Drivers of technical efficiency in agriculture in the Western Balkans and New EU Memeber States

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Danilo Đokić
MSc in Agricultural Economics
Institution: University of Novi Sad, Faculty of Economics in Subotica
Address: Segedinski put 9-11, Subotica, Serbia
E-mail: danilo.djokic@ef.uns.ac.rs

Stanislav Zekić
PhD in Agricultural Economics
Institution: University of Novi Sad, Faculty of Economics in Subotica
Address: Segedinski put 9-11, Subotica, Serbia
E-mail: zekics@ef.uns.ac.rs

Žana Jurjević
MSc in Agricultural Economics
Institution: University of Novi Sad, Faculty of Economics in Subotica
Address: Segedinski put 9-11, Subotica, Serbia
E-mail: zana.kleut@ef.uns.ac.rs

Bojan Matkovski
PhD in Agricultural Economics
Institution: University of Novi Sad, Faculty of Economics in Subotica
Address: Segedinski put 9-11, Subotica, Serbia
E-mail: bojan.matkovski@ef.uns.ac.rs

Abstract

All former socialist countries have gone through a transition process in the past 30 years that has had a significant impact on agriculture. This paper will specifically investigate technical efficiency in agriculture and its drivers in two groups of counties: the Western Balkan countries and the New Member States (without Cyprus and Malta), all of which are part of Central and Eastern Europe (CEEC). Technical efficiency (TE) scores were obtained through Data Envelopment Analysis (DEA). The results of the analysis show that technical efficiency improved during the period 1999-2016 and is at a similar level in both groups. The determinants of efficiency were investigated using the Tobit model. According to results of the model, there are three factors that positively affect TE: land per worker, fertilizers used per hectare and membership in the European Union. Furthermore, the share of organic production in total agricultural land has a negative impact.

Key words: Efficiency. Agriculture. Western Balkan.

1. Introduction

In the end twentieth century, countries of Central and Eastern Europe (CEEC) had been significantly affected by political, economic, and institutional reforms as part of the transition process. These reforms had a massive impact on agriculture that resulted in an output decline of this sector. According to Jackson and Swinnen (1995) output decline in the initial phase of transition in CEEC was caused by: a combination of declining terms of trade following price and trade liberalizations, transition-related disturbances caused by property rights reforms and enterprise restructuring, extreme weather conditions in some years, and a statistical bias in that effective output is overreported in the pre-reform years, while the statistical coverage underestimated the actual production after the reforms. T

his period had a significant impact on the performances of agriculture in CEEC and defined their initial conditions in the process of European Union (EU) integration. It is challenging to determine when the transition process has ended in CEEC. More likely, it has only grown into a process of EU integration. In 2004, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia joined the EU, while Bulgaria and Romania became members of the EU in 2007.

Croatia joined in 2013, while other Western Balkan countries (WB) are still in the process of EU integration. So, CEEC is now divided into two groups New Member States (NMS), the countries that joined the EU after 2004, and Western Balkans. As Csáki and Jámbor (2013) have noticed EU accession has had a significant impact on agriculture in the NMS, although member states capitalized their opportunities in different ways due to initial conditions and pre- and post-accession policies.

There are two goals of this paper. The first goal is to compare the technical efficiency of agriculture in WB and NMS in the period after 1999. Additionally, these regions are compared with two more groups of countries. EU-6 countries (Luxembourg is excluded due to the low value of agricultural production) have been added to serve as a benchmark, as both the WB and NMS countries tend to achieve the performance of the EU-6 agrarian sector.

In contrast, four more Former Soviet Union countries (FSU) have been included in the analysis due to similar historical development as WB and NMS countries: Russian Federation, Ukraine, Belarus, and the Republic of Moldova. The second goal is to find out what are the drivers of the technical efficiency of agriculture in WB and NMS.

2. Literature Review

Many studies analyze the agricultural sector of CEEC, but only a few investigate the transitional period and its effect on agriculture. In their research of agricultural productivity for 23 transition economies (included CEEC) in the period 1992-1999, Cungu and Swinnen (2003) concluded that during the reform period, almost all countries in the CEEC had shown continuous productivity improvements compared to 1992. On average, aggregate productivity has increased by 20.9 percent. These developments reflect changes in resource use and the technical progress in 1999 compared to 1992.

In more detailed research on performances of the agricultural sector in transition economies, Swinnen and Vranken (2010) showed that in the period 1989-2005, countries witnessed an initial decline in productivity that differs enormously between countries. Their analysis indicates that the productivity changes were related to the extent of the pre-reform distortions, initial resource endowments and technology use, and the reform implementation in the countries. They also suggested that after this initial phase, all countries witness an increase in productivity.

Analysis of the efficiency of production processes became the focus of interest on the part of economists in the 1950s. This trend was initiated by the studies of Debreu (1951) and Farrell (1957), in which a measure of the technical and overall efficiency of production was introduced (Błażejczyk-Majka and Kala 2015).

The technical efficiency of agriculture in CEEC countries is subject to many studies. Latruffe et al. (2004) analyzed determinants of technical efficiency of crop and livestock farms in Poland and concluded that livestock farms are more technically efficient than crop farms. They also found that large farms are more efficient. Bojnec et al. (2014) analyzed determinants of technical efficiency in agriculture in new EU member states from CEEC. They concluded that technical efficiency in agriculture is significantly positively associated with agricultural factor endowments, average farm size, farm specialization, small-scale farms, and technological change.

Most recently, in their study of technical efficiency and its determinants in the European Union agriculture Nowak et al. (2015) showed that, the level of the technical efficiency of agriculture is diverse, and the difference between the states with the highest and the lowest efficiencies is 40%. Considering the factors determining the efficiency of the agriculture, it should be noted that the stimulants have proven to be such factors as the soil quality, the age of the head of the household, and the surcharges for investments. On the other hand, the size of the farm appeared to be irrelevant from the viewpoint of the technical efficiency of the agricultural sector. For the period 2007-2011, Kočišová (2015) showed that, on average, the EU agrarian sectors performed efficiently, as evidenced by the relatively high value of the average input and output efficiency.

Bojnec and Latruffe (2009) used the parametric stochastic frontier and DEA methods to show that the degree of technical efficiency had increased during the transition. Also, farm specialization associated with technological change was found to be a crucial determinant for increasing technical efficiency. Many studies analyze the agricultural sector in WB, but only Horvat et al. (2020) analyze the technical efficiency of agriculture in Western Balkans and the EU. They showed that the highest average technical efficiency was achieved by the EU-15 countries for the entire period (2006-2016), while the Western Balkan countries had the lowest score.

3. Materials and Methods

As previously mentioned, the goals of this paper are to compare the technical efficiency of agriculture in Western Balkans and the New Member States, without Cyprus and Malta, and to find out the drivers of technical efficiency. Cyprus and Malta were left out of the analysis for two reasons.

The first is because these countries do not have the same historical development as other NMS, while the second reason is that the importance of the agricultural sector of these countries for EU agriculture is negligibly small. Results are compared for the period 1999-2016 to cover the period of transition and EU integration as well as the period after accession in some countries. Additionally, EU-6 countries are added in analysis to serve as a benchmark due to its high performance of the agricultural sector.

Also, four Former Soviet Union countries (FSU) that are not in the EU or the process of EU integration are included due to similar historical development as WB and NMS countries. According to these goals, the analysis has been decomposed into two stages. First, the DEA method, a non-parametric method developed by Charnes et al. (1978), was used to obtain technical efficiency scores (TE). Second, the Tobit model is used to determine its drivers. Only NMS and WB countries are included in this model.

Originally, Farrell (1957) defined technical efficiency as a measure of a firm’s ability to convert inputs into outputs. According to the input-output relation, the DEA method can be input or output-oriented. Input-oriented TE measures address the question: „By how much can input quantities be proportionally reduced without changing the output quantities produced?“ while output-oriented measures address the question „By how much can output quantities be proportionally expanded without altering the input quantities used?“ (Coelli et al. 2005).

In this paper, the input-oriented method was used because the modern agricultural policy of European countries is more oriented on input reduction, than output growth. The DEA is carried out by solving the following model (Banker et al.1984) of linear programming for each Decision Making Unit (DMU) separately for each year:

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \qquad (1)$$

$$s.t. \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{io} \quad i = 1, 2, \dots, m;$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{ro} \quad r = 1, 2, \dots, s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \quad \forall \quad i, j, r$$

where n is the number of DMUs. DMU_o represents the country being evaluated. Assume that there is s output variables and m input variables. Observed output and input values are y_r and x_i respectively, thus y_{ro} is the amount of output r used by DMU_o, while x_{io} is the amount of input i used by DMUo. s_r^+ and s_i^- are the output and input slacks. λ is the DMU’s weight and ε is a non-Archimedean element smaller than any positive real number.

The efficiency score is θ. DEAP 2.1 software developed by Coelli (1996) was used in order to calculate TE scores for observed data. Due to the lack of micro-level data (such as Farm Accountancy Data Network-FADN) for the whole observation period for all countries (there is no data for all Western Balkan countries), all data were downloaded from FAOSTAT. Based on literature review, one output and three inputs were chosen: Y1-Value of agricultural production; X1- agricultural land; X2- labour; X3- capital. Labour input was measured by the number of people working in agriculture, while land input was measured by the number of hectares of agricultural land expressed in thousands of hectares.

Capital input was measured by capital stock in agriculture as the value of gross fixed capital formation of agriculture, forestry, and fishing, expressed in millions of USD (current prices), and data were retrieved from the FAOSTAT database (2019). This measurement of capital input for agricultural production is used in a few studies (eg. Horvat et al. 2020).

According to Simar and Wilson (2007), many studies analyzed efficiency have used a two-stage approach, where efficiency is estimated in the first stage. Then the estimated efficiencies are regressed on covariates (typically different from those used in the first stage) that are viewed as representing environmental variables. Most of the studies employ a censored (Tobit) model for the second stage (e.g. Latruffe et al. 2004; Nowak et al. 2015). The stochastic model underlying Tobit may be expressed by the following relationship:

$$y_t = X_t\beta + u_t \quad \text{if} \quad X_t\beta + u_t > 0$$

$$y_t = 0 \qquad\qquad \text{if} \quad X_t\beta + u_t \leq 0,$$

$$t = 1, 2, \ldots, N,$$

where N is the number of observations, y_t is the dependent variable, X_t is a vector of independent variables, β is a vector of unknown coefficients, and ut is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2 (McDonald and Moffitt 1980). In order to estimate parameters in the Tobit model, the maximum likelihood estimation was utilised. Since the obtained parameters are non-linear, the predictions of the estimations are performed by iterations.

The Newton-Raphson method has been used here, since it requires less time and fewer iterations according to Jamil (2013). In this paper, the dependent variable is technical efficiency scores obtain by DEA, which is limited between 0 and 1, therefore it has a censored structure. Independent variables are (Table 1):

Z1- Agricultural land per worker (LPW). Very often, authors decide to chose the average size of a farm as an independent variable in Tobit analysis (eg. Nowak et al. 2015; Bojnec et al. 2014). Unfortunately, there is no data for the observed period for all countries (especially for WB due to lack of FADN data).

To overcome this shortcoming, land (in hectare) per worker was included in the analysis as an independent variable. It is assumed that the regional differences in this indicator are similar to those of the average farm size. There are considerable variations in this indicator between countries (Coefficient of variations (CV) = 68%). This indicator is higher in Montenegro (57 ha/worker) and lower in Albania (1.9 ha/worker)

Z2- Share of the value of livestock production in the value of agricultural production in % (LVP). Due to the higher added value, a higher share of livestock production is expected to have a positive impact on agricultural production and, therefore, on technical efficiency. If this indicator is observed, there are the least variations between countries (29%).

Z3-Share of land under permanent crop in total arable land in % (PMN). Permanent crops have a higher value of production per hectare than other crops (eg. Wheat, corn…), therefore it can be expected that higher share would have a positive impact on TE. Together with the share of the value of livestock production this indicator represents the structure of agricultural production.

Z4-Fertilizers (N,P,K) per hectare (tonne per hectare) (FPH). Fertilizers per hectare can be observed as an indicator of intensification of production. It could be expected that more intensive use of fertilizers will result in the efficiency increase. On the other hand, more intensive fertilizers use have an adverse impact on the environment.

Z5-Share of land under organic production in total arable land in % (ORG). According to Končar et al. (2019), organic products, especially food products of organic origin, are continuously increasing, and more and more participants in the supply chain are redirecting their production and service processes towards organic technology. There is no doubt that this trend is positive, primarily for health and environmental reasons, but the question is what impact does the increase in organic production have on the performance of the agricultural sector.

Z6-Membership in EU in years (MEU). Based on the results of technical efficiency scores of agriculture in the EU provided by Horvat et al. (2020) and Nowak et al. (2015), it could be concluded that “older“ EU members had a higher TE score than new members. Additionally, as the main positive effects on agriculture of EU accession in NMS, Csáki and Jámbor (2013) listed: the enlarged EU market, increased farmers’ incomes, the solid and uniform policy and institutional framework. Also, in the case of Hungary, Bakucs et al. (2010) indicated that before EU accession efficiency was decreasing, while it started to increase again after accession. According to this, it can be assumed that membership in the EU could have a positive impact on technical efficiency.

Table 1: Descriptive statistics of variables

Variable	Max	Min	Avg	St.Dev	CV
TE	1.00	0.31	0.76	0.21	0.28
LPW	57.07	1.91	15.77	10.76	0.68
LVP	0.71	0.21	0.44	0.13	0.29
PMN	0.11	0.01	0.04	0.02	0.67
FPH	0.33	0.01	0.07	0.05	0.70
ORG	18.04	0.01	3.13	3.86	1.23
MEU	13.00	0.00	2.94	4.11	1.40

Source: The authors' calculations

4. Results and Discussion

In this paper, technical efficiency is calculated for a sample of 25 countries in period 1999-2016 based on FAOSTAT data. Technical efficiency scores are presented in Table 1. In the last period, the difference between the most and the least efficient country is 44%. The results showed that nine states had technically efficient agriculture (TE score = 1): Belgium, France, Germany, Montenegro, Netherlands, Moldova, Russia, Serbia and Ukraine. There is a slight increase in technical efficiency for the whole group in the observed period. Croatia and Hungary have the highest growth rate (more than 3.5%).

Table 2: Technical efficiency of agriculture in observed countries in period 1999-2016 (3-years average)

	1999-01	2002-04	2005-07	2008-10	2011-13	2014-2016
Albania	0.568	0.553	0.619	0.707	0.734	0.771
Belarus	0.699	0.715	0.372	0.338	0.384	0.591
Belgium	1.000	1.000	1.000	1.000	1.000	1.000
B&H	0.436	0.482	0.529	0.614	0.670	0.664
Bulgaria	0.924	0.860	0.934	0.892	0.847	0.837
Croatia	0.542	0.544	0.645	0.798	0.838	0.925
Czechia	0.539	0.457	0.531	0.642	0.487	0.597
Estonia	0.620	0.712	0.650	0.653	0.561	0.787
France	1.000	1.000	1.000	1.000	1.000	1.000
Germany	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	0.663	0.586	0.891	0.957	0.967	1.000
Italy	1.000	1.000	1.000	1.000	0.978	0.968
Latvia	0.654	0.402	0.321	0.469	0.372	0.561
Lithuania	0.416	0.393	0.478	0.787	0.575	0.596
Montenegro	1.000	1.000	1.000	1.000	1.000	1.000
Netherlands	1.000	1.000	1.000	1.000	1.000	1.000
North Macedonia	0.998	1.000	1.000	1.000	0.891	0.798
Poland	0.944	1.000	1.000	0.993	0.985	0.988
Moldova	1.000	1.000	1.000	1.000	1.000	1.000

Romania	0.762	0.727	0.821	0.805	0.783	0.904
Russia	1.000	1.000	1.000	1.000	1.000	1.000
Serbia	1.000	1.000	1.000	1.000	1.000	1.000
Slovakia	0.666	0.557	0.539	0.591	0.601	0.699
Slovenia	1.000	1.000	1.000	0.933	0.813	0.610
Ukraine	1.000	1.000	1.000	1.000	1.000	1.000

Source: The authors' calculations

Except for Belarus, which had the worst results, all other FSU countries performed at a full efficient level. Comparison of TE of agriculture in NMS, EU-6 and WB is shown in Figure 1. TE for these regions was calculated as a weighted average (weights are shares in the total value of agricultural production of the region). Due to late accession to the European Union, Croatia was observed as part of WB. According to these results, EU-6 almost performed at a full efficient level for the whole period. Improvements in TE are recorded in WB and NMS.

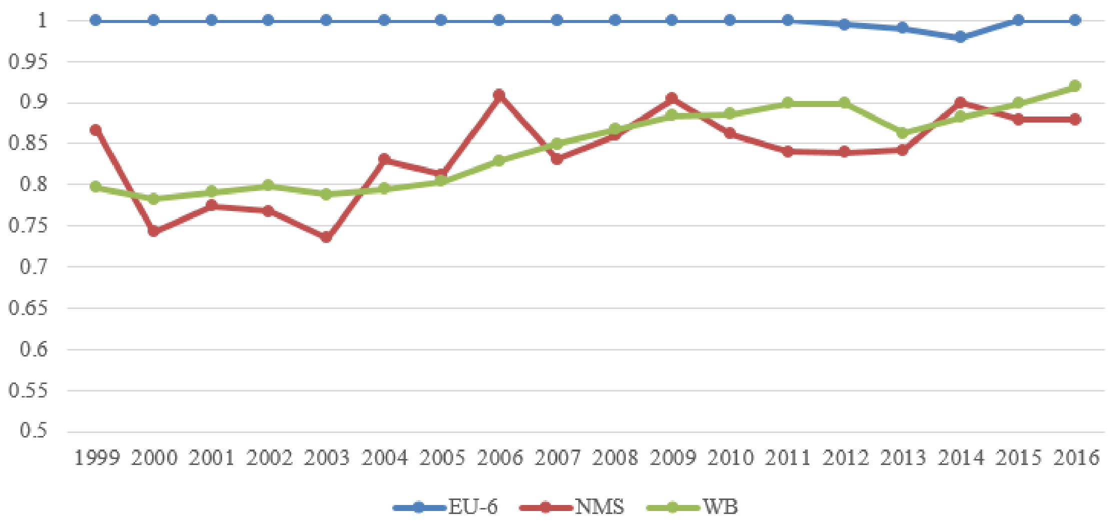

Fig 1: Technical efficiency of agriculture in EU-6, NMS and WB in period 1999-2016
Source: The authors' calculations

Tobit analysis showed that four of the six indicators are significant at a level of 5% (Table 3). Land per worker has a small and positive impact on technical efficiency, as well as membership in the EU. On the other hand, a higher share of land under organic production has a negative effect. The most crucial factor with a positive impact on TE is the intensification of production presented by fertilizers use per hectare of agricultural land. Indicators that represent the structure of agricultural production (LVP and PMN) are not significant.

Table 3: Parameters and test values of the Tobit regression

Variable	Coefficient (β)	Std. Error	z-Statistic	p-value
Z_1-LPW	**0.004547**	**0.001331**	**3.415.021**	**0.0006**
Z_2-LVP	-0.027869	0.026168	-1.065.026	0.2869
Z_3-PMN	0.733558	0.608776	1.204.972	0.2282
Z_4-FPH	**0.540596**	**0.244446**	**2.211.513**	**0.0270**
Z_5-ORG	**-0.034874**	**0.005172**	**-6.743.175**	**0.0000**
Z_6-MEU	**0.015319**	**0.004064**	**3.769.410**	**0.0002**
C	0.696896	0.040716	1.711.604	0.0000

Source: The authors' calculations

LPW has a small but positive impact on TE of agriculture. As already mentioned, LPW is a variable that was included instead of farm size, as a frequently used variable in Tobit analysis. This result is in line with the findings of Błażejczyk-Majka et al. (2012). They indicate that the most prominent farms achieved the highest efficiency, but those from the NMS regions at the same time had a low efficiency of scale, while the EU-15 countries were operating at a level that was close to the optimal.

Also, Bojnec et al. (2014) have concluded that the average farm size has a positive effect on TE in NMS countries. Western Balkan countries are characterized by small average farm size, so increasing the average size is likely to lead to improved efficiency (primarily due to more efficient use of machinery). On the other hand, some studies suggest that farm size is irrelevant or that it has a negative impact on TE. For example, Gorton & Davidova (2004) concluded that small family farms appear to be less inefficient compared to larger cohorts as against countries where small family farms are a relatively new phenomenon. However, it is difficult to determine the optimal size of the farm, and most likely, it is not unique for all countries; therefore, the given results should be interpreted very carefully.

The second factor that has affected TE is FPH. FPH has a very positive impact on TE (β=0.54). According to FAOSTAT data, average fertilizer use is still on the lower level in WB (120 kg/ha) than in EU (140 kg/ha), and more intensive use of mineral fertilizers will most likely lead to improved technical efficiency in these countries.

However, the impact of such intensification on the environment is questionable. Nitrogen surplus, arising from the application of excessive amounts of manure and chemical fertilizer, is treated as an environmentally detrimental input (Reinhard & Thijssen, 2000).

Therefore, it is essential that the use of mineral fertilizers is rational. With adequate use, it is possible to improve the economic results of agriculture and the environmental ones, which is undoubtedly in the interest of all EU countries and those in the process of integration.

The third factor affecting TE is the share of agricultural land under organic production (ORG). This is the only factor that has a negative effect. It can lead to two important conclusions. The first is that organic production is not as efficient as conventional, so it reduces the TE of agriculture. The second is that such a production system is still in the development phase, and therefore technical improvements are possible. Of course, it is indisputable that organic production has a positive impact on the environment, so this result should not lead to the simple conclusion that it is better to reduce the area under organic production. Moreover, they may indicate that additional investments are needed to make such a production system more efficient.

And last, membership in the EU has a positive impact on TE of agriculture. As the countries of the Western Balkans are in the process of European integration, this can be a positive signal for their policymakers.

5. Conclusion

There is a few conclusion of this paper. First, results showed that technical efficiency had been improved in the period 1999-2016 in WB and NMS, while both groups were on a similar level. Second, three factors positively affect TE: land per worker (the variable included in the analysis due to lack of data instead of farm size), fertilizers used per hectare, and membership in the European Union. Share of organic production in total agricultural land has an adverse impact, while the share of livestock production in total agricultural production and share of land under permanent crops in agricultural land are not significant. Third, probably the most critical factor is the use of mineral fertilizers. The reason for this is that increased consumption affects both economic and environmental results. More intensive use of fertilizers leads to the improvement of technical efficiency while at the same time, the environment is disturbed if that use is not rational. This will be especially important for all EU countries (as well as those aspiring to the EU) because, in the future, it will be necessary to find a balance between economic and environmental goals of agriculture.

This paper provides a contribution to the literature in the field of agricultural economics in two ways. First, no study analyzes drivers of TE in Western Balkan. Second, there is no study that analyzes TE in such a long period in NMS (1999-2016). However, this study does have some limitations. When analyzing the technical efficiency of agriculture, it is desirable to use micro-level data. Unfortunately, due to a lack of FADN data for Western Balkan countries, the FAOSTAT database was used. It can be expected that with the process of European integration, micro-level data for the countries of the Western Balkans will become available. Hopefully, the analysis of TE on farm level in WB will be the subject of future studies.

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