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Application of the DEA on the measurement of efficiency in the EU countries

Kristína KOČIŠOVÁ

Department of Banking and Investment, Faculty of Economics, Technical University of Košice, Košice, Slovak Republic

Abstract: The purpose of the paper is to investigate the relative technical efficiency of the agricultural sector in the European Union (EU) using the Data Envelopment Analysis (DEA) during the period 2007–2011. The authors investigated efficiency using both the input and output-oriented models with the assumption of a variable return to scale. They looked for causes of inefficiency and made recommendations for inefficient agricultural sectors. The results show that, in average, the EU agricultural sectors performed efficiently, as evidenced by the relatively high value of the average input and output efficiency. The efficiency of the EU agricultural sectors had changed over the past few years, and in both models the efficiency has generally decreased over time. As the main source of inefficiency was labelled the input "total utilised agricultural area" and as the strength with a positive impact on efficiency, there was labelled the "crop output." By calculating the optimal values for the input and output variables for inefficient agricultural sectors, it has been found that for the efficient production of a given quantity of outputs, it was necessary to reduce the value of the input "total labour" in average by 6.18%, the "total utilised agricultural area" in average by 14.45% and the "total assets" in average by 5.93%. In case of the output-oriented model for efficient use of a given quantity of inputs, the agricultural sectors should produce up to 111.85% of their crop output and 113.41% of their animal output.

Key words: agricultural sectors in the European Union, agriculture, Data Envelopment Analysis, technical efficiency DEA, technical efficiency

Agriculture has been playing and will continue to play a vital role for humanity, because the human welfare depends on the amount and stability of agricultural production, as determined by crop yield and cultivated area (Garibaldi et al. 2011). The agricultural sector is one of the economic sectors that still have the European Union policymakers' attention. The European Union (EU) agricultural sector is continually undergoing structural changes, which have significantly impacted the efficiency and productivity growth not only in the agricultural sector, but also in the economy as a whole.

In the today's highly competitive environment, efficiency is one of the most frequently applied terms to help identify the strengths and weaknesses of the evaluated units. The evaluated units can be firms, national economic sectors, or the entire economies of the evaluated countries. This study is trying to analyse efficiency, which assumes that the evaluated units are doing things right, as determined by the relationship between the consumed inputs and the produced outputs. However, this evaluation should be accomplished through a more detailed analysis. The Data Envelopment Analysis, or the DEA, is one of the available tools that have become very popular in many sectors for assessing efficiency. The advantage of the DEA is its ability to handle multiple inputs and outputs.

This study aims to address the following objectives: to define the concept of efficiency, to analyse the efficiency in the agriculture of the EU countries during the years 2007–2011, and to make recommendations for increasing the efficiency of the inefficient EU agricultural sectors. Along with these objectives, this paper seeks to address the following research questions:

(1) Is the agricultural sector of the EU performing efficiently?

(2) Has the efficiency of the EU agricultural sector changed over the last several years?

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(3) What are the main sources of inefficiency, and is there a way to improve efficiency of the agricultural sector in the EU?

The answers to these questions may be beneficial to three main constituencies. The knowledge of the level of efficiency is important to agricultural firm managers, since it reflects the quality of daily operations in utilising inputs and outputs, and other decisions can be based on this knowledge. Policymakers are the second group that may benefit from this information, because they can use it to compare the agricultural sector's performance before and after any regulatory changes took place, and consequently they can evaluate if the changes were beneficial to the agricultural sector or not. Finally, researchers can also benefit from a paper analysing the efficiency of the agricultural sector. They can use the previous studies in this area to observe a gradual development in the measuring techniques of efficiency, which may enable them to identify gaps in the research.

LITERATURE REVIEW

In the modern society, a number of approaches exist for defining efficiency. Our definition is based on a study by Farrell (1957), who proposed that a firm's efficiency has two components: technical efficiency and allocative efficiency. Technical efficiency reflects the ability of the firm to obtain the maximal output from the given set of inputs. Allocative efficiency reflects the firm's ability to use the inputs in optimal proportions, given their prices and production technology. These two types of efficiency are then combined into the overall economic efficiency, which can be examined from the perspective of an input or an output-based model. We can also talk about the overall cost efficiency (input perspective) or the overall revenue efficiency (output perspective). The Farrell's paper led to the development of many approaches for measuring the input and output efficiency. The most important ones were the Stochastic Frontier Approach (SFA), created by Aigner et al. (1977), and the Data Envelopment Analysis (DEA) developed by Charnes et al. (1978).

Methods for the efficiency measurement can be divided into a number of groups. The earliest techniques, which used to measure efficiency through the ratio analysis, examined the financial statements of the evaluated units and compared them with a benchmark. Parametric methods, which include the Stochastic Frontier Approach (SFA), the Thick Frontier Approach (TFA) and the Distribution Free Approach (DFA), are used to measure economic efficiency. Non-parametric methods, which include Data Envelopment Analysis (DEA) and the Free Disposal Hull (FDH), are used to measure technical efficiency. The fourth group addresses the multi-criteria decision problems, which are described by a set of alternatives, a set of evaluation criteria, and by the links between the criteria and alternatives. A decision maker enters the basic information about criteria and alternatives to formulate a multi-criteria model. This model has the option to enter the additional information the investigator may have failed to state explicitly, which would not have been included in the basic model. The next group, the Balanced Scorecard (BSC), was described in a paper by Gavurová (2011) as a system, which reacts to the criticized explanatory ability of the value criteria for measuring the performance of an enterprise. What distinguishes the Balanced Scorecard system is that it extends and links the performance measurements of purely financial indicators to indicators from other perspectives of the enterprise's activity. The correct construction of measurements for a company's strategy is to tip its strategic priorities, and by the means of a causal-subsequent connection, it is possible to tip the way for the strategy realization. Gavurová (2012) and Šoltés and Gavurová (2013) showed that besides many positive responses to the implemented BSC systems and their contributions to effective measurements and performance control in companies, negative experiences were also observed, citing an insufficient contribution of the BSC, the dissatisfaction with the system, and the failure. This suggested that the BSC system was not functional without some modifications, therefore the authors tried to identify the problematic areas of the BSC system implementation and to propose possible solutions for overcoming these problems using the MICMAC method (Matrice d'Impacts Croises Multiplication. Appliquee a un Classement, in English the Cross-Impact Matrix).

The purpose of this paper is to investigate the relative technical efficiency of the agricultural sector in the European Union countries using the Data Envelopment Analysis (DEA). Table 1 presents a review of literature dealing with the use of the DEA in the evaluation of efficiency in the agricultural sector. Each author used different input and output variables to study the agricultural sector and the state

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Table 1. Literature review

Author (Year)	Country	Input and output variables	Results
Mathijs and Vranken (2000)	Bulgaria and Hungary	Inputs: total cultivated area; annual working units; capital Outputs: value of physical production	Based on the survey data of Bulgarian and Hungarian crop and dairy farms in 1998, a double-peaked distribution of technical efficiency was observed. Majority of farms reached an efficiency level between 30–60%. The average technical efficiencies confirmed the idea that cooperatives were in average less efficient than companies, while the business companies performed worse than family farms. Family farms reached average 58% efficiency, business companies reached 50%, and cooperatives reached 44%.
Dios-Palomares and Martínez-Paz (2011)	Andalusia	Inputs: skilled labour; unskilled labour; olives milled; floating capital; fixed capital Outputs: olive oil production; quality index; environmental index	This paper studied the level of technical efficiency in the olive oil industry from a multi-output perspective, and examined olive oil production in quantitative and qualitative terms. They examined the olive oil industry, because production of olive oil in Andalusia (Spain) is the most important agricultural food industry in the whole region, and it represents 30% of the world's olive oil production. The results showed a medium-high level of the relative technical efficiency, and highlighted the importance of efficiency factors involving production and marketing associations.
Khai and Yabe (2011)	Vietnam	Inputs: seed expenditures, pesticide costs, fertilizer quantity, machinery services, hired labour, small tools and energy, other rice expenditures, family labour for rice, rice land area Outputs: rice output	This study measured the technical efficiency of rice farmers in Vietnam. The calculated technical efficiency was around 81.6%. The study demonstrated that the most important factors having a positive impact on technical efficiency were intensive labour in rice cultivation, irrigation, and education. These played an important role in terms of the TE score change, while agricultural policies did not help farmers to cultivate rice more efficiently.
Akande (2012)	EU-15	Inputs: labour, utilized agricultural area, buildings, machinery, cost of materials, livestock Outputs: crop output, animal output	An average technical efficiency of 87% was observed for the EU-15 region as a whole. By breaking the EU-15 into four regional groups, the West European Region was more efficient with the highest average technical efficiency of 95%, while the Central European Region shared the same technical efficiency level of 85% with the Southern European Region. Meanwhile, the Northern European region was the least technically efficient (84%).
Hengzhou and Tong (2013)	China	Inputs: area of farmland measured in hectares, total power of agricultural machinery measured in kilowatts, number of workers Outputs: agricultural income of households measured in RMB Yuan	The results indicated that the average value of the comprehensive efficiency of the farmland used for all investigated households is 0.758, that is, the practical output occupied 75.8% of the ideal output, in other words, the space for efficiency improvement is 0.242.
Zamanian et al. (2013)	MENA countries	Inputs: land, tractor, labour, livestock, fertilizer Outputs: feed, seed	The purpose of this paper was to investigate the levels of technical efficiency in the agricultural sector of the MENA countries by using the DEA and SFA approaches in 2007–2008. The results showed that the total highest average technical efficiency was reached using the BCC model, then using the CCR model and the lowest efficiency was reached using the SFA model. The best performance in both models was related to Qatar. Furthermore, the empirical results indicate that both the parametric and non-parametric methods provided the same rank for countries. However, in all cases the SFA results were lower than those found by using the DEA, which suggests high levels of random error in the data.

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Author (Year)	Country	Input and output variables	Results
Arita and Leung (2014)	Hawaii	Inputs: labour, land, machinery, other expenses Outputs: total sales generated from production	Using data from the US Census of Agriculture, they examined technical efficiency of the population of the Hawaii aqua farms across different types of farms over time. The results showed that only 12% of the farms in 2007 may be classified as efficient, with a steady decline in efficiency over time.
Bojnec et al. (2014)	10 New EU Member States* (BG, CZ, EE, HU, LV, LT, PL, RO, SK, SI)	Inputs: total labour force, number of agricultural tractors, agricultural area, total fertilizers use, number of animal livestock units Output: gross value added	This paper studied the level of technical efficiency in 10 New EU Member States during the period 2001–2006. The results vary over time and between the analysed countries. All countries had the scores of efficiency below 1, implying opportunities for the better use of agricultural resources. In average, Bulgaria and Slovakia achieved the highest scores during the whole period. Between the 2002 and 2006, Hungary has made the greatest catch-up in its DEA efficiency. The Baltic States and Poland have experienced the lowest scores in agriculture.
Špička (2014)	101 EU regions	Inputs: utilized agricultural area, Labour input, Economics size, Livestock units, Stocking intensity Outputs: Crop output, Livestock output	The analysis reveals 56 efficient and 45 inefficient regions in 2011. There are generally larger farms in the efficient regions in average. In the Czech Republic and Slovakia, the mixed type of farming, and three regions in Hungary was technical efficient. All four regions in Poland are inefficient with the increasing return to scale. The decreasing return to scale was typical for the regions with largest farm such as the regions in the former East Germany. The efficient regions had a higher land, labour, energy, capital productivity and productivity of contract work that the inefficient regions.

*BG – Bulgaria, CZ – Czech Republic, EE – Estonia, HU – Hungary, LV – Latvia, LT – Lithuania, PL – Poland, RO – Romania, SK – Slovakia, SI – Slovenia

of the economy in the evaluated country, based on the method he/she selected.

The Data Envelopment Analysis (DEA) is a non-parametric approach for the frontier estimation. Basic models are discussed in the works of many authors, and they are applied in many areas. In the Slovak and Czech Republic, the DEA models have been used to measure the efficiency of financial institutions, for example in the work of Stavárek (2006), Jablonský and Grmanová (2009); Stavárek and Řepková (2012). The DEA was also used to measure efficiency in other areas. For example, Dlouhý et al. (2007) used the DEA to measure the efficiency of hospitals. They analysed 22 Czech acute-care hospitals using a constant return to scale and a variable return to the scale model. Also Koróny and Gavurová (2013) used the DEA analysis as an indicator in eight Slovak regions with the one-day healthcare during 2009–2011. Separately, they evaluated the efficiency from the viewpoint of the patients who were under age and from the viewpoint of the patients over 18. The DEA models can also be used to measure the efficiency in education. Lima (2013) employed the DEA to describe the evidence of the functioning and the dynamics of labour markets, and to evaluate the efficiency in the use of knowledge as a strategy for increasing growth in the PIGS economies. Jeck and Sudzina (2009) applied the DEA models directly to evaluating the relative efficiency of the departments of Slovak universities. Another area of application is evaluating the efficiency of public transportation. Kráľ and Roháčová (2013) used an input oriented slack-based model under the variable return to scale to measure the efficiency of transport companies in the Slovak Republic. Finally, there are many other areas where it is possible to apply the DEA method.

After reviewing the studies dealing with the application of the DEA for measuring efficiency in the Slovakia and Czech Republic, we have concluded that there is a lack of such studies in agriculture. The question of the scale efficiency was examined in the work of Bielik and Rajčániová (2004). They examined the relationship between the farm size and the efficient land use as a basic production factor. Their research has been done on a selected sample of agricultural enterprises in the Slovak Republic. The DEA approach allowed them to investigate the difference in efficiency of 110 agricultural enterprises

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of varying sizes. The research has proved that about 10% of the analysed farms were operating at the optimal scale, 77% at the above optimal scale, and 13% could increase their efficiency by increasing their agricultural land area.

Bielik et al. (2010) performed an analysis of the return to scale on the basic industry enterprises in Slovakia. During the whole analysed period (1999–2007), there was estimated the most numerous group of companies which occurred in the area of decreasing returns to scale. This confirmed that the total input exploitation in agricultural companies was not profitable, because in comparison with the production inputs, lower profits were reached. On the basis of these results, it was not possible to estimate which inputs were indispensable for the optimal performance (for a more specific estimation, it is necessary to apply the non-radial DEA methods), despite the fact that the low measure of input profitability was confirmed.

Bielik and Hupková (2011) measured the technical efficiency of agricultural basic industry subjects in the Slovak Republic during the period 1999–2007, and they identified a developing trend. They found that since 2001, when the technical efficiency reached its highest level, there was a marked decline in the technical efficiency. Based on their results of the technical efficiency measurements, they expected to see a widening gap between the companies in the future.

The question of the technical efficiency was also examined in the work of Čechura (2010). According to Čechura (2010), the technical inefficiency is a significant phenomenon in the Czech agriculture. The average level of the technical efficiency is around 90% for Czech agricultural companies.

Jánová et al. (2012) discussed the possibility of applying the DEA in the bankruptcy prediction models in the field of agribusiness. They collected their primary data set on the Czech agriculture firms' financial performance, then they applied a DEA based model, and they evaluated the obtained results and discussed the predictive power of these approaches in the agriculture industry.

METHODOLOGY

This study is trying to analyse efficiency, meaning that the evaluated units (DMU) are doing things right, and it examines this mainly by looking at the relationship between the inputs used and the outputs produced. However, such evaluation requires a more thorough analysis. The Data Envelopment Analysis, or the DEA, is one of the available tools, which have become very popular in many sectors for assessing efficiency, and it has the advantage of being able to handle multiple inputs and outputs.

The basic DEA model developed by Charnes et al. (1978) was based on the assumption of the constant return to scale. This basic model has been modified by Banker et al. (1984) to be based on a variable return to scale. Both these DEA models have been created in both forms – the input and output-oriented.

In this study, the units of analysis are agricultural sectors. Consider n agricultural sectors (DMU_j, $j = 1, 2, \ldots, n$), each consuming m different inputs (x_{ij}, $i = 1, 2, \ldots, m$) to produce s different outputs (y_{rj}, $r = 1, 2, \ldots, s$). The matrix of inputs is marked as follows $X = \{x_{ij}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n\}$ and the matrix of outputs $Y = \{y_{rj}, r = 1, 2, \ldots ,s; j = 1, 2, \ldots, n\}$. Since the used inputs and the produced outputs have different levels of significance for each agricultural sector, they have different weights. The advantage of a DEA model is that the weights of the utilized inputs and the produced outputs are the result of solving an optimization of a linear programming problem, and they are not based on a subjective perception. The optimal weights are obtained by solving the following mathematical programming problem:

$$\text{Max} \ \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \leq 1 \qquad (1)$$

$$\text{Subject to} \ \sum_{r=1}^{s} u_r y_j \Big/ \sum_{i=1}^{m} v_i x_j \leq 1 \quad j = 1, 2, \ldots, n$$

$u_r \geq 0 \ \ r = 1, 2, \ldots, s$

$v_i \geq 0 \ \ i = 1, 2, \ldots, m$

Where:

u_r = the optimized weight of r^{th} output ($r = 1, 2, \ldots, s$)

v_i = the optimized weight of i^{th} input ($i = 1, 2, \ldots, m$)

y_{rq} = the produced amounts of r^{th} output ($r = 1, 2, \ldots,s$) for DMU_q

x_{iq} = the consumed amounts of i^{th} input ($i = 1, 2, \ldots, m$) for DMU_q

y_{rj} = the produced amounts of r^{th} output ($r = 1, 2, \ldots, s$) for DMU_j ($j = 1, 2, \ldots, n$)

x_{ij} = the consumed amounts of i^{th} input ($i = 1, 2, \ldots, m$) for DMU_j ($j = 1, 2, \ldots, n$)

This functional linear program can be transformed into an ordinary linear program, which can be expressed as a dual problem. The resultant linear programming problem assumes a constant return to

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scale, and it is known as the CCR (Charnes, Cooper and Rhodes) model. The assumption of the constant return to scale can be accepted only if the DMUs operate under the condition of their optimal size. Imperfect competition, financial constraints, control steps, and other factors can cause the DMUs not to operate at their optimal size. A DEA model that allows calculations with a variable return to scale has been developed to overcome this problem. This model is called the BCC model (Banker, Charnes, Cooper). The DEA models (CCR model or BCC model) can be based on inputs or outputs. The input-oriented models make recommendations regarding how the inefficient units can achieve efficiency in the form of reductions on the input side. The output-oriented models require an increase on the output side to achieve efficiency. The efficiency of a particular DMU_q can be obtained by solving the linear programming programs. The input-oriented model with slack variables, which assumes a variable return to scale (BCC model), can be defined as follows (Coelli et al. 2005):

$$\text{Min} \quad \theta_q - \varepsilon\left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right] \tag{2}$$

$$\text{Subject to} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_q x_{iq}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = y_{rq}$$

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

$$\lambda_j;\ s_i^-;\ s_r^+ \geq 0$$

Where:

θ_q = the efficiency of DMU_q, ε is the non-Archimedean constant (10^{-6}or 10^{-8})

s_r^+, s_i^- = the input or output slacks

λ_j = the weight assigned to the DMU_j (j = 1, 2, ..., n)

Performing a DEA analysis requires solving n linear programming problems in the above form, one for each DMU. The DMU_q is termed fully efficient if and only if the optimal value $\theta_q = 1$ and all the slack variables are equal to zero. If $\theta_q = 1$ but the slack variables are not equal to zero, we can talk about the "pseudo-efficiency". If the slack variables are equal to zero but $\theta_q < 1$, then the value θ_q signals the inefficiency. This inefficiency can be eliminated by a proportional (radial) reduction in all inputs of the DMU_q by $(1 - \theta_q)$ 100%, and thus a shift on the efficiency frontier can be achieved. If the slack variables aren't equal to zero and $\theta_q < 1$, the non-radial shift expressed by slack variables is necessary to achieve efficiency.

DATA DESCRIPTION

This section gives the description of the data used for the measurement of the technical efficiency. The dataset used for this paper was obtained from the database published annually by the Farm Accountancy Data Network (FADN). The FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy. It consists of an annual survey carried out by the Member States of the European Union.

The summary and definitions of both input and output variables are described below. In our analysis, three input variables and two output variables were used. Three main sources were used as the input variables: labour, land and capital. Two main outputs in the agricultural sector were used as the output variables: crop output and animal output. We report the descriptive statistics for these variables in Table 2.

The first input, labour, was measured by the "Total Labour Input" expressed in the Annual Work Units (full-time worker equivalent). The second input, land, was measured by the "Total Utilized Agricultural Area" expressed in hectares (Ha). The last input variable, capital, was measured by the "Total Assets," which are in the ownership of agricultural holdings expressed in EURO. The total assets were calculated as the sum of the fixed assets and current assets, while the fixed assets were defined as the sum of farm buildings, forest capital, buildings, machinery and equipment, and breeding livestock, all expressed in EURO. The current assets were defined as the sum of non-breeding livestock plus the turn-over capital, expressed in EURO. The first output was measured by the "Total Output Crops and Crop Production" (sales plus the intermediate consumption and own consumption), expressed in EURO. The second output variable was measured by the "Total Output Livestock and Livestock Products" (livestock production, plus change in the livestock value, and animal products), expressed in EURO.

EMPIRICAL ANALYSIS AND RESULTS

The aim of the study was to investigate and compare the relative technical efficiency of agricultural

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Table 2. Descriptive statistics on variables used for the efficiency measurement

		Total labour input	Total utilised agricultural area	Total assets	Total output crops & crop production	Total output livestock & livestock products
2007	Average	2.6133	74.7563	518 817.4444	57 394.1852	54 030.3704
	Min	1.14	3.12	27 378	4 633	6 024
	Max	18.05	584.02	2 013 572	296 529	176 227
	St. dev.	3.2339	111.0154	520 712.9010	63 949.8444	52 204.5495
2008	Average	2.5737	75.0589	533 808.0000	57 031.7407	58 326.3333
	Min	1.13	3.01	36 231	5 625	4 428
	Max	18.06	585.34	2 644 430	304 957	207 617
	St. dev.	3.2214	111.2275	579 687.0766	64 859.8393	57 274.2528
2009	Average	2.4156	74.9174	545 046.5185	48 069.8519	50 819.4815
	Min	1.12	3.31	34 130	5 591	4 640
	Max	14.25	513.19	2 726 002	174 284	195 107
	St. dev.	2.5369	99.6441	612 817.5824	47 258.3283	50 376.3367
2010	Average	2.3352	74.4430	570 101.3704	56 706.5185	55 591.9259
	Min	1.11	2.73	35 519	7 053	5 825
	Max	13.3	508.77	2 607 737	213 231	224 420
	St. dev.	2.3687	98.5306	625 356.9173	57 557.8792	57 069.4312
2011	Average	2.3741	76.4022	590 742.4444	66 747.1481	63 772.7407
	Min	1.12	2.63	39 293	7 667	6 008
	Max	14.67	552.91	2 543 294	367 810	267 060
	St. dev.	2.6046	106.0666	624 607.2381	77 981.6387	66 478.6373

Source: Author's calculations

production in 27 European Union countries during the years 2007–2011, and to propose recommendations in order to increase the efficiency of the inefficient EU agricultural sectors. The term "relative" efficiency refers to the achieved efficiency of evaluated agricultural sectors within the group and given the criteria used (input and output variables). The term "technical efficiency" reflects the ability of an agricultural sector to obtain the maximal output from the given set of inputs. In addition to the "technical efficiency", we can encounter the term "overall economic efficiency" in the literature. This type of efficiency can be estimated when the price data are available. Then we can talk about the overall cost efficiency (input perspective) or the overall revenue efficiency (output perspective).

In our study, we analysed the relative technical efficiency of agricultural sectors through the basic DEA models using the criteria described in the previous section. The analysed EU_member states included: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

To analyse efficiency, we used both the input and output-oriented models with the assumption of a variable return to scale (BCC model), which overcame the need for the perfect competition, since we are aware that the presence of the imperfect competition, financial constraints, control steps, and other factors can cause the agricultural sectors not to operate at their optimal size. The efficiency scores in this study were estimated using the computer program "EMS" provided by Scheel (2000). The average technical efficiency calculated using the input and output-oriented BCC model for all of

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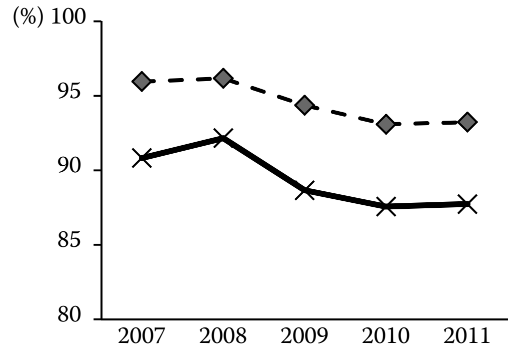

	2007	2008	2009	2010	2011
BCC_IN	95.96%	96.17%	94.37%	93.08%	93.23%
BCC_OUT	90.82%	92.16%	88.66%	87.56%	87.73%

Figure 1. Average technical efficiency in the EU countries

Source: Author's calculations

the periods under consideration (2007 to 2011) is presented in Figure 1.

We pooled the cross-country data and used them to define the common best practice efficiency frontier for each year. Figure 1 shows the results for the average input and output efficiencies obtained relative to the whole sample during the analysed period. Both models show that the efficiency of agricultural sectors has generally decreased over time. The average input efficiency at the beginning of the analysed period was 95.96%, indicating that the agricultural sectors had to improve their efficiency in average by 4.04%. This efficiency slightly rose to 96.17% in 2008, indicating a decreasing room for the efficiency improvement (3.83%). Since 2008, the average input efficiency decreased to reach its minimum in 2010. In that year, the average efficiency for all agricultural sectors was 93.08% (the room for the efficiency improvement was at its peak, 6.92%). In the last year, the average input efficiency increased slightly to 93.23%. The average output efficiency was considerably lower than it was in the input-oriented model. In the case of the output efficiency, we can observe the same trend. It is possible to detect an improvement in the average output efficiency between 2007 and 2008. The highest output efficiency was reached in 2008 (92.16%). From this year onward, the average efficiency decreased, reaching its minimum in 2010 (87.56%). In the last year of the analysed period, the average output efficiency increased slightly to 87.73%. The next table shows that the highest efficiency was obtained in 2008, which means that during that year the agricultural sectors were most efficient in their management of inputs and outputs. Since then, the average efficiency decreased. A greater variability was observed in the output efficiency. The output efficiency fluctuated from the 43.91% (2008) to 100%, as compared to the fluctuations from 72.06% (2010) to 100% for the input efficiency, while the variability in the output-oriented model was the highest in 2009 (the standard deviation of 0.1526) and the lowest in 2008 (the standard deviation of 0.1377).

The level of the relative technical efficiency was calculated separately for each country. The results from the input and output-oriented BCC models for the analysed European Union countries are presented in Table 3.

Table 3 shows that 13 agricultural sectors were marked as relatively technically efficient in both models during the whole analysed period (Belgium, Denmark, Greece, France, Hungary, Ireland, Italy, Malta, the Netherlands, Romania, Finland, Sweden, and Slovakia). "Relatively" means that these agricultural sectors were efficient within the analysed group of countries, taking into account the specified input and output variables. If other variables were used for the analysis, or if we changed the number of the analysed countries, the results of the efficiency measurements could be quite different.

In the analysed sample, we can also find countries, which were marked as relatively efficient at the beginning, but during the analysed period, they lost their efficiency and became inefficient. The agricultural sectors in Bulgaria, the Czech Republic, and Latvia belong to this group. On the other hand, the agricultural sectors in Estonia and Finland moved from the inefficient group to the efficiency margin.

The lowest efficiency was reached mainly in by the agricultural sectors in Slovenia and Poland. The agricultural sector in Slovenia reached its minimum values in both models for 2007, 2008 and 2010; and in the output-oriented model also for 2011. The Polish agricultural sector reached its minimum in both models for 2009; and in the input-oriented model also for 2011.

The Spainish agricultural sector was markedly more efficient in its use of inputs than in its production of outputs. This can be seen from the values for the input and output efficiency, which show that the Spanish agricultural sector reached a higher level of the input efficiency. The same situation, namely the higher input efficiency, can be observed in other inefficient agricultural sectors like those of Cyprus, Germany, Lithuania, Luxembourg, Austria, Poland, Portugal, Slovenia, and the United Kingdom. The

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opposite trend, i.e. a higher output efficiency, can be seen in the Czech agricultural sector. This was the only agricultural sector, which was more efficient at producing its outputs than at using its inputs.

One of the important advantages of the DEA analysis is its ability to identify the potential areas of improvement for the inefficient agricultural sectors. The input-oriented model gives recommendations for the inefficient agricultural sectors to achieve efficiency in the form of reductions on the input side. The output-oriented model requires increases on the output side for achieving efficiency.

Over the whole analysed sample, we found that to improve the input efficiency, it was necessary to reduce the value of the "Total Labour" in average by 6.18%, the "Total Utilised Agricultural Area" in average by 14.45%, and the "Total Assets" in average by 5.93%. This means that to achieve an efficient production of the given quantity of outputs, the agricultural sectors should use only 93.82% of their

Table 3. Input (IN) and output (OUT) technical efficiency in the EU countries (%)

Country	2007		2008		2009		2010		2011	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Belgium	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bulgaria	100.00	100.00	100.00	100.00	100.00	100.00	88.03	87.18	93.55	92.72
Cyprus	97.84	86.31	100.00	100.00	96.26	82.89	92.45	69.96	88.50	69.37
Czech Republic	100.00	100.00	97.16	97.70	95.21	96.95	92.02	94.97	89.05	91.32
Denmark	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Germany	84.14	80.14	88.06	82.10	86.79	80.23	87.57	81.02	89.14	84.97
Greece	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Spain	90.97	74.10	89.74	71.55	88.84	61.79	93.85	74.02	88.01	63.73
Estonia	99.83	99.84	95.23	93.76	87.57	86.28	93.58	93.45	100.00	100.00
France	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hungary	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ireland	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Italy	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Lithuania	94.78	87.12	93.95	88.27	86.11	76.74	79.25	76.09	83.53	79.00
Luxembourg	97.02	92.97	100.00	100.00	95.20	91.56	89.44	80.20	89.64	81.92
Latvia	100.00	100.00	100.00	100.00	92.50	90.91	88.18	87.75	87.41	86.56
Malta	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Netherlands	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Austria	87.47	54.87	88.03	63.75	89.30	65.16	91.39	66.62	85.67	57.92
Poland	94.09	86.09	89.98	80.26	77.48	51.98	75.48	53.99	74.99	61.28
Portugal	93.43	79.42	96.13	89.58	89.63	79.08	84.44	70.11	84.77	65.72
Romania	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Finland	98.51	93.25	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sweden	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Slovakia	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Slovenia	74.04	45.23	73.70	43.91	78.22	52.18	72.06	50.18	82.07	57.52
United Kingdom	78.70	72.91	84.72	77.39	84.81	78.07	85.51	78.71	80.98	76.74

Source: Author's calculations

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labour, 85.55% of their utilised agricultural area, and 94.07% of their total assets. The highest reduction rate was required in 2010, when the input efficiency was at its lowest.

In case of the output-oriented BCC model, it was necessary to increase outputs to become efficient using the given inputs. In the whole analysed sample, we found, that for the improvement of the output efficiency it was necessary to increase the "Crop Output" in average by 11.85% and the "Animal Output" in average by 13.41%. This suggests that for the efficient use of a given quantity of inputs, the agricultural sectors should produce up to 111.85% of their crop output and 113.41% of their animal output.

Another advantage of the DEA analysis is its ability to identify the strengths and weaknesses within a set of inputs and outputs through the values of their optimal weights. Lower weights signal the factors, which had a negative impact on efficiency. On the other hand, higher weights signal factors with a positive impact on efficiency. When we looked at optimal weights obtained by solving the linear programming problems, we found that during the whole analysed period, the "Total Utilised Agricultural Area" was the weakest factor on the input side. The "Crop Output" was the strongest factor with a positive impact on efficiency. The reason we used the analysis through optimal weights for the identification of strengths and weaknesses instead of the regression analysis was to highlight the benefits of the DEA models.

CONCLUSION

The objective of this paper was to investigate and compare the relative technical efficiency of the agricultural production in the European countries at the national level. To reach this objective, we attempted to answer the following research questions: "(1) Is the agricultural sector in the EU performing efficiently? (2) Has the efficiency of the EU agricultural sector changed over the last several years? (3) What are the main sources of inefficiency, and is there any way of improving the efficiency of the agricultural sector in the EU?"

We investigated efficiency using both the input and output-oriented models using the assumption of a variable return to scale in 27 agricultural sectors of the European Union (EU) countries during the period 2007–2011. The results showed that, in average, the agricultural sector in the EU performed efficiently, as evidenced by the relatively high values of the average input and output efficiency. There were 13 agricultural sectors, which were determined to be relatively technically efficient in both models during the whole analysed period (Belgium, Denmark, Greece, France, Hungary, Ireland, Italy, Malta, the Netherlands, Romania, Finland, Sweden, and Slovakia). The lowest efficiency was observed mainly in the agricultural sectors in Slovenia and Poland. In the analysed sample, there were also countries, which were observed to be relatively efficient at the beginning, but during the analysed period they lost their efficiency and became inefficient. The agricultural sectors in Bulgaria, the Czech Republic, and Latvia belong to this group. On the other hand, the agricultural sectors in Estonia and Finland moved from the inefficient group to the efficiency margin. "Relatively" means that these agricultural sectors were efficient within the analysed group of countries, taking into account the specified input and output variables. If other variables were used for the analysis, or if we changed the number of the analysed countries, the results of the efficiency measurement could be quite different.

The efficiency of the EU agricultural sector has changed over the past few years, and in both models it could be seen that the efficiency has generally decreased over time. The average input efficiency at the beginning of the analysed period was 95.96%, indicating that the agricultural sectors had to improve their efficiency in average by 4.04%. In the last year, this efficiency reached 93.23%. The average output efficiency was considerably lower than in the input-oriented model. The output efficiency at the beginning of the analysed period was 90.82%, and in the last year it declined to 87.73%.

We have also found that the main source of inefficiency, while taking into account only the input and output variables, was the "Total Utilised Agricultural Area," and that the "Crop Output" had the strongest positive impact on efficiency. By calculating the optimal values for the input and output variables of the inefficient agricultural sectors in the EU, we have found that to improve the input efficiency at the given quantity of outputs, it was necessary to reduce the value of the input "Total Labour" in average by 6.18%, the "Total Utilised Agricultural Area" in average by 14.45%, and the "Total Assets" in average by 5.93%. Using the output-oriented BCC model, it was determined that for the efficient use of a given quantity of inputs, the agricultural sectors should

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produce up to 111.85% of their "Crop Output" and 113.41% of their "Animal Output."

The answers to the analysed questions may be beneficial to three main constituencies. The knowledge of the level of efficiency is important to agricultural firm managers, since it reflects the quality of daily operations in utilising inputs and outputs, and other decisions can be based on this knowledge. Policymakers are the second group that may benefit from this information, because they can use it to compare the agricultural sector's performance before and after any regulatory changes took place, and consequently they can evaluate if the changes were beneficial to the agricultural sector or not. Finally, researchers can also benefit from a paper analysing the efficiency of the agricultural sector. They can use the previous studies in this area to observe a gradual development in the measuring techniques of efficiency, which may enable them to identify gaps in the research.

In our study, we analysed the relative technical efficiency of agricultural sectors using the basic DEA models with the criteria described in the previous section. The term "relative technical efficiency" reflects the ability of an agricultural sector to obtain the maximal output from the given set of inputs within its group and the criteria used (input and output variables). The findings of this paper should be updated on a larger scale, for example using all European countries, in order to investigate the evolution the efficiency of the EU agricultural sectors in a larger set of the surveyed countries. The future analysis may also benefit from using the DEA models with the information about prices to evaluate the overall economic efficiency in the form of cost, revenue, or profit efficiency. Other benefits of the future analysis may also include the examination of the impact of variables beyond the inputs and outputs used in the DEA models. The impact of various factors such as the technology, the relative factor abundance, the institutional and policy reforms, the market environment, and other on the relative technical efficiency or the overall economic efficiency of agricultural sectors in the analysed countries can be analysed through the regression analysis.

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Contact address:

Kristína Kočišová, Technical University of Košice, Faculty of Economics, Department of Banking and Investment, Nemcovej 32, 04001 Košice, Slovak Republic
e-mail: kristina.kocisova@tuke.sk