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APPLYING A NON-PARAMETRIC EFFICIENCY ANALYSIS TO EVALUATE FARM ECONOMIC VIABILITY
PRIMENA NEPARAMETARSKE ANALIZE EFIKASNOSTI U OCENI EKONOMSKE ODRŽIVOSTI FARMI

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ABSTRACT

The aim of this research is to investigate technical efficiency in different types of farming in Republic of Serbia and then to determine achieved level of farm economic viability. The research is based on FADN data from 2020 year. An input-oriented data envelopment analysis method with variable return to scale is used for calculating farm technical efficiency. One output and four input variables are used in the model. Research has shown that farm technical efficiency in Serbia is on relatively low level (0.346). This indicates that there are significant reserves for potentially input reduction, without output reducing. According to types of farming the most efficient farms are the ones involved in horticulture production (0.542), followed by granivores (0.458) and vineyards and fruits (0.433), while the least efficient are dairy production (0.292). It is noticeable that more intensive types of farming have better output-input ratio, which indicates that those farms reached higher economic viability level. Of course, farm economic viability is wider term and further research should be directed at one comprehensive farm economic viability analysis which would take into consideration other relevant productivity indicators as well as profitability, liquidity and stability indicators. Thereby, considering FADN base limitations that are particularly noticeable when calculate liquidity and stability indicators, is necessary to continuously work on data quality improvement and to make the whole system better.
Key words: technical efficiency, economic viability, farms, data envelopment analysis, FADN.

REZIME

Cilj istraživanja je da se oceni tehnička efikasnost različitih tipova poljoprivrednih gazdinstava Republike Srbije i na osnovu toga utvrdi dostignuti nivo ekonomske održivosti gazdinstava. Istraživanje se zasniva na FADN (Sistem računovodstvenih podataka na poljoprivrednim gazdinstvima) podacima iz 2020. godine. U radu je primenjena neparametarska analiza obavijanja podataka ulazno orijentisana sa promenljivim prinosom na obim. Model čini jedna autput varijabla: ukupna vrednost proizvodnje, i četiri input varijable: ukupno korišćena radna snaga, ukupno korišćeno poljoprivredno zemljište, ukupna međufazna potrošnja i vrednost ukupne imovine. Tehnička efikasnost gazdinstava Srbije je na relativno niskom nivou (0,346). Ovo ukazuje na činjenicu da postoje značajne rezerve za potencijalno smanjenje korišćenih inputa, a da pritom vrednost autputa ostane ista. Posmatrano po tipovima proizvodnje najefikasnija su gazdinstva koja se bave hortikulturom (0,542), zatim slede gazdinstva koja se bave svinjarstvom i živinarstvom (0,458) i voćarstvom i vinogradarstvom (0,433), dok je najmanje efikasno mlečno govedarstvo (0,292). Primetno je da intenzivniji tipovi gazdinstava imaju bolji autput-input odnos, što ukazuje na to da ova gazdinstva dostižu i viši nivo ekonomske održivosti. Naravno, ekonomska održivost je znatno širi pojam i dalja istraživanja treba da idu u pravcu sveobuhvatnije analize ekonomske održivosti gazdinstava koja će, pored tehničke efikasnosti, uzeti u obzir i druge relevantne indikatore produktivnosti, kao i profitabilnosti, likvidnosti i stabilnosti. S obzirom na ograničenja FADN baze koja su posebno primetna kod obračuna indikatora likvidnosti i stabilnosti, takođe je potrebno kontinuirano raditi na poboljšanju podataka i unapređenju celokupnog sistema.
Ključne reči: tehnička efikasnost, ekonomska održivost, poljoprivredna gazdinstva, analiza obavijanja podataka, FADN.

INTRODUCTION

An increase in technical efficiency (TE) is one of the main goals for farm managers to achieve. This is because efficiency in general represents an output-input ratio, where achieved results are on the output side and production factors (labour, land, capital) are on the input side. Following this, main approaches to achieve higher efficiency level are to reduce inputs used or to maximise output. This is strongly related with model orientation, which can be input or output-oriented.

Technical efficiency is one of the most used methods for calculation farm productivity, next to partial productivity and total factor productivity. Also, efficiency is often applied to understand level of competitiveness between different types of farming (*Popović et al., 2020*). Consequently, this approach could be very reliable in measuring farm economic viability. Of course, beside productivity, there are few other indicators mostly used for evaluating farm economic viability as: profitability, stability and liquidity (*Latruffe et al., 2016*). Nevertheless,

technical efficiency as productivity measure is widely-accepted method in the literature to assess achieved level of farm economic viability (*Spicka et al., 2019*).

There are two main approaches of calculating technical efficiency. The first one is a non-parametric efficiency analysis by applying data envelopment analysis (DEA) and the second one is a parametric approach using stochastic frontier analysis (SFA). Both methods have their advantages and disadvantages but in specific farm technical efficiency evaluation, DEA approach is rather applied, especially because one can apply two and more output variables in DEA model.

In the literature, analyses of farm technical efficiency and factors affecting TE are mostly provided. *Galluzzo (2018)* find out that specialized farm as dairy and granivores are more efficient then mixed and wine farms in Bulgarian rural areas. Also, he pointed out the financial subsidies allocated by Common Agricultural Policy as a significant factor that had a positive impact on increasing TE of farms. *Nowak et al. (2015)* investigated farm technical efficiency in European Union (EU)

agriculture and concludes that there are huge discrepancies between the states with the highest and the lowest efficiencies (about 40%). As the main factors which influences on TE, authors highlighted soil quality, the age of the head of the farm and the surcharges for investments, and turned out that farm size was irrelevant. *Bojnec and Latruffe (2007)* explored economic efficiency in Slovenian farms, and find out that crop, dairy, livestock using own feed, fruit and forestry farms are fully efficient in domestic conditions.

Serbian agriculture is dominated by small farms and is quite impossible for them to be competitive with large farms in both Serbian and European countries in terms of production volume. But, is there any chance for small farms to compete on the international markets with larger ones? We think that there is by focusing on more efficient types of production and we find this as managerial question. Therefore, the main aim of the paper is to investigate technical efficiency in different types of farming in Republic of Serbia (RS) and considering given results to determine achieved level of farm economic viability.

The paper is structured as follows. The next section describes the data used and the applied method. After describing methodology, the research results and discussion are presented. Finally, conclusion and recommendations are given in the last section.

MATERIAL AND METHOD

The Serbian FADN (Farm Accountancy *Data* Network) dataset for 2020 year provided by the Ministry of Agriculture, Forestry and Water Management is used. Farms are divided into seven basic types of farming which dominates in domestic conditions. According to the official FADN methodology, there are 62 different types of farming (*www.ec.europa.eu*), but most of them aren't represented in RS. So, for the purpose of the research, we merged some cells into seven following types: (1) field crops – FC; (2) horticulture, both outdoor and indoor – HC; (3) vineyards and fruits – VF; (4) dairy production – DP; (5) grazing livestock, all sheep, goats and cattle – GL; (6) granivores, pigs and poultry – GN; (7) mixed crops-livestock production – CL.

In order to define achieved level of technical efficiency in different types of farming, a non-parametric efficiency approach is performed. DEA method proposed by *Charnes et al. (1978)* was primarily used for evaluating efficiency level of non-profitable institutions like schools and hospitals. During the time its utilisation spread out, and nowadays, among other, is often applied in measuring farm technical efficiency. A lot of research is being done in order to evaluate technical efficiency of farms using DEA method (*Galluzzo, 2018; Nowak et al., 2015; Vukelić et al., 2015; Bojnec and Latruffe, 2007*). The input variables used in these studies are mostly the main factors of production (land, capital and labour) and output variables are total values of crop, livestock and other production.

There are two main approaches in this analysis: input-oriented and output-oriented. In an input-oriented model, the tendency is to produce one unit of output by reducing the inputs. An output-oriented approach implies maximisation of output with existing inputs used. In this research an input-oriented DEA method with variable return to scale (VRS) is applied. This because in domestic conditions farms operate by noticeable lack of labour and land input and farm managers need to try to achieve full efficiency level by reducing the inputs. Also, the method with VRS developed by *Banker et al. (1984)*, is more appropriate to use in imperfect competition conditions, unlike the method with constant return to scale (CRS) assumption

which is suitable when all farms operate at optimal scale, i.e. economic size (*Coelli et al., 2005*).

For each farm in the sample, i.e. decision making unit (DMU), technical efficiency score is calculated by implementing one output variable and four standard input variables in the model. Total output or total value of production (SE 13) is an output variable and input variables are: total labour input (SE 010) expressed in annual work units (AWU) that are full-time person equivalents and one AWU corresponds to 1,800 hours work per year; total utilised agricultural area (SE 025); total intermediate consumption (SE 275); total assets value (SE 436).

The influence of outliers on the obtained results was reduced by using the Tukey fence method, according to which all values of observed indicator below $Q_1 - 1.5IQR$ or above $Q_3 + 1.5IQR$ were removed from the series, where Q_1 is the first quartile, Q_3 is the third quartile, and IQR is interquartile difference (*Hlavsa et al., 2020*). A ratio between total output and total intermediate consumption, also known as the coefficient of economy, is used as the indicator. At the beginning, 1,668 farms were in the sample and after excluding the outliers, 1,544 farms remained. Descriptive statistics were performed in order to calculate arithmetic mean, median, standard deviation and quartiles for all variables in the sample.

Software used for calculating technical efficiency is Data Envelopment Analysis Programme (DEAP) version 2.1 developed by *Coelli (1996)* and IBM SPSS 21 software is applied for statistical data processing. All values are expressed in euros according to the average exchange rate of the National Bank of Serbia for the respective year (*www.nbs.rs*).

RESULTS AND DISCUSSION

In general, total output is mostly used as an output variable in DEA analysis of farm technical efficiency. On the input side three main factors of agricultural production are used: land, labour and capital factor. Total utilised agricultural area is used as land factor, labour input expressed in AWU as labour factor and total assets value as capital factor (*Bojnec and Latruffe, 2007*).

Based on the results of descriptive statistics analysis (Table 1), total output of farms on average was € 51,186 while the median value was significantly lower (€ 30,280).

Table 1. Descriptive statistics of variables used in DEA analysis

Variable	Average	Median	Standard deviation	Q_1	Q_3
Total output	51,186	30,280	196,521	18,085	55,824
Total labour input	1.9	1.8	1.2	1.1	2.3
Total utilised agricultural area	23.0	12.0	32.5	6.5	23.0
Total intermediate consumption	19,522	12,723	19,603	7,144	23,721
Total assets value	153,120	92,491	267,108	53,976	165,103

Source: Authors' calculations based on FADN data

According to quartile values is obvious that 25 % of the observed farms had the total output up to € 18.085 and 25 % of them had value above € 55,824. Total labor input averaged 1.9 AWU, and 25% of the observed farms had up to 1.1 AWU which indicates that numerous farms perform with low labour input. This is mostly the result of very large number of small and

less intensive farms in the sample, which don't have high demands for labour input. Total utilised agricultural area was 23.0 hectares and the median value was much lower (12.0 ha). This means that half of farms organize their production on less than 12.0 ha and when we observe also the quartile value is noticeable that one quarter of farms had agricultural area below 6.5 ha. This is expected having in mind previously mentioned large number of small farms in the sample and also in RS in general.

Total intermediate consumption on average was € 19,522, and total assets value € 153,120. Having in mind that land and mechanisation value have the highest share in the structure of total assets value, this high mean value of total assets can be explained with increased mechanisation renewal in domestic farms. Namely, farmers have the opportunity to apply for grants by numerous domestic and European funds in order to improve and modernise its production process and to be more ecologically sustainable. From the other side, 25 % of farms had relatively small total assets value of less than € 53,976 which indicates that this process should be continued. High variability is characteristic of all observed variables, which is visible based on high values of standard error of each of the observed indicator. This is normal having in mind variations in economic size of farms where are represented farms with standard output (SO) value from € 4,000 to more than € 100,000.

When forming the DEA model is necessary to examine the relationship between the selected input and output variables. Because of that, the correlation coefficients between the variables were calculated and their significance was tested. According to the results shown in Table 2, can be noticed that all values of correlation coefficients are statistically significant (p<0.05), i.e. there is a high degree of correlation between all observed variables.

Table 2. Correlation matrix of input and output variables used in DEA analysis

Variable	Total output	Total labour input	Total utilized agricultural area	Total intermediate consumption	Total assets value
Total output	1.00				
Total labour input	0.04*	1.00			
Total utilized agricultural area	0.18**	-0.09**	1.00		
Total intermediate consumption	0.22**	0.12**	0.69**	1.00	
Total assets value	0.81**	-0.01*	0.49**	0.39**	1.00

Source: Authors' calculations based on FADN data

Relative technical efficiency is calculated for 1,544 farms (DMU) and estimated values by CRS and VRS ranged from 0 to 1, where 1 indicates fully efficient farm. Scale efficiency is calculated as ratio of CRS and VRS TE score (*tab. 3*). The average technical efficiency for the Serbian farms in 2020 was 0.346, which is relatively low score and indicates potentially input reduction. Namely, in order to maximise TE score farm managers should better manage with the existing technology and resources. Of course in the sample were farms which have better management practices and also those ones that operate below the efficiency limit, but in general there is a need for better resources management.

Table 3. Technical efficiency scores for different types of farming

Type of farming	DMU	CRS	VRS	Scale efficiency
FC	519	0.157	0.318	0.562
HC	52	0.312	0.542	0.582
VF	201	0.161	0.433	0.412
DP	311	0.119	0.292	0.450
GL	121	0.113	0.335	0.392
GN	59	0.253	0.458	0.593
CL	281	0.137	0.339	0.455
Total	1,544	0.152	0.346	0.489

Source: Authors' calculations based on FADN data

Regarding the differences between types of farming, the best TE score had farms involved in horticulture production (0.542), followed by granivores (0.458) and vineyards and fruits (0.433). This indicates that farms with higher intensity level have predispositions for achieving better TE results and to better utilise available resources. This is very important to emphasize, because there is a lot of small farms in RS which could be more efficient if they introduced more intensive production lines in their structure of production. These, of course, by contemplate different natural, social and economic conditions that are predominant in the region or county where the specific farm operates. On the other side, two the worst TE types of farming were field crops and dairy production with 0.318 and 0.292 TE scores, respectively.

It is possible to evaluate achieved level of farm economic viability by perceiving given TE scores for different types of farming. Of course, in order to give such a statement should be careful and take into account profitability and other relevant indicators (e.g. stability and liquidity) as well as productivity of farms. But in general considering given results, we could state that better preconditions for achieving higher level of economic viability had HC, GN and VF farms. This is in line with *Miljatović et al., (2020)* who claims that the most profitable farms in Vojvodina (Serbian North region) are horticulture and poultry farms. Oppositely, less chance to acquire adequate viability level had farms involved in field crops and dairy production.

CONCLUSION

Farm productivity expressed by farm technical efficiency is one of the most important indicators in evaluating farm economic viability. Technical efficiency, as an output-input ratio, should indicate to farm managers whether factors of production were appropriately managed. For this purpose a non-parametric DEA method is applied to evaluate achieved efficiency level of farms and to indicate farm economic viability in RS.

The results have shown that there is a space for improving technical efficiency of Serbian farms by reducing input consumption. Regarding types of farming, more intensive farms such as HC, GN and VF have better TE scores (0.542, 0.458 and 0.433, respectively) in comparison with FC and DP (0.318 and 0.292 respectively). Of course, there is a room for improvement in all types and that is conditioned by different factors. Namely, smaller farms, which are predominant in the sample, should consider the option to improve technical characteristics of mechanisation and other equipment by using available funds that would enable reduction of labour costs on the farm. Also, there is a need for land costs reduction by introducing the second crop.

In this way farm productivity will increase and consequently farm economic viability.

The main contribution of this research is to indicate the utilisation of technical efficiency as a tool for evaluation farm economic viability. Also, this would help the competent institutions to create adequate agrar policy measures. At micro level, farm managers would benefit from an analysis like this by getting the feedback about their farm economic viability and to perceive where they are in comparison to other farms in the country and farms from developed European countries. This could be very useful for the heads of the farm and help them to better manage the farm.

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