in agriculture in the studied countries is lower than that observed, for example, in Western European countries [Baráth, Fertő 2017], so further growth should be expected.

Technological change (measured by TFP) in the analyzed countries, as well as the World, plays a dominant role in achieving an increase in agricultural production and an increase in the efficiency of other inputs. In the analyzed countries, the decrease in the amount of inputs in agriculture, which in the analyzed period was as high as 20%, was more than compensated for by the introduction of technological progress, which increased the productivity of production factors.

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ROLA POSTĘPU TECHNOLOGICZNEGO WE WZROŚCIE PRODUKCJI ROLNEJ W NOWYCH CZŁONKOWSKICH KRAJACH UNII EUROPEJSKIEJ

Słowa kluczowe: UE, wskaźnik całkowitej produktywności, zmiana technologiczna, substytucja ziemi, produktywność nakładów

ABSTRAKT

Wzrost produktywności nakładów wykorzystywanych w rolnictwie jest bardzo ważny. Umożliwia to uzyskiwać wyższą produkcję, wyżywić rosnącą populację ludności, a także zmniejszyć presję rolnictwa na środowisko. Celem pracy jest określenie znaczenia wzrostu produktywności czynników (TFP) dla zwiększenia produkcji rolnej w nowych krajach członkowskich UE na tle znaczenia nakładów produkcyjnych. Analizą objęto dane za lata 2000-2016. Materiały do badań pochodziły z bazy danych USDA. W badaniach wykorzystano metodę reszty Solowa. Ustalono, że w badanych krajach produkcja rolna zmniejszyła się bezpośrednio po transformacji ustrojowej, a po 2004 roku w pięciu z dziewięciu krajów zaobserwowano dalszy jej spadek. Tylko w trzech krajach bałtyckich i w Polsce nastąpił wzrost produkcji. We wszystkich krajach, poza Polską, obserwowano spadek intensywności produkcji. Podobnie zmniejszyła się powierzchnia użytków rolnych we wszystkich krajach z wyjątkiem krajów bałtyckich. W każdym z analizowanych krajów odnotowano wzrost produktywności czynników produkcji, najwyższy na Litwie (72%), w Estonii (57%) i na Łotwie (51%), a najniższy na Węgrzech (7%) i w Polsce (21%). W każdym z krajów wzrost TFP prowadził do wzrostu produkcji rolniczej, albo ograniczał jej spadek wynikający ze zmniejszenia zużycia nakładów. Zmiana technologiczna odgrywała dominującą rolę w osiąganiu wzrostu produkcji rolnej i wzroście produktywności innych nakładów.

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