A TWO-STAGE DEA MODEL TO EVALUATE AGRICULTURAL EFFICIENCY IN CASE OF SERBIAN DISTRICTS

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A R T I C L E   I N F O

A B S T R A C T

Since the efficient agricultural sector is one of the most important drivers of country's economic development, the main objective of this paper was to examine relative technical efficiency of agricultural production in 25 Serbian districts using two-stage data envelopment analysis. Results of this research indicate that the efficiency score values lie between 70% and 100%, therefore it can be concluded that the agricultural sector of Serbia performs at a high level of efficiency, with the average efficiency score of 90%. The lowland region of Vojvodina is characterized with the highest efficiency scores, while districts in the southeastern part of Serbia have the lowest efficiency score values. Furthermore, the Tobit regression model was applied that one may examine the drivers of technical efficiency scores. The results show the significance of agricultural training among farm managers, land irrigation and age of farm holders in altering agricultural efficiency among Serbian districts.

Introduction

Agricultural productivity and technical efficiency of agriculture are some of the main drivers of the overall economic development of the country (Zamanian, 2013; Ciric et al., 2019). Agriculture has a crucial position in the economy of every country, including Serbia. Nowadays, in current extremely competitive environment, "efficiency is one

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of the most frequently applied terms to help identify the strengths and weaknesses of the evaluated units" (Kocisova, 2015). Studies which analyse efficiency of agricultural sector of Serbia on regional level are rare. Because of that, our paper is trying to expand the literature in this field and analyse technical efficiency of agriculture of Serbian districts, by application of two-stage DEA model. In that context, the main objective is to determine the efficiency of agriculture in 25 Serbian districts and to evaluate the impact of different factors on technical efficiency. This paper tends to explore the possible sources of inefficiency and to suggest the ideas of improving efficiency in this important sector.

The DEA has become a very popular non-parametric method for efficiency analysis and it can be successfully applied in different fields and on various levels. The DEA method is designed to accept multiple different input and output parameters in order to determine the effectiveness of different decision-making units (Ilić & Petrevska, 2018). There is a wide academic literature of application of this method in agriculture. This paper accentuates a unique approach of the observation of agricultural units. Most of the papers, that analyses the efficiency of agriculture, considers as decision making units farms (for example Ghaderi et al., 2019; Lekic et al., 2018; Popovic, 2018; Galluzzo, 2017; Fazekaš et al., 2017; etc.), agricultural enterprises or countries (Moreno-Moreno et al., 2018; Kocisova, 2015; Bojnec, 2012; etc). In this research we will use districts as decision making units, which is the novelty of this research. It is noteworthy to mention some studies that motivated the research presented here. Group of authors (Toma et al., 2015) in their paper applied DEA at regional level to analyze the performance of agricultural production in plain, hill and mountain areas in 36 Romanian counties. The technical efficiency of areas was calculated using input oriented CRS and VRS DEA model with three input variables and production value at the side of output variables. Results showed that only 14 counties operate at their optimal scale. Spicka (Spicka, 2014) analyzed the efficiency and its factors of mixed crop and livestock farming among the 101 EU regions. Results showed that efficient regions had higher level of land, labor, energy and capital productivity and productivity of contract work than less efficient regions. Another interesting application of DEA on regional level is presented by group of authors (Bagchi et al., 2019). They analyzed growth in agricultural productivity in 19 Bangladeshi regions for 23 years period using a bootstrapped DEA procedure. Noteworthy is also to mention the study conducted by the group of authors (Pang et al., 2016) that examines eco efficiency in Chinese regions by application of DEA and the Theil index approach.

The second stage in DEA analysis was proposed by Ray (Ray, 1988) through the adjustment of a linear regression model where dependent variable is presented as estimated DEA efficiency scores. Many authors (Silva et al., 2019; McDonald, 2009) propose an application of Tobit model in order to involve and assess the influence of different factors on technical efficiency. A Tobit model is suitable in the second stage of DEA analysis when the dependent variable is either censored or corner solution outcomes. A corner solution outcomes is continuous and restricted from above or below and takes the results from those boundaries with a positive probability (Hoff,

2007). Second stage analysis provides separate statistical evidence of the impact of different variable sets on the efficiency scores that is why it can be appropriate for governmental regulators (Silva et al., 2019). Yan (Yan, 2019) applied two stage DEA model to analyze the efficiency of agricultural enterprises in China. The results of DEA model show the low level of efficiency at the observed agricultural enterprises. In the second stage, Tobit regression model was applied to identify the factors that influence the efficiency. Another authors (You, Zhang, 2016) from China also applied an input-oriented DEA model to analyze eco efficiency in 31 provinces of China in case of intensive agricultural production, where only six provinces can be considered as fully efficient. Furthermore, they used a Tobit model specification to detect the regressors of significant influence on the eco efficiency.

Methodology

The main goal of this research is to examine the relative technical efficiency of agriculture in Serbian districts using DEA, as well as to provide a further analysis on factors that influence the efficiency score by application of Tobit regression model. On the contrary to the parametric statistical approaches, DEA compares the efficiency of each decision making unit with the highest efficiency score in the observed sample, rather than the mean value. This method does not require preliminary assumption about the analytical form of the relation between input and output variables. All the variables in the model can be presented by various types of metric. The results of the DEA model are relative efficiency measures, since they depend on the number of decision making units involved in the analysis, as well as the number and the choice of input and output variables. Results of DEA method show how many decision making units (DMUs) are ineffective, compared to the effective ones. From the results of DEA it is also possible to recommend the necessary reduction or increase of the observed inputs and outputs, in order to improve the efficiency.

In this paper, the output-oriented DEA model with a variable return to scale is applied to examine the technical efficiency of agriculture in Serbian districts. The analysis is carried out by solving the model (Banker, Charnes, Cooper, 1984) for each district:

$$\max \phi \qquad (1)$$

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

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

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

$$\lambda_j \geq 0$$

where n is the number of DMUs and DMU_o represents the district under evaluation. Assume that we have 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 DMU_o. λ is the DMU's weight and the efficiency score is ϕ.

A detection of the drivers of the technical efficiency results by applying a regression model is the main goal of the second stage of DEA analysis. The standard linear regression model with no constraints is not suitable for such an analysis, because of the fact that estimated or predicted values of efficiency scores can be found beyond the unit interval boundaries. The basic idea of a Tobit model is to censor the dependent variable by determining the threshold of the latent dependent variable. The general formulation of the model is given as follows (Greene, 2003):

$$y_i^* = x_i'\beta + \varepsilon_i, \qquad (2)$$

$$y_i = 0 \text{ if } y_i^* \leq 0$$

$$y_i = y_i^* \text{ if } y_i^* \geq 0$$

Where y_i^* is the latent dependent variable of the technical efficiency result, related to the ith region, x_i' is the vector of regressors and ε_i is the error term.

Results and Discussion

This study assessed the relative technical efficiency of agriculture for 25 Serbian districts in 2018. The term "relative" explains the efficiency obtained within the observed group of DMUs under the given set of inputs and outputs. Therefore, it is necessary to define input and output variables used in this research. Based on an extensive review of previous studies in this field and available data, three input variables were selected for our DEA model:

- Utilized agricultural area, measured in hectares

- Livestock unit, expressed in number of heads

- Labor, presented by the number of annual working units directly employed by holding. Annual working unit representing the equivalent of one person's full time working day of 225 days a year.

- On the side of outputs, only one variable has been included in the DEA model:

▪   Economic size of farm, represented as a value of the standard output of agricultural production (in millions of euros).

The data was retrieved from the Statistical Office of the Republic of Serbia database (2019). The descriptive statistics are presented in the Table 1.

Table 1. Descriptive statistics

	Utilized agricultural area	Livestock unit	Annual working unit	Economic size of farm
Min	46595.00	16752.00	8928.97	36.00
Max	314579.00	190294.00	57282.32	403.00
Average	139035.68	77353.56	25829.32	194.40
St. Dev.	71973.68	41399.53	12377.11	99.57

Source: Author's calculations

The MaxDEA 8 Basic software has been used to calculate the efficiency scores. In this case, the district is observed as one decision making unit and its relative efficiency is calculated by solving a linear programming model (1). Table 2 shows the results of output-oriented BCC DEA model with variable return to scale.

Table 2. Efficiency score of DEA model

District	Efficiency Score
Beogradska district	0.961
Zapadnobacka district	1.000
Juznobanatska district	1.000
Juznobacka district	1.000
Severnobanatska district	0.927
Severnobacka district	1.000
Srednjobanatska district	1.000
Sremska district	1.000
Zlatiborska district	0.849
Kolubarska district	0.873
Macvanska district	1.000
Moravicka district	0.854
Pomoravska district	0.764
Rasinska district	1.000
Raska district	0.729
Sumadijska district	0.766
Borska district	0.911
Branicevska district	0.707
Zajecarska district	0.716

District	Efficiency Score
Jablanicka district	0.999
Nisavska district	0.761
Pirotska district	1.000
Podunavska district	0.820
Pcinjska district	0.793
Toplicka district	1.000

Source: Author's calculations

The presented results show that the agricultural sector of Serbia performs with a high efficiency, with the average efficiency score of 90%. Ten Serbian districts operate under the maximum efficiency, while eight district achieved efficiency score between 80% and 100%. Seven districts, mainly located in the southeastern part of the country, obtained the lowest efficiency scores between 70% and 80%. The lowest efficiency, within the analyzed group of districts, is achieved at Branicevska district with the efficiency score of 70.7%. Our results show that in the lowland region of Vojvodina six districts achieved the maximum technical efficiency of 100% and only Severnobanatska district has efficiency score lower than maximum value (92.7%).

Furthermore, second stage analysis is performed in order to identify the drivers of the technical efficiency scores. Assuming the potential drivers on technical efficiency from literature review and available data in case of Serbian regions, this paper introduces four independent variables:

- Percentage of utilized agricultural area

- Percentage of irrigated agricultural area

- Percentage of farm managers with full agricultural education

- Percentage of farms led by managers under 45 years old.

Table 3. Estimated coefficients of the TOBIT model

Variable	Coefficient	z-Statistic
Constant	0.7539***	12.6302
Percentage of farm managers with full agricultural education	13.5785***	4.5502
Percentage of irrigated agricultural area	1.0043**	2.0939
Percentage of farms led by managers under 45 years old	0.6961**	-2.2269

Notice: *** and ** indicate the significance at the level of 1% and 5%
Source: Author's calculations

The Table 3 presents the results of an estimation of the Tobit model coefficients. The backward coefficient selection procedure is utilized to eliminate insignificant variables from the model. The results show the significance of agricultural training and education among farm managers, land irrigation and age of farm managers in affecting the

agricultural technical efficiency among Serbian regions. All three involved variables have positive impact on the level of technical efficiency.

As expected, the level of fully trained and educated farm managers had a positive impact on the agricultural technical efficiency. The education obviously plays important role in achievement of higher level of technical efficiency. Even tough, the percentage of fully educated farm managers does not exceed 20% in any particular region. Likewise, another authors (Raheli et al., 2017; Shanmugam & Ventkataramani, 2006) show that education is powerful driver of efficiency at the district level in the long term. Nevertheless, there are some studies (Novak et al, 2015; Idris et al, 2013) claiming that the level of training and education is not related with the agricultural efficiency.

The technical efficiency is significantly and positively affected by the land irrigation. The problem is very poor network of irrigation systems that do not covering more than 10% of agricultural area in any particular region. Yuya (Yuya, 2014) also revealed that farms involved in irrigation practice have an improvement in technical efficiency compared to those farms have not such a practice.

Although some studies (Nowak et al, 2015) emphasized the experience as an important efficiency driver, farm managers under 45 years old show some innovative approach and better energy towards improvement in agricultural technical efficiency. Another group of authors (Saiyut et al., 2017) indicated that younger farmers reduce the technical inefficiency in Thai agricultural production. The eliminated variable from the model is the percentage of utilized agricultural area which is more or less similar among observed regions.

Conclusions

Since the efficient agricultural sector is one of the most important drivers of countries economic development, the importance of examining the relative technical efficiency of the agricultural production in 25 Serbian districts took place. In order to attain presented aim of the paper, we attempt to answer the following research questions: "Is the agricultural sector of Serbia performing efficiently? What are the main drivers of technical efficiency and is there any way of improving the efficiency of agricultural production in Serbian districts?"

We applied the output oriented DEA model under the assumption of variable return to scale, with three input variables (utilized agricultural area, livestock and labor) and one output variable (economic size of farm). The results show that the efficiency score values lie between 70% and 100%, therefore it can be concluded that the agricultural sector of Serbia performs with the average efficiency score of 90%. The lowland region of Vojvodina is characterized with the highest efficiency scores, while the southeastern part of Serbia has the lowest efficiency score values.

Furthermore, the Tobit regression model was applied with the intention of investigation of the causes that significantly affect the achieved technical efficiency scores. The results

show the significance of agricultural training and education among farm managers, land irrigation and age of farm managers in affecting the technical efficiency of agricultural production among Serbian districts. The model results should be able to recommend some decision policies towards agricultural efficiency. In other words, the future investment process in agriculture needs to be directed towards technical modernization and staff education, but also in promoting young people working on lands.

The outcomes of this paper can be updated by various choice of variables, since the results of DEA efficiency scores significantly depend on the selection of input and output variables. The further analysis in case of Serbian districts may also took advantage from the application of DEA models over a longer period of time, which would allow to track the possible trends and cyclic movements in the efficiency of agricultural production of this geographic area.

Conflict of interests

The authors declare no conflict of interest.

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