Regional differences in technical performance of Slovak farms

Jaroslava Košařová[1], Marta Urbaníková[2]

Abstract: The assessment of regional differences in the technical performance of farms in Slovakia requires a comprehensive analysis of various factors and sources, with technical efficiency in agriculture referring to the ability of a farm to produce a given level of output with a minimum amount of inputs or resources. The aim of the contribution was to evaluate the technical efficiency of Slovak farms at the regional level using the widely used method of Data Envelopment Analysis. We used an output-oriented DEA model to calculate a technical efficiency score for each farm and identify the most efficient farms. We found statistically significant differences between efficiency scores at the regional level. The highest technical efficiency scores were achieved by farms in Western Slovakia, and the lowest efficiency scores were achieved by farms in Eastern Slovakia. Farms in Eastern Slovakia lag behind those in Western Slovakia. While all farms are catching up with the most efficient farms in the Nitra region, it's worth noting that these farms experienced the highest decline during the period from 2014 to 2019. In conclusion, it can be concluded that in most regions the overall efficiency of agriculture has not been fully realized. These farms have the potential to improve efficiency by optimizing the use of resources, specifically by reducing their scale.

Keywords: technical efficiency, regional differences, data envelopment analysis, agriculture
JEL Classification: C14, C23, R58, Q16

1 Introduction

The agricultural sector plays a key role in the economic sector of Slovakia. Ensuring the efficiency and competitiveness of farms in this sector is key to sustaining agricultural growth, food security and rural development. The Common Agricultural Policy (CAP) supports farm incomes through two main areas, with the first pillar focusing on direct income support through direct payments. As the second pillar of the CAP, the EU's rural development policy is designed to support investments in agricultural farms, payments under agrienviromental schemes, LFA payments and economic diversification in rural areas. One of the measures proposed by the European Commission for the CAP proposal was the development of agricultural enterprises also through non-agricultural activities in rural areas (European Parliament, 2023). Agriculture in Slovakia currently does not create enough job opportunities. The constant decrease in the number of employees in agriculture ranks Slovakia among the countries with the lowest share of workers in agriculture in the total number of employees. The unemployment rate in rural areas is above the EU average (8.4%). Solving the unfavorable situation will require investments in infrastructure, diversification of the rural economy and an increase in human capital (European Commision, 2023). Diversification of economic activities is an important part of the policy of sustainable rural development and the basic means for maintaining and improving the balance between economic opportunities and social conditions of the rural population.

Slovak agriculture is characterized by a double structure of agricultural enterprises with a high proportion of small agricultural enterprises and a smaller number of large agricultural enterprises (European Commission, 2023). Institutional support for agricultural holdings in the crop and livestock sector focuses on resource efficiency and investment, as well as on the development of small family farms and non-agricultural farm activities. Important differences can be observed between the economically richer, especially more industrialized West compared to the East, which also affects job opportunities in the agricultural sector. One of the ways to increase competitiveness is to use available resources efficiently. Higher efficiency allows the farm to better perform strategic activities, which will also lead to gaining a competitive advantage. For this purpose, the analysis of the efficiency of Slovak farms performing other gainful activities through the Data Envelopment Analysis (DEA) approach is of primary importance.

To analyze of efficiency and productivity in agriculture empirical research emphasizes the application of the DEA technique. Błażejczyk-Majka et al., (2012) pointed out the connection between technical efficiency and production

[1] Constantine the Philosopher University in Nitra, Institute of Economics and Management, Faculty of Natural Science, Trieda A. Hlinku 1, 949 01 Nitra, Slovakia, jkosarova@ukf.sk.
[2] Constantine the Philosopher University in Nitra, Institute of Economics and Management, Faculty of Natural Science, Trieda A. Hlinku 1, 949 01 Nitra, Slovakia, murbanikova@ukf.sk.

https://doi.org/10.32725/978-80-7694-053-6.37

specialisation, and economic size. Toma et al. (2015) examined efficiency at the regional level using different inputs and outputs to analyze the performance of agriculture practiced in plain, hill, and mountainous regions. Similarly, Imran et al. (2019) used an input-oriented intelligent DEA to investigate technical, economic, and water efficiency to investigate the impact of climate agriculture. Alem et al. (2021) found regional differences in dairy farms in technical efficiency using a stochastic meta-frontier approach. In the study, Tenaye (2020), an analysis of the technical efficiency of smallholder agriculture was conducted at a regional level. The study's findings indicated that regional disparities in technical efficiency were primarily influenced by agroecological factors, soil fertility, and the amount of rainfall. Bagchi et al. (2019) examined shifts in both regional productivity and efficiency. To counter regional disparities and diminishing technical efficiency, they put forward recommendations for investment in research and development, agricultural expansion, and crop diversification. In intensive agriculture, a pivotal consideration is finding the right balance of inputs to achieve the desired output without causing harm to the environment. The optimal level of intensive agricultural production can be described as one that minimizes input usage while attaining a specific output level.

In summary, the use of DEA at the regional level can facilitate the identification of best practices and resource optimization strategies within intensive agriculture, helping regions strike the optimal balance between productivity and environmental preservation. In the context of intensive agriculture, DEA provides a quantitative approach to assess how efficiently agricultural regions utilize their inputs to generate outputs. When applied regionally, DEA can shed light on which areas are achieving the desired output levels with the least amount of inputs, but also those regions that may be using excessive inputs to achieve similar or lower output levels. In this contribution, we analyze regional differences in the technical capability of Slovak farms performing other profitable activities.

2 Methods

Data Envelopment Analysis (DEA) is a mathematical optimization techniqueand also powerful quantitative method widely used in the agricultural field to evaluate and compare the relative performance of individual entities, such as farms, with multiple inputs and outputs. In agriculture, efficiency can be examined from the point of view of the input-oriented DEA model or the output-oriented DEA model. In this paper, the technical efficiency of Slovak farms is investigated using data envelopment analysis employing an output-oriented model that considers multiple outputs and inputs. Output-oriented DEA models for efficiency analysis are suitable in case of greater control over production inputs. In the output-oriented DEA model, the goal is to maximize the production of outputs while minimizing the use of inputs. This model is particularly useful when identifying units that are inefficient in generating output and seeking ways to improve their performance.

The first DEA model proposed by Charnes et al. (1978) is a CCR model that assumes constant returns to scale. Banker et al. (1984) extended it to the BCC model for the case of variable returns to scale. We estimated the technical efficiency score for each farm, assuming constant return to scale (TE_{CRS}) and variable return to scale (TE_{VRS}). The TE_{CRS} is derived by solving the following linear programming:

$$max_{\theta,\lambda}\theta_i \; s.t. \sum_{j=1}^{n}\lambda_j y_j - \theta_i y_i - s = 0; \sum_{j=1}^{n}\lambda_j x_{kj} + e_k = xk_i \; ; \; \lambda_j \geq 0; s \geq 0; \; e_k \geq 0 \tag{1}$$

where θ_i is the potential proportional increase in output achievable by the i-th farm. Meanwhile, λ_j is a vector of weights relative to the efficiency observation for all N farms, s denotes the output slack, and e_k represent the k-th input slack.

By introducing the convexity constraint N 1'λ = 1, the model can be transformed into the TE_{VRS} DEA. In this modified model, a farm is considered to have achieved efficiency when both θi and λi equal 1, while λj equal 0. Conversely, an observation is classified as inefficient when θi > 1, λi = 0, and λj ≠ 0.

The technical efficiency of each farm was calculated using a common production frontier and then the farms were categorized into three groups based on regions. In this case, it was unreasonable to calculate three production function frontiers for each region separately, because we assume that these farms also perform other income-generating activities in different regions and work under the same technology.

Next, we employed the non-parametric Kruskal-Wallis test to determine whether the scores of technical efficiency differed significantly among individual regions. To analyze efficiency, we used output-oriented models with the assumption of both constant and variable returns to scale.

Balanced panel data from 215 agricultural enterprises engaged in other gainful activities were used, sourced from the FADN database. These enterprises continuously conducted agricultural activities from 2014 to 2019. The variables for the model were selected based on the most commonly used variables in the application of DEA models in agriculture.

A single output variable was utilized, specifically total production of the enterprise expressed in thousand euros. Inputs were categorized into five groups, including farming overheads and depreciation (FOD), total specific costs (TSC), labour and machinery costs (LMC). These three inputs were calculated according to FADN methodology and are expressed in thousands of euros. Another input was agricultural labor converted into annual work units (AWU). Finally, the last input was the hectare area expressed as the total utilized agricultural area (UAA). Descriptive statistics of these variables in 2014-2019 are presented in Table 1. In practice, technical efficiency is calculated using linear programming, where we utilized the DEAP 2.1 program, and for other analyses, we worked with Stata 18.0 software.

Table 1 Descriptive statistics on selected variables for Data Envelopment Analysis

Variables	Total sample mean (st. dev.)					
	2014	2015	2016	2017	2018	2019
Total production	3207.46 (1051.92)	2667.05 (1039.85)	3113.28 (1027.11)	2956.99 (1022.23)	3288.83 (1012.7)	3061.06 (1000.52)
Utilised agricultural area	1028.18 (968.3)	1016.1 (949.08)	1004.2 (935.92)	999.82 (932.48)	990.79 (932.21)	979.51 (895.79)
Total employed work	23.74 (26.21)	23.76 (25.84)	22.91 (24.94)	22.41 (24.05)	21.90 (24.39)	21.01 (23.38)
Farming overheads and depreciation	349.71 (414.08)	360.89 (415.62)	368.66 (415.96)	366.23 (420.48)	368.62 (410.11)	379.32 (451.18)
Labour and machinery cost	519.24 (627.78)	476.16 (549.95)	501.74 (590.65)	522.11 (616.82)	535.91 (634.35)	551.76 (655.37)
Total specific costs	663.08 (904.03)	592.93 (757.42)	569 (716.41)	565.41 (708.97)	445.08 (583.05)	718.69 (913.63)

Source: Own processing

3 Research results

Technical efficiency scores of Slovak farms divided by region into Western Slovakia, Central Slovakia and Eastern Slovakia are shown in Table 3. The highest efficiency scores in the observation period are achieved by farms in Western Slovakia, in the regions of Nitra, Bratislava, and Trnava. The most inefficient farms are in Eastern Slovakia in region Prešov and Košice. Farms in Eastern Slovakia are lagging behind the farms in Western Slovakia. Although all farms are catching up with the most efficient farms in the Nitra region, these farms achieved the highest decline in the period 2014-2019.

The average technical efficiency score under constant returns to scale for farms in western Slovakia is 0.64, with 2014 and 2015 being the years in which these farms were most efficient. The years 2014 and 2018 were the most efficient in terms of variable returns to scale, with an average technical efficiency score for WS farms of 0.77.

The average technical efficiency score of farms in central Slovakia, in terms of constant returns to scale, is 0.55, with 2014 and 2015 being the most efficient years, similarly to the western Slovakia. The same is true in the case of variable returns to scale where the average technical efficiency score is 0.65.

Under constant returns to scale, the average technical efficiency score of farms in eastern Slovakia is the lowest at 0.52 and in 2017 these farms were the best performers. In the case of variable returns to scale, the most efficient farms were in 2014 and 2015, with the average technical efficiency of western Slovakia farms being 10% higher than at constant returns to scale. The lowest early technical efficiency of eastern Slovakia farms was in 2018 with an average efficiency score below 0.5. In the case of variable returns to scale, higher values are achieved compared to constant returns to scale due to the stricter evaluation of efficiency than the VRS frontier.

Table 2 Technical efficiency scores and Kruskal-Wallis test for differences between efficiency scores

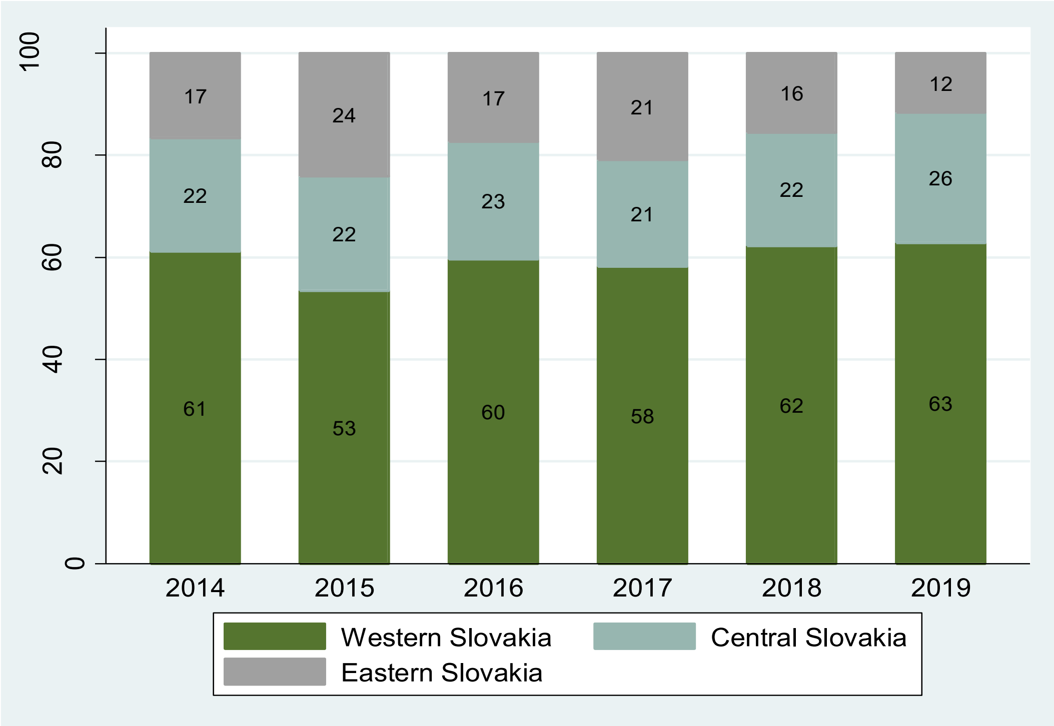
	NUTS	**TE for the type of farming**						
		2014	2015	2016	2017	2018	2019	Mean
TE_{CRS}	**Western Slovakia**	0.67	0.67	0.64	0.60	0.66	0.57	0.64
	Central Slovakia	0.58	0.60	0.52	0.53	0.57	0.52	0.55
	Eastern Slovakia	0.54	0.57	0.49	0.55	0.49	0.49	0.52
	chi square	21.869***	11.241***	28.384***	4.795*	27.569***	4.539	83.057***
TE_{VRS}	**Western Slovakia**	0.82	0.77	0.79	0.75	0.78	0.73	0.77
	Central Slovakia	0.70	0.67	0.63	0.61	0.64	0.62	0.65
	Eastern Slovakia	0.64	0.65	0.61	0.63	0.57	0.59	0.62
	chi square	26.261***	13.013***	29.726***	13.670***	33.150***	18.266***	129.127***

Source: Own processing; Note *, **, *** the null hypotheses are rejected at the 1%, 5%, 10% level

To investigate whether there are statistically significant differences between regional efficiency scores in panel data, we apply a non-parametric Kruskal–Wallis's test (Table 2). Technical efficiency scores across regions were statistically significantly different in all years except 2019 in the case of constant returns to scale, when the efficiency score for Slovak farms was 0.49-0.57.

Figure 1 illustrated the percentage distribution of efficient farms by region and years, whose technical efficiency score had a value of 1. More than half of the efficient farms in the total sample were located in western Slovakia. The efficiency of these farms increased towards the end of the monitoring period. Once again, farms in western Slovakia consistently outperformed those in other regions. There were relatively few efficient farms in central and eastern Slovakia. In the case of central Slovakia, there was a 4-percentage point increase in the number of efficient farms during the monitoring period. Conversely, in eastern Slovakia, there was a significant decrease of up to 5 percentage points in the number of efficient farms. Although in 2015, efficient farms in eastern Slovakia caught up with those in central Slovakia by 2 percentage points, their share declined in the subsequent years.

Figure 1 Percentage distribution of efficient farms by regions



Source: Own processing

Table 3 Optimal use of inputs achieving full efficiency (2014-2019)

Regions		**UAA**	**AWU**	**FOD**	**LM**	**SC**
Western Slovakia	Observed means	993	23	436461	607778	701672
	Optimal means	893	21	468175	631611	716010
	Savings (%)	*-10%*	*-10%*	*7%*	*4%*	*2%*
Central Slovakia	Observed means	903	23	303696	460026	539173
	Optimal means	705	21	332235	469897	693709
	Savings (%)	*-22%*	*-11%*	*9%*	*2%*	*29%*
Eastern Slovakia	Observed means	1083	21	316793	442016	488818
	Optimal means	738	14	265427	298283	431210
	Savings (%)	*-32%*	*-33%*	*-16%*	*-33%*	*-12%*

Source: Own processing; Note *, **, *** the null hypotheses are rejected at the 1%, 5%, 10% level

Table 3 displays the role of individual inputs in the efficiency calculation. Farms in eastern Slovakia have a larger average area 1083 ha compared to farms in western Slovakia (903 ha) and farms in central Slovakia (993 ha). Optimal means variables indicate the variable values that individual farms should achieve in order to attain full efficiency (TE=1), compared to the observed means of variables in the sample. These results highlight which input variables have the most significant impact on efficiency. The difference between the observed and optimal means, expressed as a percentage, represents the potential savings achievable in terms of input use if the inputs were used efficiently. In all regions, achieving efficiency requires change in scale, especially by reducing the hectare-square area of land. The least effective utilization of input resources, namely AWU, UAA, and LM, is observed among farms located in eastern Slovakia. To enhance their performance and align with other farms, Slovakian farms should prioritize the reduction of these specific input variables.

4 Conclusions

With the gradual shift towards sustainable rural development in the European Union (EU), farm diversification has gained increasing significance in EU policy. Understanding the trends and efficiency of diversified farms is crucial for enhancing the effectiveness of policies aimed at supporting farm diversification. The surveyed farms were found to be technically inefficient, exhibiting either constant or variable returns to scale, highlighting their potential to improve technical efficiency levels. This inefficiency suggests that farms have been using an excessive amount of inputs to produce their current output levels. Farm diversification often arises from multifunctional farming practices but, in some cases, can come at the expense of lower overall farm efficiency.

The results showed significant regional differences in achieving efficiency. Farms in western Slovakia achieved the highest efficiency on average, followed by farms in central Slovakia, and finally, farms in eastern Slovakia catch up the most with these more efficient farms. The input total utilized agricultural area was identified as the main source of inefficiency. In conclusion, it can be concluded that in most areas the overall efficiency of agriculture is not achieved, the farms have to decrease the level of inputs, especially the hectare area.

However, regional differences can be attributed to different access to resources, rates of technology adoption, agricultural policies, and market conditions, among other factors. Understanding these differences is essential for policymakers, farmers, and stakeholders to make informed decisions and allocate resources effectively. This information can guide targeted interventions and policies to support sustainable intensification in agriculture, ensuring that regional agricultural practices are not just efficient, but also environmentally responsible.

Acknowledgement

Scientific Paper was elaborated within the framework of the project KEGA 029UKF-4/2022: Preparation of the structure and content of the subject, textbook and e- learning course "Entrepreneurial skills" for non-economic study programs with a focus on the online environment.

References

Alem, H., Lien, G., Hardaker, J. B., & Guttormsen, A. (2019). Regional differences in technical efficiency and technological gap of Norwegian dairy farms: a stochastic meta-frontier model. *Applied Economics*, *51*(4), 409-421.

Bagchi, M., Rahman, S., & Shunbo, Y. (2019). Growth in agricultural productivity and its components in Bangladeshi regions (1987–2009): an application of bootstrapped data envelopment analysis (DEA). Economies, 7(2), 37.

Bagchi, M., Rahman, S., & Shunbo, Y. (2019). Growth in agricultural productivity and its components in Bangladeshi regions (1987–2009): an application of bootstrapped data envelopment analysis (DEA). Economies, 7(2), 37.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in

Błażejczyk-Majka, L., Kala, R., & Maciejewski, K. (2012). Productivity and efficiency of large and small field crop farms and mixed farms of the old and new EU regions. *Agricultural Economics*, *58*(2), 61-71.

data envelopment analysis. *Management Science, 30(9),* 1078–1092.

European Commission (2023). Factsheet on 2014-2022 Rural Development Programme for Slovakia. https://agriculture.ec.europa.eu/system/files/2023-05/rdp-factsheet-slovakia_en.pdf (accessed on 2 august 2023)

Hurnakova, J., Bartova, L., & Fandel, P. (2016). Efficiency and productivity of the Slovak agricultural investment support beneficiaries. *International Scientific Days 2016*, 923-930.

Charnes, A., Cooper, W.W., Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operation Research, 2(6),* 429-44. DOI 10.1016/0377-2217(78)90138-8.

Imran, M. A., Ali, A., Ashfaq, M., Hassan, S., Culas, R., & Ma, C. (2019). Impact of climate smart agriculture (CSA) through sustainable irrigation management on Resource use efficiency: A sustainable production alternative for cotton. *Land Use Policy*, *88*, 104113.

Tenaye, A. (2020). Technical efficiency of smallholder agriculture in developing countries: The case of Ethiopia. *Economies*, *8*(2), 34.

Toma, E., Dobre, C., Dona, I., & Cofas, E. (2015). DEA applicability in assessment of agriculture efficiency on areas with similar geographically patterns. *Agriculture and Agricultural Science Procedia*, *6*, 704-711.