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The impact of efficiency on the profitability of large farms in the Visegrad Four

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Abstract: The issue of productivity and performance in agriculture is significant because it affects a country's competitiveness, sustainability, and self-sufficiency in agricultural production and is reflected in European policy. This study aims to determine which country had the most efficient large farms compared to other V4 countries and whether efficiency in each country translates into the performance of large farms. The data were obtained from the EU FADN (Farm Accountancy Data Network) database from 2005 to 2019. These data were then evaluated using the statistical methods DEA: CCR-O (Data Envelopment Analysis: constant returns to scale), DEA: BCC-O (Data Envelopment Analysis: variable returns to scale), and Pearson correlation coefficient. Regarding international comparisons in achieving efficiency as measured by DEA, Hungary is the best performer among the countries compared, followed by Czechia, Poland, and Slovakia. The correlation between efficiency and performance measured by Farm Net Value Added was demonstrated only for Hungary. The international comparison provided information about which country had the most efficient large farms, what the ranking of countries was in terms of efficiency, and for which countries efficiency had / did not have a potential impact on performance. At the same time, the relationships regarding the efficiency and performance of farms with an economic size above EUR 500 000 of standard output were clarified.

Keywords: agriculture; livestock; farm performance; Data Envelopment Analysis; Pearson

Farm efficiency is critical to achieving positive farm performance and long-term sustainability (Czubak and Pawłovski 2020; Antón and Sauer 2021). The importance of efficiency was discussed by Wasilewski and Mądra (2009) and Hedija and Kuncová (2021). Pérez-Pons et al. (2020) described the relationship between efficiency and effectiveness and emphasised that it is difficult to assign or identify what leads to efficiency and, thus, profitability (Farrell 1957). The current knowledge gap can then be considered to be the lack of a sufficient description of the relationship between efficiency and effectiveness, which would yield unambiguous results based on a sufficiently representative sample and indicators suitable for measuring the efficiency-performance relationship.

Existing research on farm efficiency and performance has yet to produce precise results. Current research on farm efficiency has been limited, for example, by the fact that it has only been conducted on samples from one country (Galluzzo 2017; Hedija and Kuncová 2021), where the value of the research results can be limited

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by the specificity of a given country and the research results cannot be presented as universally applicable, or it was a comparison of countries with different histories and management conditions (Błażejczyk-Majka et al. 2012; Latruffe et al. 2012; Sielska and Kuszewski 2016). Other research is based on classical ratios such as ROE (return on equity), ROA (return of assets), etc. However, these may be affected by different tax optimisation and different levels of taxation or depreciation in different countries (Brožová and Vaněk 2013). Given the knowledge above, gaps, and limitations of current research, the authors of this paper decided that it was appropriate to use a larger sample but one with the same historical development and similar climatic conditions to measure efficiency and the relationship between efficiency and performance (Kryszak 2018). The Visegrad Group 4 (V4; Czechia, Hungary, Poland, and Slovakia) countries were selected.

Despite minor differences, the agriculture of the V4 countries is comparable in terms of the percentage of arable land, fully organic land out of the total cultivated area, livestock stocking rate (livestock unit per ha), or percentage of employees working in agriculture per population (Eurostat 2021).

Efficiency is measured in our research using the DEA (Data Envelopment Analysis) method, and the dependence between efficiency and profitability is examined based on correlation (Pearson coefficient). The Pearson coefficient is widely used to quantify the impact of one variable on another in agriculture (Rahman 2011; Kravcakova Vozarova and Kotulic 2016). Conclusions arising from studies by Farrell (1957) or Pérez-Pons et al. (2020) were also accounted for as research uncertainty that selected inputs may not contribute significantly to the efficiency of the firms in question. Another research uncertainty is that it may be concluded that efficiency is not related to firm performance, as Hedija and Kuncová (2021) concluded in their research. Our research is concerned with how efficient firms are with each other in terms of a model based on constant returns to scale (DEA-CCR model) and variable returns to scale (DEA-BCC model) and whether efficiency affects performance (Pearson coefficient).

Clarifying these relationships can fill the knowledge gap regarding the efficiency and performance of farms with an economic size above EUR 500 000 of standard output. Our research focuses on field production; however, if the findings are the same for all V4 countries, we can assume their causality and transferability to other agricultural sectors. Sielska and Kuszewski (2016) also used the DEA method to examine the efficiency of different countries. Kryszak (2018) then looked at the efficiency of countries that have been grouped into clusters using the TFP (total factor productivity) method. Galluzzo (2017) or Hedija and Kuncová (2021) focused on only one country. These studies are important, but they focused on a different segment of knowledge or only one country. Evaluated indicators are not fully comparable among different countries or group of countries, and it is impossible to draw a threshold of effectiveness for the V4 countries. Within the European Union, production efficiency has been addressed by several authors. However, these studies compare enterprises across all countries regardless of production focus or economic size, i.e. enterprises with entirely different structures (Kočišová 2015; Sielska and Kuszewski 2016). Błażejczyk-Majka et al. (2012) describe differences in farm efficiency between long-term EU members and countries after their accession, i.e. with a different historical development. Our research focuses on efficiency and its impact on the profitability of large farms in V4 countries (similar historical development and climatic conditions) based on FADN data. This study aims to determine which country has the most efficient large farms compared to other V4 countries and whether efficiency in each country translates into farm performance, which we consider an essential contribution to farm efficiency research.

Based on the above findings, we formulated the research assumptions (*RA*) below:

RA_1: We assume that efficiency has performance implications.

RA_2: We assume that the selected inputs contribute significantly to the efficiency of the firms in question.

RA_3: We assume that there is no need to include factors mentioned by Işik and Özbugday (2021), e.g. weather conditions, agricultural input costs, currency exchange rates, international trade, population growth, etc.

MATERIAL AND METHODS

Based on the above assumptions, the authors of this article set out a hypothesis:

H_1: Efficiency affects the performance of farms with an economic size above EUR 500 000 of standard output in the V4 countries.

H_2: The country with the highest efficiency will also be the country with the highest performance.

The data analysed in the international comparison were obtained from the EU public FADN database from 2005 to 2019. Data for 2020–2023 were not avail-

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able during the study's writing. Hence, the period under study is free of major external geopolitical influences. The EU FADN database contains economic and production information on farms in all EU Member States. The methodology of data collection and calculation of indicators is standard across the EU, and the data obtained are, therefore, easily comparable between countries. There is no risk of inaccurate interpretation due to different methodologies. The V4 countries compared were Czechia, Hungary, Poland, and Slovakia. Total output (EUR/farm), total labour costs (EUR), total utilised agricultural area (ha), total livestock units (LU), and Farm Net Value Added (*FNVA*; EUR) were used for the analysis. These data were then evaluated using statistical methods. Profitability, productivity, and efficiency vary by farm size, with larger farms being more efficient than smaller farms (Błażejczyk-Majka et al. 2012; Mugera et al. 2016; Forleo et al. 2021; Chavas et al. 2022; Čechura et al. 2022). Therefore, the authors decided to research farms that fall into the same category of economic size as defined by the EU FADN methodology (≥ EUR 500 000 of standard output) to make the results fully comparable.

The DEA method has been used to determine the level of technical efficiency of farms in individual countries (Kočišová 2015; Sielaska and Kuszewski 2016). The essence of the method is to compare farms (production units) against each other, with the farms with the highest input efficiency forming the efficiency frontier. An enterprise is efficient if no other enterprise achieves the same output with a lower quantity of inputs or a higher quantity of output with the same quantity of inputs.

Efficiency in agriculture could be evaluated by using other methods, for example, by decomposing efficiency using the Malmquist efficiency index (Kryszak 2018) or the TFP (total factor productivity) method, which is used to analyse inputs (labour, capital) in order to determine how much output can be produced with a certain amount of inputs (Kryszak 2018; Čechura et al. 2022).

Machek and Hnilica (2013) stated that TFP takes into account all outputs and inputs of a given firm. However, the authors of this paper focused only on selected inputs (available from the EU FADN database) to find the efficient frontier for each country and thus provide an international comparison. Given this, the most appropriate method is DEA. In examining the relationship between efficiency and performance, the Person correlation coefficient was used, which measures the strength of the linear relationship between two variables and is a commonly used descriptive statistic in agriculture (Taylor and Bates 2013; Díaz 2016; Tian et al. 2022), however, the authors of this paper are aware of the shortcomings that may be introduced by the use of the Person correlation coefficient as reported in Armstrong (2019).

Methods for examining effectiveness. The output-oriented DEA method was used to assess the efficiency of the farms in the states. The efficiency of the farms was analysed in terms of technical efficiency, i.e. how inputs (combinations of inputs) such as labour, cultivated area, and livestock units were used to achieve total output. DEA models based on constant returns to scale (CCR model) and variable returns to scale (BCC model) were used for comparison.

Thus, the DEA model used was CCR-O, which evaluates the output rate with normalised inputs and assumes the existence of constant returns to scale.

$$\Phi_H = \frac{\sum_{i=1}^{m} v_{iH} x_{iH}}{\sum_{j=1}^{n} u_{jH} y_{jH}} \rightarrow MIN \quad (1)$$

where: Φ – technical efficiency coefficient; x_{iH} – value of the i-th input of unit H; y_{jH} – value of the j-th output of unit H; v_{ik} – weights assigned to input i; u_{jk} – weights assigned to output j for unit k; MIN – for each unit H, the weights are set using linear programming so that Φ takes the smallest possible value

Subject to the following conditions:

$$\frac{\sum_{i=1}^{m} v_{iH} x_{ik}}{\sum_{j=1}^{n} u_{jH} y_{jk}} \geq 1, k = 1,2,\ldots,p$$
$$u_{jH} \geq 0, j = 1, 2, \ldots, n \quad (2)$$
$$v_{iH} \geq 0, i = 1, 2, \ldots, m$$

The second model used was the DEA: BCC-O model, which differs from the previous one in assuming that returns to scale are non-constant. It defines the efficiency of unit H as

$$\Phi_H = \frac{\sum_{i=1}^{m} v_{iH} x_{iH} + q_H}{\sum_{j=1}^{n} u_{jH} y_{jH}} \rightarrow MIN \quad (3)$$

Subject to the following conditions

$$\frac{\sum_{i=1}^{m} v_{iH} x_{ik} + q_H}{\sum_{j=1}^{n} u_{jH} y_{jk}} \geq 1, k = 1,2,\ldots,p$$
$$u_{jH} \geq 0, j = 1, 2, \ldots, n \quad (4)$$
$$v_{iH} \geq 0, i = 1, 2, \ldots, m$$

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where: x_{iH} – i^{th} input variable; y_{jH} – j^{th} output variable for enterprise H.

Constants u_{jH}; v_{iH}, and q_H were the values obtained by solving the linear programming problem described by the equations, and were determined for each enterprise so that the resulting efficiency was the most favourable of all possible ones.

Due to the adjustment of the coefficients to the interval (0;1⟩, where the value 1 denotes the effective unit, all resulting efficiencies were inverted

$$\Phi'_H = \frac{1}{\Phi_H} \tag{5}$$

Methods for examining the impact of efficiency on performance. The dependence between efficiency and performance was investigated through Pearson's coefficient, i.e. the dependence between the results of DEA models: CCR-O, BCC-O on Farm Net Value Added. Whereby Farm Net Value Added (X) was representative of efficiency and the results of the models DEA Φ_H (Y) were the efficiency proxies for each country.

$$\rho_{x,y} = \frac{E\left[\left(X - E(X)\right)\left(Y - E(Y)\right)\right]}{\sigma_x \sigma_y} \tag{6}$$

where: ρ – Pearson correlation coefficient; $E(X)$ –mean value of the Farm Net Value Added estimated from the sample by arithmetic mean; $E(Y)$ – mean value of the efficiency Φ_H; σ_x, σ_y – standard deviation of the random variables X and Y.

RESULTS AND DISCUSSION

The analysis compares data for large farms in the Visegrad Four countries (Czechia, Hungary, Poland, and Slovakia) that fall into the category of economic size ≥ EUR 500 000 of standard output as defined by the EU FADN. The results are summarised in tables for reference. Table 1 presents the results from the statistical analysis of the DEA models (CCR-O and BCC-O) and the results of the Person correlation coefficients. Table 2 presents the essential characteristics of the firms, describing the differences and similarities across countries and the reasons for the different results.

Model DEA: CCR- O. The DEA: CCR-O model resulted in the most efficient use of inputs or combination of inputs to achieve output [measured by the average values (mean) over a given period]: Hungary (0.874501), followed by Czechia (0.833317), Poland (0.792645), and Slovakia (0.682016). Hungary has the highest mean value (mean) of 0.874501. The highest value (1) was reached in one year for Hungary, i.e. an efficiency frontier was created, and the other mean calculations for each country's years were related to this frontier.

Model DEA: BCC-O. The result of the DEA: BCC- O model was that the most efficient way to increase output with given inputs [measured by the average values (mean) over a given period] was Hungary (0.913216), followed by Czechia (0.888693), Poland (0.886943), and Slovakia (0.818328).

In the comparison of European countries, the lowest efficiency values were found in Slovenia and Poland in 2007–2011. Bulgaria, Czechia, and Latvia were among the relatively efficient countries, but they lost their efficiency during the evaluated period. On the other hand, Estonia and Finland improved their efficiency during the same period (Košičová 2015). Błażejczyk-Majka et al. (2012) report pure technical efficiency values of 0.56–0.93 and scale efficiency values of 0.68–0.95 for V4 countries (new EU members) based on DEA analysis of field crop farms, and pure technical efficiency values of 0.66–0.90 and scale efficiency values of 0.75–0.96 for long-term EU members (EU-15). Similarly, Náglová and Rudynskaya (2021) calculated technical efficiency for 'old' EU members at level 0.903 and 'new' EU members at 0.897. These calculated values for the V4 countries ('new' EU members) are comparable to our results. In the analysis of Błażejczyk-Majka et al. (2012), the V4 countries showed low capital values relative to labour, low land productivity, and labour productivity shortly after EU accession compared to the 'old' EU countries. The productivity and capital of mixed-production farms were higher in the EU-15 countries than in enterprises specialised in field crops. In the 'new' countries (V4), the labour force's productivity and provision of fixed and working capital to labour was higher in the field crop farms, but the land productivity was higher in the mixed farms. However, the analysis included enterprises of all economic sizes (minor, medium, large, and very large), whereas our analysis focuses only on enterprises with an output above EUR 500 000 of standard output.

Person correlation coefficients. The correlation dependence of efficiency was examined through Person's correlation coefficient. We examined the relationship between DEA: CCR-O and Farm Net Value Added scores. In the case of Hungary, a strong linear relationship was found (0.7382) which is statistically significant at the level $\alpha < 0.01$. The dependence was not statistically

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Table 1. DEA results: CCR-O, BCC-O, Person correlation coefficients

Statistics	Czechia	Hungary	Poland	Slovakia
DEA: CCR-O				
Mean	0.833170	0.874501	0.792645	0.682016
SD	0.134024	0.110244	0.089039	0.104775
Minimum	0.592789	0.695668	0.627498	0.473643
Maximum	0.978785	1.000000	0.976545	0.838551
DEA: BCC-O				
Mean	0.888693	0.913216	0.886943	0.818328
SD	0.114379	0.103632	0.105544	0.117508
Minimum	0.659297	0.703841	0.66851	0.585296
Maximum	1.000000	1.000000	1.000000	1.000000
Person correlation coefficients (DEA: CCR-O, BCC-O) and Farm Net Value Added				
CCR-O	0.2073	0.7382***	0.2978	0.3071
BCC-O	0.1852	0.6460***	0.0655	0.2909

*** statistical significance at $\alpha \leq 0.01$; DEA: CCR-O – Data Envelopment Analysis: constant returns to scale; DEA: BCC-O – Data Envelopment Analysis: variable returns to scale
Source: Own processing based on FADN (2021)

Table 2. Characteristics of crop production farms (average of 2005–2019 period)

Characteristics	Czechia	Hungary	Poland	Slovakia
Number of farms	524.0	572.0	542.0	316.0
Utilised area (ha)	1 207.7	1 348.4	1 081.9	1 549.5
Ration of arable soil (%)	95.0	97.2	95.9	90.7
Livestock units (LU)	122.3	39.5	63.7	160.6
Labour input (*AWU*)	27.5	23.6	20.8	34.9
Labour input (*AWU*/100 ha)	2.3	1.8	1.9	2.2
Work costs (EUR)	**418 229.0**	**317 294.0**	**311 134.0**	**466 112.0**
Total crop output (EUR/ha)	1 056.3	862.6	1074.9	795.1
Total livestock output (EUR/ha)	101.4	26.3	58.5	86.3
Other output (EUR/ha)	145.4	241.4	34.1	132.6
Total output (EUR/ha)	**1 303.1**	**1 130.3**	**1 167.5**	**1 014.0**
Farm Net Value Added (EUR)	**597 762.0**	**645 314.0**	**438 363.0**	**462 154.0**
Farm Net Value Added per *AWU* (EUR/ha)	**23 392.0**	**27 903.0**	**22 016.0**	**14 930.0**

Bold – most important characteristics; *AWU* – annual work units
Source: FADN (2021)

evident for the other countries (Slovakia: 0.3071, Poland: 0.2978, Czechia: 0.2073). Similar results were found when examining the correlation between DEA: BCC-O and Farm Net Value. A robust linear dependence was found for Hungary (0.646) at statistical significance at $\alpha \leq 0.01$, while for the other countries, the dependence was not statistically conclusive (Slovakia: 0.2909, Czechia: 0.1852, and Poland: 0.0655). Thus, we can reject hypothesis H_1, which states that efficiency affects the performance of farms with an economic size above EUR 500 000 of standard output for the V4 countries.

For the states examined, it was found that the efficiency measured by DEA: CCR-O and DEA: BCC-O ranked the states in the same order relative to each other. This can be interpreted as Hungary, Czechia, Poland, and Slovakia being the best performers in com-

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petitive efficiency, irrespective of whether the efficiency was based on constant returns to scale (CCR model) or variable returns to scale (BCC model). In both cases, Hungary tended to achieve higher efficiencies than other countries. Based on the results obtained, in terms of competition between countries measured by DEA efficiency, it can be concluded that Hungary was the leader in efficiency (for both DEA models). Based on this result and the results of the DEA method, we can confirm hypothesis H_2, i.e. that the country with the highest efficiency is also the country with the highest performance.

The characteristics of the farms of the compared countries are shown in Table 2. The characteristics of the economic indicators (outputs) were converted per unit of agricultural land (ha) for better comparability; the indicator Farm Net Value Added was converted to annual work unit (*AWU* = full-time person equivalent, 2 000 hours).

Due to the uniqueness of this research, it was challenging to compare our results with those of other authors. The analysis showed that Hungary's higher efficiency compared to the other countries evaluated resulted from several factors. Hungary showed the lowest value regarding the number of workers per unit area (measured by the number of *AWU* per 100 ha). At the same time, Hungary had the lowest wage costs of all the countries analysed (Table 2). This created a cost advantage over other countries. The worse efficiency results of high labour costs are confirmed by Błażejczyk-Majka et al. (2012).

On the other hand, in our analysis in terms of production, Hungary showed a lower value of crop output but a high value of other output, which represents output from other profitable activities on the farm. The dominant part in Hungary is probably mainly crop processing, which has a higher value-added and a higher valuation of production compared to net output from crop cultivation. In addition to crop processing, other output generally included income from agro-tourism, livestock product processing, land and machinery renting, services to other entities, and other financial income. Better efficiency of farms with diversified production or other gainful production was described by Forleo et al. (2021) or Náglová and Rudinskaya (2021). According to Błażejczyk-Majka et al. (2012), field crop farms from countries that have been long-term members of the EU had lower cultivated land area and higher efficiency values than the V4 countries. Poland showed the lowest cultivated land area of the countries we compared, but the total output was comparable to the other countries. On the other hand, the highest area under cultivation was farmed in Slovakia, characterised by the lowest crop output, total output, and efficiency value. The value of labour input (*AWU*) was the highest in this country. Also, Kočišová (2015) reported higher utilised agricultural area and total labour as inefficiency factors, while crop output positively impacted efficiency. Čechura et al. (2022) reported lower technical efficiency values for smaller farms (in Czechia and Hungary), regardless of the type of farming (filed crops, milk production, cattle breeding). Generally, permanent improvers (innovations) can enhance farm productivity more than occasional actions dominantly due to lower labour need, lower inputs, lower land endowments, or herd size (Antón and Sauer 2021; Forleo et al. 2021; Von Hobe et al. 2021; Batzios et al. 2023). Participation in collective producer's organisation can improve farm competitiveness and efficiency, as well (Bartova and Fandel 2020; Batzios et al. 2023). Dong (2023) described faster technical progress and technical efficiency in agricultural corporations than in family farms. The results of the relationship between efficiency (DEA models CCR-O and BCC-O) and performance measured by Farm Net Value Added showed a statistically significant effect only for Hungary. For the other countries, Czechia, Poland, and Slovakia, this linear dependence needed to be demonstrated by to low values of Pearson's coefficient. Although the analysed countries showed comparable total output, the low *AWU* value again makes the resulting Farm Net Value Added for Hungary conclusively higher than that of the other countries (Table 2). The number of working units related to employee costs naturally influences the Farm Net Value Added.

CONCLUSION

Our research focused on efficiency and its impact on the profitability of large farms in the V4 countries. A significant contribution was the comparison of farms specialised in field crop production with the same economic size (above EUR 500 000 of standard output) in countries with similar historical development and comparable climatic conditions. It ensured maximum comparability of the data analysed. The analysis showed that efficiency did not affect farm performance in the compared V4 countries. The exception was Hungary, which showed relatively low values of labour input and crop output but high values of other output, which were probably the result of a high share of processing of crop products. Thus, the study's main conclusion is that efficiency cannot be considered

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a universal factor in predicting performance. It was further confirmed that the country with the highest efficiency was also the country with the highest output.

Based on our results and the findings of other researchers, farm effectivity could be improved by regular technology innovations, improvement of the knowledge of farm managers and the use of new technologies in production, participation in producer's organisation, decrease of inputs (e.g. due to better technology or lower labour need), diversification of production or other gainful production (such as processing, agri-tourism or services to other farms), and others.

Given the findings, the authors recommend that further research be directed towards analysing efficiency decomposition using the Malmquist performance index, possibly incorporating different/other inputs than those used in our analysis. Also, further follow-up research should be guided by the competitiveness issue to determine whether, in international comparisons, only farms with some competitive advantage, which may be based on aspects other than the efficiency of the factors we examined, translate efficiency into performance.

The results of our analysis and other follow-up research may provide valuable input (implication) for setting subsidies in national and European policies to support farm competitiveness.

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