

Article

Technical Efficiency in the Agricultural Business—The Case of Slovakia

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Abstract: The key element of the European Union (EU) Common Agricultural Policy is sustainable agriculture where the social, economic, and environmental objectives should be fulfilled. This role can fulfill only those agricultural holdings that are effective in the transformation of inputs to outputs, and which do not waste the inputs. Therefore, we analyze the technical efficiency of the agricultural holdings in the Slovak regions, and try to identify the factors that are able to influence the efficiency of agricultural holdings. We can conclude that there are regional disparities in technical efficiency in Slovakia; however, the problem of inefficiency is not typical only for the agricultural holdings in the areas with natural constraints. These regional disparities should be considered when adopting a new political measure to support sustainable agriculture. By the results of econometric models, we find that the agricultural production diversity, the policy of the labor market, and tax policy are the important factors influencing the technical efficiency of the agricultural holdings in Slovakia.

Keywords: agricultural business; technical efficiency; regional disparities; agricultural production diversity

1. Introduction

In the 21st century, agriculture is still a basic instrument in the fight against poverty and sustainable development. The main role of agriculture consists of economic activities, environmental services, and livelihood [1]. International organizations, policymakers, national governments, and local institutions are interested in sustainable agriculture, and they consider it as one of the most important objectives [2]. Sustainable agriculture is a core issue of the 2030 Agenda and the first step to eliminating hunger. In the 2030 Agenda, all sectors, including agriculture, are considered from the economic, social, and environmental dimension of sustainability [3]. Sustainable agriculture has to ensure the needs of living and future generations as well as profitability, environmental health, and equity [3]. It is also a core objective for the European Union in its amended Common Agricultural Policy [4], which is one of the largest agricultural policies of the world. It was focused primarily on the support of agricultural production and farm income; nowadays, the Common Agricultural Policy (CAP) integrates instruments to support the environmental and societal challenges, but the overall set of objectives remains incoherent and unbalanced [5–7]. The European Commission [8] argued that the economic, ecologic, or social objectives of sustainable agricultural and rural development do not support always each other, and they compete with each other. In this case, the sustainability is related to the need to find the balance among these elements [8]. Astier et al. [9] added that we need agricultural sustainability focused on the improvement of current systems and practices, mainly in the context of natural

resource management. The core component for improving agricultural sustainability is measuring farm sustainability [10]. De Koeijer et al. [11] argue that increasing the output per unit of input reduces environmentally harmful emissions and increases income by reducing costs or increasing output [11]. In addition, improving the end-use efficiency of resources is necessary, regardless of renewable or non-renewable resources [12]. However, efficiency is only a precondition for resource use that should be ethically acceptable, because inefficiency tends to waste [13]. Then, efficiency is necessary but not sufficient for the fairness that is embodied in the concept of sustainability, but efficiency increasing may result in a sustainability improvement [14–16]. In our paper, we try to calculate the efficiency of the agricultural holdings in Slovakia to identify how the agricultural holdings are effective in the transformation of inputs to outputs in the particular regions of the country, and to identify the factors that are able to influence the technical efficiency.

2. Literature Overview

Since Charnes, Cooper, and Rhodes [17] have created the non-parametric technique of data envelopment analysis, there are many studies and papers trying to evaluate the efficiency and productivity in the various fields of the economy, including agricultural holdings [18–23] or holdings in the food industry [24]. Since 1978 up through the year 2009, around 4500 Data Envelopment Analysis (DEA) related papers, both theoretically and practically oriented, have been published in the ISI Web of Science database [25]. In addition to this collection, around 2000 papers have been published in the same database during the period from 2010 to 2014 [26].

According to our objective, we wanted to find the papers interested in the efficiency of the agricultural holdings. Most of the studies are from Asiatic countries, e.g., [27–30]. In Europe, Burja [31] showed that the poor performance of agriculture in Romania and the efficiency recorded at the level of the development regions varies. Baráth and Fertő [32] investigate the relative productivity levels and decompose productivity change for European agriculture between 2004–2013. Cuerva [33] confirms that agricultures move very close to their stationary states, which differ among themselves, in such a way that productivity differences will persist in the long term. Ezcurra et al. [34] reveals a decrease in regional agricultural productivity disparities, while intra-distribution mobility is found to be relatively limited during the study period. Galluzzo [18] pointed out that specialized Bulgarian farms have had higher levels of technical efficiency compared to mixed farms, and financial subsidies allocated by the CAP have had a positive impact toward farmers, both increasing the technical efficiency and also reducing the socio-economic marginalization of Bulgarian rural areas. Marongiu et al. [35] focused on the efficiency of the Italian and French dairy farms situated in the Alps. Munroe [36] conducted a survey of economic efficiency in southern agriculture to understand why small-scale farming in Poland is inefficient, despite longstanding secure property rights. In Slovakia, the efficiency of agricultural holdings is a subject matter of several authors, e.g., [37–39]. They focused on the relationship between the efficiency of the agricultural holdings and their legal forms, size, number of employees, or acreage of agricultural land. Sojková et al. [40] focused on the comparison of the efficiency of agricultural holdings between the agricultural holdings from the production regions and the agricultural holdings from the less favored areas. However, they analyzed the comparison by the stochastic frontier analysis, and they recommended comparing the results also by DEA analysis. Based on this review, we try to use DEA analysis to compare the efficiency of agricultural holdings in the particular Slovak regions, and moreover to identify the factors that are able to influence the technical efficiency. Our paper is organized as follows: firstly, we try to calculate the efficiency of the agricultural holdings in Slovakia by the DEA analysis; secondly, we try to find out if there are regional disparities in the efficiency of the agricultural holdings among the administrative classification (regions (NUTS III) and districts (LAU 1) in Slovakia) and among the agricultural classification of Slovakia (according to the production regions 1 to 5 defined below). Thirdly, we try to identify the factors that are able to influence the technical efficiency.

3. Data and Methods

We use data collected by the Ministry of Agriculture and Rural development of Slovak Republic among the agricultural holdings in 2015 and 2016. The ministry provided us data about 913 agricultural holdings; of it, only 744 were used, because 169 agricultural holdings were excluded due to zero revenues for their goods and services. Therefore, we interviewed some more agricultural holdings from the regions (districts) with the missing data. We received together 1109 agricultural holdings, of which there were 582 agricultural business companies, 232 agricultural cooperatives, and 295 individual farmers.

The technical efficiency of agricultural holdings was evaluated by the non-parametric input-oriented BCC DEA model proposed by Banker et al. [41]. This model is expressed as follows:

$\min \theta$

subject to:

$$\begin{aligned} Y \times \lambda &\geq y_i \\ -\theta \times x_i + X \times \lambda &\leq 0 \\ 1^T \times \lambda &= 1 \\ \lambda &\geq 0 \end{aligned}$$

where $y_i = (y_1, \dots, y_m)$ is a vector of m outputs, $x_i = (x_1, \dots, x_k)$ is a vector of k inputs for each of these agricultural holdings, Y ($n \times m$) is a matrix of m outputs of each from the n agricultural holdings, X ($n \times k$) is a matrix of k inputs of each from the n agricultural holdings, θ is a scalar, and λ is a 1×1 vector of constant. The value θ is the efficiency score for the i -th agricultural holding. θ is from the interval $\langle 0, 1 \rangle$, and a value 1 indicates a point on the frontier and a technically efficient farm. If $\theta < 1$, then θ stipulates how much the evaluated agricultural holding should reduce its inputs to be effective in the output production. The convexity constraint $1^T \times \lambda = 1$ enables modifying the CRS (constant returns to the scale) model for the VRS model (variable returns to the scale), because the agricultural holdings have had different sizes related to the acreage of land or number of employees. The model deals with the four inputs (land in ha; capital assets in EUR; average number of employees; costs for materials, energy, and services in EUR) and one output (revenues for goods and services in EUR) (Table 1).

Table 1. Inputs and outputs descriptive statistics.

	Average	Standard Deviation	Minimum	Maximum
Input				
capital assets (€)	1,328,276.44	3,388,517.80	180.00	64,146,334.00
land (ha)	693.33	862.88	2.35	5834.20
average number of employees	15.37	26.45	0.00	236.00
costs for materials, energy and services (€)	659,207.97	1,160,747.17	33.00	16,911,140.00
Output				
revenues for goods and services (€)	803,329.20	1,556,413.55	280.00	25,915,578.00

We identify the statistical significant differences among the regions according to the administrative classification (NUTS III) and the regions according to the agricultural classification of Slovak country (1—maize production area; 2—sugar beet production area; 3—potato production area; 4—potato—oat production area; 5—mountain production area) by the Kruskal–Wallis test and multiple range tests available in the programme Statgraphics Plus. The Kruskal–Wallis test was characterized as follows:

$$H = \left(\frac{12}{N(N+1)} \times \sum_{j=1}^k \frac{R_j^2}{n_j} \right) - 3 \times (N+1) \quad (1)$$

H —Kruskal–Wallis test characteristics

N —total number of agricultural holdings (all regions combined)

R_j —rank total for each region

N_j —number of agricultural holdings in each region

k —number of regions

In the next step, we calculate the agricultural production diversity of each agricultural holding by the Shannon's equitability index, which is expressed as [42]:

$$H = - \sum_{i=1}^s p_i \ln(p_i) \quad (2)$$

where s is number of agricultural products and p_i is the proportion of amount of one particular species (n) divided by the total amount of agricultural production (N). The Shannon's equitability index (E_H) is computed as:

$$E_H = \frac{H}{H_{max}} \quad (3)$$

where H is the Shannon's diversity index, and H_{max} is calculated as $\ln(s)$. Shannon's equitability index assumes a value between 0–1, with 1 being complete evenness. In Slovakia, most of the agricultural holdings are focused on the mixed (crop and animal) production. The most favored crops are cereals (wheat, barley, maize), fodder crops, and industrial crops, e.g., [43,44]. The most favored animal production is beef meat, milk, pig meat, sheep meat, poultry, and eggs, e.g., [45].

At last, we try to identify the factors that are able to influence the technical efficiency by using the OLS and TOBIT model, because of censored dependent variable bordered by 0 and 1. We were able to use only data from the ministry due to missing several data of interviewed agricultural holdings. From 744 agricultural holdings, only 683 of them were integrated in the models. The rest of them were excluded from various reasons (e.g., mistakes in the data, missing some of the data, or the data were outliers). The econometric software GRETL was used. The heteroskedasticity was tested by the Breusch–Pagan test. The linear regression model is expressed as:

$$y_j = \alpha + \beta_1 x_{1j} + \beta_2 x_{2j} + \beta_3 x_{3j} + \beta_4 x_{4j} + \beta_5 x_{5j} + \beta_6 x_{6j} + \gamma x + \varepsilon_j \quad (4)$$

where y_j is the technical efficiency of agricultural holding j as a dependent variable; α is the intercept; x_{1j} is Shannon's equitability index of an agricultural holding; x_{2j} is a single farm payment (SAPS); x_{3j} is a payment for greening; x_{4j} is a payment for less favorite areas called areas with natural constraints (ANC); x_{5j} is an agri-environmental scheme payments (AES); x_{6j} is a payment for animal welfare (WELFARE); β_1 expresses how many percentage points the technical efficiency changes if Shannon's equitability index increases by one percentage point; β_2 to β_6 expresses how many percentage points the technical efficiency changes if a particular payment increases by 1 euro; x is a vector of the control variables in the model with particular regression coefficients expressed as vector γ ; and ε_j are residuals that are independent and identically distributed. The vector of control variables consists of independent (explanatory) variables that include the distance from the city, labor costs, total revenues share in total costs, revenues from the animal production share in revenues of the agricultural production, number of members, number of new jobs, rent payment for 1 ha of agricultural land, land taxes, share of property taxes in total costs, ANC land, irrigated agricultural land, region, production area, and membership in the farmers' associations. The descriptive statistics of the mentioned variables are shown in Table 2.

Table 2. Statistics of the variables integrated into the econometric models. ANC: areas with natural constraints.

Variable	Description	Unit	Mean	Std. Dev.	Min	Max
Shannon's equitability index	-	-	0.37	0.27	0.00	1.00
SAPS	Single area payments 2015 per ha	EUR	110.55	83.84	0.00	629.11
Greening	Payments for sustainability and care for natural resources 2015 per ha	EUR	38.51	44.93	0.00	695.37
ANC	Less favored areas scheme payments 2015 per ha	EUR	22.87	36.10	0.00	354.51
AES	Agri-environmental schemes 2015 per ha	EUR	11.00	50.91	0.00	516.76
WELFARE	Payments for animal welfare 2015 per ha	EUR	0.89	6.78	0.00	121.70
Distance from the city	Distance of the agricultural holdings from the district city (LAU 1)	km	11.40	13.33	1.00	67.30
Labor costs	Share of labor costs in total costs	-	0.08	0.09	0.00	0.80
Total revenues share in total costs	Share of total revenues in total costs	-	1.05	0.21	0.06	2.47
Revenues from the animal production share in revenues of the agricultural production	Share of revenues from animal production in revenues from agricultural production	-	0.23	0.36	0.00	1.00
Number of members in an agricultural holding	Number of members who doing business together within an agricultural holding	-	11.10	74.15	1.00	1403.00
Number of new jobs	Number of new jobs in 2016	-	0.29	1.80	0.00	35.00
Rent for land	Rent payment for one hectare of agricultural land	EUR	44.40	56.27	0.00	480.38
Land taxes	Land tax for one hectare of agricultural land	EUR	19.16	19.62	0.00	227.67
Property taxes in total costs	Share of property taxes in total costs		0.01	0.01	0.00	0.12
ANC land	Share of ANC land in the total agricultural land		0.34	0.45	0.00	1.00
Irrigated agricultural land	Share of irrigated land in the total agricultural land		0.03	0.14	0.00	1.00
Region	Dummy variable: Banská Bystrica region (BB)—benchmark Bratislava region (BA) Košice region (KE) Nitra region (NR) Prešov region (PO) Trenčín region (TN) Trnava region (TT) Žilina region (ZA)					
Production area	Dummy variable: Maize production area—benchmark legal form Sugar beet production area Potato production area Potato-oat production area Mountain production area					
Membership in the farmers' associations	Dummy variable: Non-member—benchmark membership Member					

We take into account the CAP payments for 2015 to find out the impact on the technical efficiency in 2016, because we assume that the CAP payments paid on the end of the particular year have a stronger impact on the technical efficiency in the next year than the CAP payments paid on the end of the year when technical efficiency was calculated.

4. Results

4.1. Technical Efficiency of Agricultural Holdings

We estimate the technical efficiency of agricultural holdings by DEA input–orientation model with the aim to minimize inputs given the output. We use the EMS software (Efficiency Measurement System) to calculate the relevant technical efficiency. The technical efficiency scores for 1109 agricultural holdings were distributed into the regions (NUTS III), districts (LAU 1), and production areas. We analyzed firstly the administrative classification by the regions and districts, and the results are presented in Table 3. The administration units are characterized by the geometric mean, maximum, and minimum of technical efficiency scores. We used the geometric mean, because it is less influenced by the outliers than the arithmetic mean.

Table 3. Efficiency scores of agricultural holdings in the regions (NUTS III) and the districts (LAU 1).

Region	Geomean TE VRS	Max TE VRS	Min TE VRS	District	Geomean TE VRS	Max TE VRS	Min TE VRS
Banská Bystrica region	100.00%	2.29%	Žiar nad Hronom (ZH)	16.18%	63.16%	5.52%	
			Krupina (KA)	19.97%	61.30%	6.04%	
			Žarnovica (ZC)	9.27%	100.00%	2.29%	
			Banská Bystrica (BB)	25.98%	60.37%	13.83%	
			Revúca (RA)	28.15%	43.20%	12.36%	
			Banská Štiavnica (BS)	33.79%	59.71%	22.22%	
			Poltár (PT)	28.48%	72.83%	7.02%	
			Rimavská Sobota (RS)	33.55%	100.00%	7.96%	
			Brezno (BR)	32.41%	91.59%	7.34%	
			Lučenec (LC)	34.15%	100.00%	2.54%	
			Zvolen (ZV)	44.62%	87.97%	22.54%	
			Veľký Krtíš (VK)	42.18%	82.98%	5.68%	
Bratislava region	49.01%	100.00%	Detva (DT)	49.78%	62.42%	39.50%	
			Pezinok (PK)	45.89%	74.75%	25.12%	
			Bratislava (BA)	40.68%	100.00%	1.39%	
			Malacky (MA)	67.69%	100.00%	34.25%	
Košice region	36.04%	100.00%	Senec (SC)	68.64%	100.00%	21.43%	
			Gelnica (GL)	13.21%	43.21%	5.64%	
			Sobrance (SO)	31.92%	70.25%	8.64%	
			Spišská Nová Ves (SN)	28.29%	100.00%	5.36%	
			Rožňava (RV)	36.03%	100.00%	10.77%	
			Košice (KE)	36.93%	100.00%	5.97%	
			Trebišov (TV)	39.63%	100.00%	5.48%	
Nitra region	53.33%	100.00%	Michalovce (MI)	43.05%	100.00%	8.05%	
			Zlaté Moravce (ZM)	41.10%	71.07%	19.29%	
			Nové Zámky (NZ)	51.55%	100.00%	14.95%	
			Komárno (KN)	53.87%	100.00%	22.49%	
			Topoľčany (TO)	53.14%	100.00%	28.46%	
			Šaľa (SA)	55.55%	100.00%	33.43%	
			Leivce (LV)	56.30%	100.00%	25.10%	
Nitra (NR)	59.50%	100.00%	21.71%				

Table 3. Cont.

Region	Geomean TE VRS	Max TE VRS	Min TE VRS	District	Geomean TE VRS	Max TE VRS	Min TE VRS
Prešov region	24.41%	100.00%	2.00%	Medzilaborce (ML)	16.85%	52.08%	7.60%
				Poprad (PP)	18.46%	46.34%	5.77%
				Stropkov (SP)	16.75%	81.01%	3.63%
				Sabinov (SB)	21.03%	55.20%	3.81%
				Vranov nad Topľou (VT)	26.40%	68.28%	6.49%
				Stará Ľubovňa (SL)	23.55%	69.58%	5.06%
				Levoča (LE)	27.29%	69.26%	8.04%
				Humenné (HE)	15.91%	100.00%	2.00%
				Prešov (PO)	25.79%	100.00%	6.19%
				Bardejov (BJ)	29.73%	82.89%	6.89%
				Snina (SV)	30.67%	100.00%	8.17%
				Svidník (SK)	35.83%	97.66%	6.56%
Trenčín region	38.63%	100.00%	5.98%	Kežmarok (KK)	46.84%	100.00%	19.76%
				Púchov (PU)	20.82%	65.66%	5.98%
				Myjava (MY)	28.01%	62.34%	11.44%
				Ilava (IL)	30.37%	40.41%	17.91%
				Považská Bystrica (PB)	32.43%	100.00%	8.42%
				Nové Mesto nad Váhom (NM)	42.24%	100.00%	20.37%
				Bánovce nad Bebravou (BN)	40.90%	100.00%	14.05%
				Prievidza (PD)	47.67%	89.44%	17.66%
				Partizánske (PE)	62.98%	100.00%	28.24%
				Trenčín (TN)	61.24%	100.00%	32.12%
Trnava region	54.20%	100.00%	3.49%	Senica (SE)	29.25%	100.00%	10.77%
				Piešťany (PN)	48.58%	70.36%	21.68%
				Hlohovec (HC)	50.72%	88.23%	32.42%
				Dunajská Streda (DS)	52.68%	100.00%	3.49%
				Skalica (SI)	58.41%	88.38%	42.52%
				Trnava (TT)	61.08%	100.00%	28.03%
				Galanta (GA)	59.04%	100.00%	20.13%
Žilina region	23.98%	100.00%	2.65%	Žilina (ZA)	13.03%	46.08%	2.65%
				Bytča (BY)	17.09%	33.06%	9.71%
				Dolný Kubín (DK)	22.17%	48.13%	7.75%
				Námestovo (NO)	23.50%	38.94%	10.48%
				Liptovský Mikuláš (LM)	22.41%	41.71%	10.40%
				Martin (MT)	27.38%	49.48%	11.50%
				Kysucké Nové Mesto (KM)	17.25%	88.64%	4.29%
				Čadca (CA)	27.07%	100.00%	4.32%
				Tvrdošín (TS)	27.68%	100.00%	3.51%
				Ružomberok (RK)	28.39%	100.00%	12.51%
				Turčianske Teplice (TR)	45.52%	83.44%	23.82%

The results suggest that the technical efficiency scores of the agricultural holdings in the particular regions range from 23% to 54% in 2016 and an input waste ranges from 46% to 77%. The smallest technical efficiency is in the Žilina region on the north of the country where the poorest soils are concentrated and the mountain occupied the most area of the region. There are 11 districts and the district Turčianske Teplice has received the biggest technical efficiency score (45.52%) from all districts

in the Žilina region. However, there are also agricultural holdings in Čadca district, Tvrdošín district, or Ružomberok district where some of the agricultural holdings are effective (maximum efficiency score is 100%). It means that it is possible to be effective also in the regions where the conditions for agricultural business are not ideal. The most efficient region is the Trnava region with the technical efficiency score 54.2%. However, there is also a very big gap among its seven districts, mainly between the Senica districts and the rest of them. In spite of this fact, the Senica district is one of those where the agricultural holdings are able to be effective for 100%. We can say that the natural conditions for agriculture are not the barriers to be effective in agricultural business. The most of agricultural holdings do not know or do not want to transform inputs to effective output.

To compare the results among the regions, we use the non-parametric Kruskal–Wallis test and the multiple range tests available in Statgraphics Plus. The technical efficiency is statistically significant different among the regions (Test statistic 198.11 with the p -value = 0.0). The multiple range tests showed that the statistically significant differences are among three groups of regions. The first one is created by the Bratislava region, the Nitra region, and the Trnava region with the best technical efficiency scores (from 49.01% to 54.2%). The second group is created by the Košice region (36.04%) and the Trenčín region (38.63%). The third group with the smallest technical efficiency scores is created by the Žilina region (23.98%) and the Prešov region (24.41%). Only the Banská Bystrica region (30.59%) cannot be without doubt to include in the second or the third group. On the basis of multiple range tests (the Tukey highly significant difference (HSD) test, the Scheffe test, and the Bonferroni test), the Banská Bystrica regions should be included in the third group. However, the least significant difference (LSD) test, Duncan test, and Newmann–Keuls test are confirmed as included in the second group. We prefer to include the Banská Bystrica region in the second group on the basis of the interval classification of districts presented below. Regardless of the groups of regions, the results confirm that it is necessary to increase the technical efficiency scores of agricultural holdings in each region from 46% to 77%. The results confirm that the most of the effective agricultural holdings are concentrated on the west of Slovakia. Similar results were confirmed by Bartová et al. [46] and Čechura et al. [47] that analyzed the technical efficiency of dairy farms in the Czech Republic and Slovakia on the level NUTS II. In both studies, the best technical efficiency scores of dairy farms were found in west Slovakia in comparison to Middle and East Slovakia. Bartová et al. [46] argued that the problem of inefficiency of dairy farms is related to all Slovak regions, and was mainly a result of managerial underperformance and then a non-optimal farm scale. However, Table 3 confirms that not only the districts of West Slovakia are able to be effective. Regarding the minimum and maximum values of the technical efficiency scores in Table 3, it is not possible to conclude that the technical efficiency of the agricultural holdings is more homogenous on in West Slovakia than in the other regions of the country. Therefore, we try to analyze the statistical significance differences among the districts. The technical efficiency is statistically significantly different among the districts (Test statistic 302.611 with the p -value = 0.0). The multiple range tests showed that the statistically significant differences are between districts of Gelnica, Žilina, and Bytča on the one hand, and Senec, Malacky, Trenčín, and Partizánske on the other hand. For better visualizing the technical efficiency of agricultural holdings in the districts, we used Figure 1. We joined the districts Bratislava I to V into one district Bratislava and districts Košice I to IV and Košice-okolie into one district Košice, due to the small number of agricultural holdings in the particular districts. We have 71 districts displayed in Figure 1.

The smallest technical efficiency scores were calculated in the Žarnovica district, and the highest one was calculated in the Senec district. The districts were divided into six classes; the first class includes the districts with the most effective agricultural holdings. The classes were calculated as the share of the range (the difference between the largest and smallest values) and the number of classes. The number of classes was calculated as follows: $0.55 \times n^{0.4} \leq k \leq 1.25 \times n^{0.4}$, where n is the number of the districts, and k is the number of classes. We chose six classes from the calculated interval <3.026; 6.88> because of a detailed view. According to Figure 1, we can conclude that five districts have an average technical efficiency that is much higher than the average technical efficiency of the

regions where the districts belong, and four districts have an average technical efficiency that is much lower than the average technical efficiency of the regions where the districts belong. The outliers are documented in Table 4.

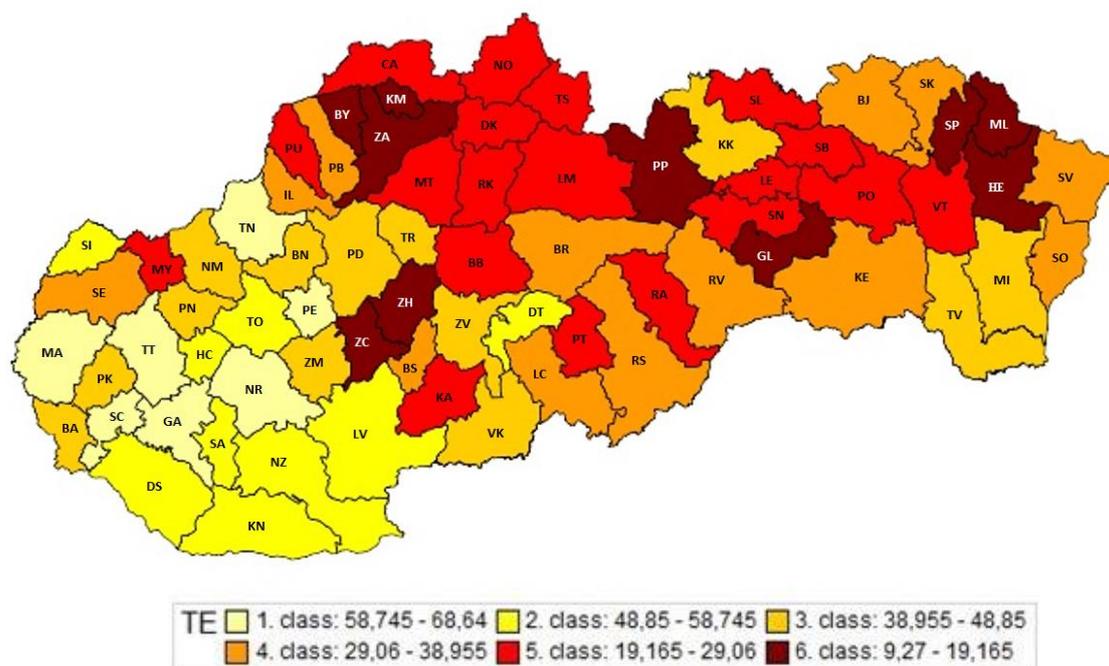


Figure 1. Technical efficiency score of agricultural holdings in the particular districts of Slovakia.

Table 4. Districts with the extreme average values of technical efficiency of agricultural holdings within the particular region.

Region	Geomean TE VRS	Higher Values		Lower Values	
		District	Geomean TE VRS	Districts	Geomean TE VRS
The Banská Bystrica region	30.59%	DT	49.78%	ZC	9.27%
		x	x	ZH	16.18%
The Bratislava region	49.01%	x	x	x	x
The Košice region	36.04%	x	x	GL	13.21%
The Nitra region	53.33%	x	x	x	x
The Prešov region	24.41%	KK	46.84%	x	x
		PE	62.98%	x	x
The Trenčín region	38.63%	TN	61.24%	x	x
		x	x	SE	29.25%
The Žilina region	23.98%	TR	45.52%	x	x

Table 4 confirms that the homogenous group of the agricultural holdings in relation to the technical efficiency scores are concentrated only in the Bratislava region and the Nitra region. Other regions received the heterogeneity of the agricultural holdings in relation to the technical efficiency scores in the particular districts that the regions include. These facts should be regarded when creating the regional policy for agriculture. Most of the regions regarding the heterogeneity of agricultural holdings in the particular districts need to take into account the special acceptance of these districts in the process of preparing the new political measures for agricultural sustainability in those districts. The results of DEA analysis enable identifying the perspective agricultural districts for agriculture as

well as the districts with special needs. The comparison of technical efficiency differences could be a basic material for the adoption of new political measures to support sustainable agriculture in the particular districts in Slovakia.

Secondly, we expected that the heterogeneity of the technical efficiency of the agricultural holdings in the particular districts of a region is dependent on the agricultural classification of the country. We have five production areas in Slovakia:

1. maize production area (up to 200 m above sea level; south-west and south-east of Slovakia where most of the lowlands are situated);
2. sugar beet production area (200–300 m a.s.l.; north parts of the lowlands mentioned above);
3. potato production area (300–500 m a.s.l.; lower parts of the highlands in Middle and North Slovakia);
4. potato–oat production area (500–600 m a.s.l.; lower parts of the mountains in Middle and North Slovakia);
5. mountain production area (over 600 m a.s.l.; mountains region in North Slovakia).

Therefore, we expected the statistically significant differences of the technical efficiency scores among the production areas. We found out by the Kruskal–Wallis test (test statistic 154.99 with the p -value = 0.0) and multiple range tests that there are statistically significant differences among the maize production area, sugar beet production area, and the rest of them; however, there are no statistically significant differences among the potato production area, potato–oat production area, and mountain production area. The results of technical efficiency scores are in Table 5.

Table 5. Efficiency scores of agricultural holdings in the particular production areas.

Production Areas	Number of Agricultural Holdings	Geomean TE VRS	Standard Deviation TE VRS
1—maize	610	47.33%	0.2319
2—sugar beet	157	34.12%	0.2614
3—potato	165	24.79%	0.2436
4—potato–oat	59	27.43%	0.2189
5—mountain	118	27.61%	0.2502

Then, we compared the results of Tables 4 and 5, and concluded that the agricultural holdings are able to be effective, regardless of the production area. Therefore, we supposed that production areas are not one of the most important factors that are able to predict the efficiency of an agricultural holding. Our hypothesis was partially confirmed by the econometric models in the further analysis.

4.2. Factors Influencing the Technical Efficiency of the Agricultural Holdings

Some of the scientific studies try to identify the factors of technical efficiency of agricultural holdings. Madau et al. [48] argued that differences in the technical efficiency may be caused by the structural differences among the agricultural holdings, such as the size of an agricultural holding, age of managers, climatic changes, and managerial skills. Nowak et al. [21] confirmed that the technical efficiency is positively influenced by factors such 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. Pechrová [49] confirmed the positive and statistically significant impact of agricultural subsidies from the Programme of Rural Development on the technical efficiency of the agricultural holdings in the Czech Republic, but she added that the projects financed from the Programme of Rural Development are different, and further research of these projects on the technical efficiency of the agricultural holdings is necessary. In Slovakia, Adamišín et al. [50] analyzed the impact of legal forms of the agricultural holdings on the productivity of the agricultural holdings by the paired t -test, and they concluded that the business companies are able to manage an agricultural business better than the agricultural cooperatives. Moreover,

the effective management of an agricultural holding in a worse production area is able to be a good inspiration for other agricultural holdings not only in the surroundings, but also in the better production areas. Sojková and Covaci [51] evaluated the technical efficiency by the parametric Stochastic Frontier Analysis (SFA analysis), and concluded that the agricultural holdings with the higher acreage of agricultural land are more effective. On the contrary, Fandel [38], Bielik, and Rajčániová [37] evaluated the technical efficiency by the non-parametric DEA analysis, and concluded that the most effective agricultural holdings cultivate up to 500 ha of agricultural land [37] or cultivate up to 100 ha and more than 1000 ha of agricultural land [38]. Sojková and Covaci [51] considered that the problem of different results consists in outliers and in data likelihood. Kollár and Sojková [39] confirmed the statistically significant impact of agricultural investment subsidies on the technical efficiency evaluated by SFA. However, the legal form and specialization of agricultural holdings were not confirmed as statistically significant factors. Sojková et al. [40] evaluated the technical efficiency of agricultural holdings in the production areas and ANC areas by the SFA. They found out the statistically significant differences in the technical efficiency of the agricultural holdings between the production areas and LFA areas; however, a higher variability of the technical efficiency was found among the agricultural holdings in the better production areas. On the base of a brief summary of the results from the studies of the technical efficiency of agricultural holdings, mainly in Slovakia, we tried to evaluate the impact of selected natural, geographical, social, and economic factors on the technical efficiency of the agricultural holdings by the econometric models.

Firstly, we considered as independent variables all of these variables:

- natural, production, and geographical conditions such as region, production area, distance from the city, soil quality, and agricultural production diversity expressed by the Shannon's equitability index;
- social conditions such as the education of managers, membership in the farmers' associations, number of members in an agricultural holding, number of new jobs, share of employees with the university education to all employees in an agricultural holding;
- legal and economic conditions such as legal form, acreage of agricultural land, average number of employees, CAP subsidies per 1 ha of land (SAPS, greening, ANC, agri-environmental scheme payments, payments for ecological agriculture, WELFARE, state subsidies, payments for the common organization of the markets, investment subsidies), share of revenues from the agricultural production in total revenues, share of revenues from the agricultural production in total costs, share of revenues from the animal production in revenues from the agricultural production, share of total revenues in total costs, share of costs for material, services, and energy in total costs, share of costs for material, services, and energy in total revenues, rent payments for 1 ha of land, share of labor costs in total costs, share of property taxes in total costs, land tax for one hectare of agricultural land, share of ANC land in the total agricultural land, and share of irrigated land in the total agricultural.

However, the models consist of the independent variables described in Table 2. Although we tried to include all above-mentioned variables, they should be excluded due to the multicollinearity of variables, heteroscedasticity of the model, or absence of the normality of residuals. We choose two models estimated by the OLS and TOBIT methods. The results are documented in Table 6. Most of the results are similar in both models; therefore, we interpreted the variables from the OLS model, and we mentioned the variable in the TOBIT model only if there is a different result. In spite of the censored variable of technical efficiency, there are no serious differences between the models.

Table 6. OLS and TOBIT models. ANC: areas with natural constraints, AES: agri-environmental scheme payments, SAPS: single farm payment, WELFARE: payment for animal welfare.

Variable	Model OLS	Model TOBIT
Shannon's equitability index	0.0691 ***	0.0665 ***
SAPS	0.0001	-
Greening	0.0001	0.0002
ANC	-0.0007 ***	-0.0007 ***
AES	0.0001	0.0001
WELFARE	0.0016	0.0017 *
Distance from the city	-0.0004	-0.0003
Labor costs	-0.2644 ***	-0.2663 ***
Total revenues share in total costs	0.3185 ***	0.3209 ***
Share of revenues from the animal production in revenues of the agricultural production	-0.0899 ***	-0.0964 ***
Number of members in an agricultural holding	0.000006	0.000008
Number of new jobs	-0.0007	-0.0009
Rent for land	0.00005	-
Land taxes	0.0025 ***	0.0026 ***
Property taxes in total costs	-3.9346 ***	-4.0138 ***
ANC land	-0.0104	-
Irrigated agricultural land	0.0806	-
Membership in the farmers' associations	0.0369 *	0.0386 **
Region		
The Banská Bystrica region	benchmark	
The Bratislava region	0.0746 **	0.0867 ***
The Košice region	-0.0152	-0.0188
The Nitra region	0.0292	0.0363
The Prešov region	-0.0299	-0.0315
The Trenčín region	0.0169	0.0141
The Trnava region	0.0513 *	0.0587 **
The Žilina region	-0.0490	-0.0497
Production areas		
1—maize	Benchmark	
2—sugar beet	-0.0346	-0.0347
3—potato	-0.0676 **	-0.0673 **
4—potato-oat	-0.0168	-0.0178
5—mountain	-0.0383	-0.0394
Intercept	0.1533 ***	0.1599 ***
R-squared	0.3896	-
adjusted R-squared	0.3625	-
Test of normality	5.5722 (<i>p</i> -value = 0.0617)	5.7556 (<i>p</i> -value = 0.0563)
LM statistics	39.0934 (<i>p</i> -value = 0.0999)	-

* *p*-value at 10%; ** *p*-value at 5%; *** *p*-value at 1%.

Agricultural production diversity is the statistically significant factor with a positive effect on the technical efficiency of the agricultural holdings. The positive regressive coefficient indicates that the technical efficiency increases with the higher agricultural production diversity. It means if the variable agricultural production diversity increases by 1 percentage point, the technical efficiency is expected to increase on average by 0.069 percentage points. This was confirmed by both models. Agricultural production diversity is one of the important factors of sustainable agriculture. Karley [4] summarized research to assess the benefits to agricultural sustainability of introducing diversity at crop, field, farm, and regional scales. In the recent years, discussions on the biodiversity conservation on agricultural land also include energy crop production [52], especially short-rotation coppice plants such as willows or poplars [53,54]. Practices that increase the diversity of crop and non-crop components of the field can contribute ecosystem services that benefit agriculture. For example, crop variety mixtures could be designed to promote the survival of rare arable plants [55]. It follows that the political measures should consider also the support of agricultural production diversity within the agricultural policy.

The second group of independent variables included in the model consists of particular subsidies of the CAP. These are statistically significant only regarding the payments for areas with natural constraints; however, the coefficient is negative one, and is close to zero. It results that the ANC payments are not an important factor of technical efficiency, although they are statistically significant coefficient. The payment for animal welfare is not statistically significant in the OLS model. In the TOBIT model, this payment was statistically significant, but only at the p -value of 10%. The welfare payment has a positive impact on the technical efficiency; however, the coefficient is close to zero. If the welfare payment increases by 1 euro per hectare, the technical efficiency is expected to increase on average by 0.0017 percentage points. We can conclude that in general, the CAP payments do not form a statistically a significant factor regarding the technical efficiency of the agricultural holdings. Pechrová [49] arrived at a similar conclusion; she argued that on one hand, the Rural Development Programme subsidies contributed to the decrease of variance of the inefficiency term, but on the other, the effect is statistically significant only at a 90% level of significance [49]. Kollár and Sojková [39] confirmed the statistically significant impact of agricultural subsidies on the technical efficiency evaluated by SFA, but the coefficients were negative ones. Galluzzo [56] recommended that Italian small farms smaller than 5 hectares need adequate financial supports allocated by the second pillar of the Common Agricultural Policy, and these subsidies are pivotal in particular toward family farms located in the upland and hilly areas. The regression coefficients of the subsidies from the second pillar of CAP for greater farms were not statistically significant. We can conclude that the present CAP subsidies do not motivate the farmers to improve their technical efficiency. Of course, there is also the question of the distribution of subsidies. We had to exclude more than 160 agricultural holdings from the econometric model because of zero revenues from the agricultural production; however, they received the particular subsidies. On the other hand, there were smaller agricultural holdings with the revenues from the agricultural production, but they refuse the subsidies because of huge administration burden.

Other statistically significant indicators include the share of total revenues in the total costs (with the positive effect), labor costs, and property taxes in total costs (with the negative effect). The lawmaker should regard these results as very sensitive when considering the legislative amendment related to the labor market and property taxes. The share of revenues from the animal production in relation to the agricultural production revenues is one of the statistically significant factors, but with a negative effect. It means that if this variable increases by 1 percentage point, the technical efficiency is expected to decrease on average by 0.08 percentage points. The reason is that firstly, animal production needs higher costs than crop production, and secondly, most of the agricultural holdings are not able to sell their animal products with the profit: they are usually able only to cover their costs. This problem could be solved at least partially by membership in the farmers' associations. There is a positive significant effect on the technical efficiency of the agricultural holdings. It means that membership in the farmers' associations increases the technical efficiency on average by 0.03 percentage points.

The factors such as distance from the city, number of members in an agricultural holding, number of new jobs, and rent for land are not statistically significant factors for technical efficiency. The statistically significant factor is land tax, which has a positive effect on the technical efficiency. The land tax depends significantly on the soil quality and is derived from Act no. 582/2004 Coll. on local taxes. The higher land tax means usually higher soil quality, which enables receiving an agricultural holding with a higher technical efficiency. However, the positive significant effect expressed by the coefficient is minimal (only 0.0025).

The production areas are not significant factors regarding technical efficiency in the most of the cases. The regression coefficient of production areas is statistically significant only for the potato production areas. All the regression coefficients are negative ones, regardless of statistical significance. It means that the agricultural holdings in the maize production areas have the highest technical efficiency. The agricultural holdings received the technical efficiency that was 0.068 percentage points smaller in the potato production areas than in the maize production areas. In other production areas, the regression coefficient is not statistically significant, but in spite of this fact, it is interesting that the technical efficiency decreases in the sugar beet production areas on average by 0.03 p.p., and in the potato areas on average by 0.06 p.p., but in the potato–oat production areas, the technical efficiency decreases only on average by 0.01 p.p., and in the mountain production areas, it decreases only on average by 0.03 p.p. as in the sugar beet production areas. However, we would expect that the decrease of the technical efficiency would be still higher with the higher production areas. It is possible to consider that drought and missing rainfall moves the technical efficiency from the production areas to the mountain areas. Of course, there is necessary further research to confirm this opinion, because our models do not provide a statistically significant regression coefficient.

The last factor—region (NUTS III)—was considered in the econometric models. The statistical significance was received only in the Bratislava region and the Trnava region in the TOBIT model. The Banská Bystrica region is a benchmark; then, the regression coefficients confirm that the higher technical efficiency was received in the regions of the first group (the Bratislava region, the Trnava region, and the Nitra region). The regression coefficient of the Trenčín region is positive; therefore, the technical efficiency in this region is higher than in the Banská Bystrica region, but the regression coefficient of the Košice region is negative, and the technical efficiency in this region is smaller than in the Banská Bystrica region. The Trenčín region and the Košice region were included in the second group of the regions together by the Kruskal–Wallis test and multiple-range tests, and the including of the Banská Bystrica region was not without doubt in the second or third group. Therefore, the Banská Bystrica region should be included in this group with the highest probability rather than in the third group. It follows that the location of an agricultural holding in the particular region regardless of administrative or agricultural classification is not statistically significant in favor of its technical efficiency.

5. Conclusions

The discussions related to the new CAP are focused on sustainable agriculture where the social, economic, and environmental objectives will be fulfilled. This role can fulfill only those agricultural holdings that are effective in the transformation of inputs to outputs, and they do not waste the inputs. The results of DEA analysis enable identifying the perspective of agricultural districts for agriculture as well as the districts with special needs. The comparison of technical efficiency differences could be a basic material for the adoption of new political measures to support sustainable agriculture in the particular districts in Slovakia. Moreover, the results proved that agricultural production diversity is one of the important factors to improve the technical efficiency of the agricultural holdings, and thus should be considered when creating the new measures of the CAP. However, not only CAP measures are important; political measures are important, too. The policy of the labor market and tax policy are also important factors that are able to influence the technical efficiency of the agricultural holdings.

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