doi: 10.17221/200/2014 -AGRICECON

Technical efficiency and its determinants in the European Union agriculture

Anna NOWAK, Tomasz KIJEK, Katarzyna DOMAŃSKA

Department of Economics and Agribusiness, Faculty of Agrobioengineering, University of Life Sciences in Lublin, Lublin, Poland

Abstract: The study concerns the measurement of the technical efficiency of agriculture in the 27 European Union (EU) countries in 2010. The studies were conducted based on the result-oriented DEA method assuming variable advantages of scale. Moreover, in the study, the factors affecting technical efficiency were identified, and the econometric modelling of their impact was performed with the use of the Tobit model. The studies indicate that across the 27 EU Member States, the level of the technical efficiency of agriculture is diverse, and the difference between the states with the highest and the lowest efficiencies is 40%. Cyprus, Denmark, Greece, France, Spain, the Netherlands, Luxembourg, Italy and Malta were identified as the countries with the thoroughly technically efficient agriculture. In turn, the least technically efficient agriculture is observed for the Czech Republic, Lithuania, Hungary, Ireland, Latvia and Slovakia. Taking into account the factors determining the technical agriculture efficiency, it should be noted that the stimulants have proven to be such factors as: the soil quality, the age of the head of the household and the surcharges for investments. In turn, the size of the farm appeared to be irrelevant from the viewpoint of the technical efficiency of the agricultural sector.

Key words: efficiency of agriculture, EU Member States, Data Envelopment Analysis (DEA)

An increase in agricultural productivity and also the technical efficiency of agriculture is a very important political goal in most countries. This phenomenon results from the fact that these are some of the major sources of the overall economic growth (Zamanian 2013). The potential for the effective usage of factors of production is also a measure of the competitiveness of the agricultural sector (Kołodziejczak 2010). Evaluation of the effectiveness of agriculture is quite complicated, not only due to the instability of weather conditions, but also because of the wide variety of households in terms of their economic strength and production profile.

Efficiency can be assessed with the use of either partial or total measures. Partial measures are defined as the relationship of the production to the individual factor of production (Fuglie 2010). These measures, however, may not be fully reliable, because it is not known what they were induced with. As observed by Fuglie and Wang (2013), such measures probably overestimate the overall improvement in efficiency, as they do not take into account any changes in other expenditures on production factors. In studies devoted to agricultural productivity, non-parametric methods have been used in parallel to the methods involving indicators.

An example of a non-parametric method used for the measurement of technical efficiency is the data envelopment analysis (DEA). In contrast to methods measuring the total productivity of the factors of production, this method directly compares the effects and expenditure of the studied subjects, indicating those with efficient economy, i.e. characterized by the highest efficiency of management (Ziółkowska 2009).

Agriculture plays an important role in the economy of many countries in the European Union. Although the impact of this sector on the macroeconomic indicators has been decreasing in the recent years, this is a general tendency observed for the developed economies. In 2011, the contribution of agriculture in 27 EU countries in terms of the total gross value added was estimated at 1.7% (in 2000 – 2.3%): ranging from 6.7% in Romania to 0.3% in Luxembourg[1]. Structural transformations in the agricultural sectors of the individual countries, globalization, and other endogenous and exogenous conditions have a

[1]Based on Eurostat data.

doi: 10.17221/200/2014 -AGRICECON

significant impact on the efficiency and the change in productivity in agriculture. There have been many attempts to assess the efficiency of management in agriculture, both for the individual countries and also for the groups of countries. An overview of studies using the DEA method is presented in Table 1.

Economists have been searching for the sources of changes in agricultural productivity and the diverse levels of efficiency between countries and regions (Coelli and Prasada Rao 2005). Problems encountered in this research area stem from the fact that the consequence of a more efficient use of production factors is the improvement of agricultural productivity (Dharmasiri 2011).

An important element of the technical efficiency analysis is the assessment of the factors which affect it. Taking into account the fact that the classical factor expenditures are taken into account during the calculation of the DEA indicators, the level of technical efficiency should be explained using

Table 1. An overview of studies on the technical efficiency of agriculture using the DEA method

Authors	Study period	Countries included in the study	Results
Mahjoor (2013)	2010–2011	Iranian broiler farms	The results of the study reveal that in the terms of constant returns to scale (CRS) and variable returns to scale (VRS), in average, the farms technical, allocative and economic efficiencies were 82, 70, 57% and 82, 73, 64% respectively. About 59 farms exhibited increasing returns to scale and 16 farms exhibited decreasing returns to scale.
Mathijas and Vranken (2001)	1998	Bulgarian and Hungarian crop and dairy farms	The majority of Hungarian crop farms reach an efficiency level between 30 and 60%. 45% of the dairy farms reach an efficiency level between 10 and 20%. In Bulgaria, more than 30% of cooperatives reach an efficiency level lower than 20%; companies reach an average efficiency of 51%; family farms reach an average efficiency of 44%. The average efficiency of cooperatives is 43%.
Latruffe et al. (2004)	2000	Polish farms specializing in crop and livestock production	On average, livestock farms are more technically efficient than crop farms. For both specializations, the size-efficiency relationship is positive, i.e. large farms are more efficient.
Fandel (2003)	2000	Slovak corporate farms	Scale efficiency grows with the farm size and the highest scores are recorded for farms of a size group below 100 ha, and above 1000 ha.
Luik et al. (2011)	2001–2009	Estonian dairy farms	Results show no significant change in the technical efficiency in Estonian dairy farms over the period 2001–2009.
Bojnec and Latruffe (2009)	1994–2003	Slovenian farms	The degree of the technical efficiency increased during the transition.
Błażejczyk-Majkaet al. (2011)	1989–2007	85 EU regions	As a result, four groups of regions were distinguished.
Burja (2011)	2008	Romanian agriculture in relation to agriculture in the European Union	Only agricultural holdings in the South-Muntenia region are positioned on the efficiency frontier next to those in the EU. Above average performance is recorded by the South-East and South-West Oltenia regions. The lowest performance is recorded by the West region (0.426).
Zamanian et al. (2013)	2007–2008	21 MENA countries	Qatar is ranked no. 1 among the 21 MENA countries in terms of efficiency scores

Source: Own elaboration

doi: 10.17221/200/2014 -AGRICECON

other variables that may be related to the quality of the factors of production or to the environment. Increased efficiency may be a result of many factors, including changes in the size of farms, the rate of the introduction of new technologies (depending on the R&D expenditure), regulations and market forces, as well as the climate variability (Mallawaarachchie 2009).

According to Mahjoor (2013), the determinants of technical efficiency in agriculture are the education and age of the farmer, as well as the membership of a producer group. In turn, Rahman and Salim (2013) list the size of agricultural holdings, the investment in research and development, the expenses incurred in the expansion of production and the specialization of plant production and the illiteracy among the factors affecting the management efficiency. The importance of the farm area is also highlighted in the studies by Munroe (2001), O'Neill and Matthews (2001); Hadley (2006), Emvalomatis et al. (2008), Carroll et al. (2009). In addition, Bhalla and Roy (1988) suggest that an important factor influencing the efficiency of agriculture is the quality of the land. This is confirmed by the studies conducted by Adhikari and Bjørndal (2011). In turn, Onyenweaku et al. (2004), Gul (2006) and Idris et al. (2013) draw attention to the existence of the relationships between the efficiency of agriculture and the age of the farm managers. On the one hand, it is reasonable to assume that there is a positive relationship between the farmer's age and efficiency, since the age is regarded as a proxy for the farming experience and knowledge-base. On the other hand, younger farmers are supposed to be more willing to use new production methods and management techniques, which may lead to an increase in their technical efficiency. For example, Yu et al. (2014) include the age in a set of the respondents' characteristics in their study on farmers' willingness to switch to organic agriculture. In turn, Čechura (2012) shows that management is an important determinant of the agricultural production efficiency. Table 2 shows the main factors determining the efficiency of agriculture and the expected direction of their influence.

Table 2. Main determinants of the technical efficiency of agriculture

Factor	The expected impact on efficiency
Size of the farm	+/–
Education of the farm owner	+
Age of the farm owner	+/–
Capital expenditure	+
Quality of soil	+

+ positive effect, – negative effect, +/– equivocal effect

Source: Own elaboration

MATERIALS AND METHODS

We calculated the relative efficiency for a sample of 27 European Union (EU) countries in the year 2010 using data from the Eurostat datasets and the Farm Accountancy Data Network-FADN database. Our measure of the aggregate output included production values of the agricultural sector at basic prices. In turn, the aggregate inputs included agricultural labour, capital and land. Labour input was measured in the annual work units, which corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis. Capital input was retrieved from the capital flow, which encompasses the intermediate consumption, i.e. the physical inputs for crop and livestock production and the overall production inputs, as well as the amortization. Land input denotes the stock of the utilised agricultural area.

We deployed the Data Envelopment Analysis (DEA) to calculate the efficiency of the countries. The DEA is a non-parametric methodology pioneered by Charnes et al. (1978) and aimed at evaluating the relative efficiencies of comparable decision- making units (hereafter DMUs) by the means of a variety of mathematical programming models. One recognized advantage of the DEA is that it allows a researcher to evaluate the performance of the individual DMUs taking into account only the observed quantities of marketable inputs and outputs and does not require an assumption of a functional form relating inputs to outputs (Picazo-Tadeo et al. 2011). Instead, a piecewise linear frontier is constructed based on empirical observations on inputs and outputs of a sample of DMUs. The technological frontier represents the best practices, while the distance to it from each DMU in the sample is used to compute a measure of its relative performance (Cook and Seiford 2009). The DEA can be either input-oriented or output-oriented. The input-oriented version requires that the DEA approach defines the frontier by seeking the

doi: 10.17221/200/2014 -AGRICECON

maximum possible proportional reduction in input usage, with the output levels held constant for each DMU. In contrast, with the output-oriented DEA, the linear programme allows for finding a DMU's potential output given its inputs if it is operated efficiently.

For the purpose of our study, the output-oriented BCC model proposed by Banker et al. (1984) was employed. This model assumes variable returns to scale – VRS. The use of the VRS specification permits the calculation of technical efficiency – TE – under the assumption that all DMUs are not operating at their optimal scale. As mentioned previously, the model deals with three inputs and one output and it can be expressed by the following mathematical formula:

$$\phi_0 = \max \phi$$

s.t.:

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq \psi y_{r0}$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq x_{i0}$$

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

$$\lambda \geq 0$$

where DMU_o represents one of the n DMUs under evaluation, and x_{io} and y_{ro} are the ith input and rth output for DMU_o, respectively. If $1/\phi^* = 1$, then the country under evaluation is efficient. Otherwise, if $0 < 1/\phi^* < 1$, the country is inefficient, i.e. this country can increase its output levels.

Once the TE is computed, the next step is to investigate its drivers. To identify the determinants of the TE, we used a Tobit model. We employed this approach due to the properties of the dependent variable, i.e. the TE, which is censored. The model is specified as follows (Greene 2006):

$$y_i^* = x_i'\beta + \varepsilon_i$$

$$y_i = a \text{ if } y_i^* \leq a$$

$$y_i = y_i^* \text{ if } y_i^* > a$$

where a is a certain threshold, y_i^* is a latent variable implying the TE related to the ith country in the year 2010, x_i' is a vector of the regressors described below and is the error term that is assumed to be normally distributed. On the basis of the literature review, we introduced five independent variables into the model that are considered to be highly relevant for the TE. These variables are as follows:

x_1 = soil productivity index, expressed in relative terms; where the score 1 represents the poorest and 8 the highest productivity soil,

x_2 = average farm size in ha,

x_3 = percentage of farms managed by holders over 55 years,

x_4 = percentage of farm managers with full agricultural training,

x_5 = subsidies on investments in euro per farm.

All independent variables used in the analysis are derived from the Eurostat datasets and the Farm Accountancy Data Network-FADN database. They refer to the year 2010, except for the soil productivity index, which, due to the data availability, denotes the year 2006.

RESULTS AND DISCUSSION

Table 3 shows the technical efficiency of agriculture in the individual countries of the European Union between 2007–2011.

The analysis of the technical efficiency of agriculture for the individual EU Member States showed a relatively large variation of its level. The difference between the most and the least efficient country in the field of agriculture was 40%.

The results show that nine Member States in the studied period had a thoroughly technically efficient agriculture, because the ratio of the total technical efficiency was equal to 1: Cyprus, Denmark, Greece, France, Spain, the Netherlands, Luxembourg, Italy and Malta.

Belgium (0.986), Germany (0.957) and the UK (0.949) should also be included among countries that have reached a relatively high level of the technical efficiency of agriculture. These countries only need an additional 1–5% to achieve the maximum level of effectiveness.

It should be noted that in all the above-mentioned countries, the level of the technical efficiency of agriculture was higher than the average for the European Union, where the value in the studied period was 0.848. For the other EU members, the results in terms of the analysed indicator were lower than the average for the Community.

doi: 10.17221/200/2014 -AGRICECON

Similar, but slightly lower levels of technical efficiency of agriculture as compared to the EU average were observed in Sweden (0.840), Poland (0.826), Portugal (0.819) and Bulgaria (0.801). These countries, following the countries which are the best in the field of technology and techniques used in agriculture, could increase the value of production in this sector by 16 to 20%.

A lower technical efficiency of agriculture was noted in five countries, i.e. Austria (0.779), Romania (0.775), Finland (0.731), Estonia (0.722) and Slovenia (0.702). For these countries, an additional22 to almost 30% is required to achieve the maximum efficiency.

In turn, the Czech Republic (0.696), Lithuania (0.696), Hungary (0.682), Ireland (0.681), Latvia (0.658) and Slovakia (0.601) have the least techni-

Table 3. Technical efficiency of agriculture in the EU countries between 2007–2011, determined with the use of the result-oriented DEA method

No.	EU member country	Constant returns to scale technical efficiency (CRSTE)	Variable returns to scale technical efficiency (VRSTE)	Scale efficiency	Type of returns to scale
1	EU–27	0.812	0.848	0.960	
2	Austria	0.776	0.779	0.997	irs
3	Belgium	0.983	0.986	0.997	irs
4	Bulgaria	0.775	0.801	0.967	drs
5	Cyprus	1.000	1.000	1.000	–
6	Czech Republic	0.692	0.696	0.995	irs
7	Denmark	1.000	1.000	1.000	–
8	Estonia	0.718	0.722	0.994	irs
9	Finland	0.727	0.731	0.995	irs
10	France	0.968	1.000	0.968	drs
11	Germany	0.852	0.957	0.890	drs
12	Greece	0.854	1.000	0.854	drs
13	Hungary	0.658	0.682	0.965	drs
14	Ireland	0.679	0.681	0.997	irs
15	Italy	0.839	1.000	0.839	drs
16	Latvia	0.645	0.658	0.980	drs
17	Lithuania	0.675	0.696	0.970	drs
18	Luxembourg	0.760	1.000	0.760	irs
19	Malta	1.000	1.000	1.000	–
20	Netherlands	1.000	1.000	1.000	–
21	Poland	0.795	0.826	0.963	drs
22	Portugal	0.746	0.819	0.911	drs
23	Romania	0.747	0.775	0.963	drs
24	Slovakia	0.600	0.601	0.999	drs
25	Slovenia	0.643	0.702	0.916	drs
26	Spain	1.000	1.000	1.000	–
27	Sweden	0.836	0.840	0.996	irs
28	United Kingdom	0.949	0.949	1.000	–

irs – increasing returns to scale, drs – decreasing returns to scale

Source: Own elaboration

doi: 10.17221/200/2014 -AGRICECON

cally efficient agriculture. This means that adopting technologies and techniques used by the best countries could have increased their production from 30 to 40%.

Based on these results, it can be concluded that the most efficient agriculture in the studied period was mainly identified for the so-called "old 15" countries because, with the exception of Cyprus and Malta, they dominated in the group of countries where the level of the technical efficiency was higher than the average reported for the EU. In turn, the group of countries in which agriculture had a lower technical efficiency as compared to the average included the newly admitted members. In the EU-15, less efficient agriculture was reported for Austria, Finland, Ireland, Portugal and Sweden.

Table 4 presents the results of an estimation of the Tobit model parameters, representing the associations between the selected factors and the technical efficiency of agriculture – TE in the European Union in 2010. Backward selection method was used to remove insignificant variables from the model.

Studies have shown that, in European Union Member States, such factors as the soil quality, the age of the head of household and the surcharges for investments positively affect the technical efficiency of agriculture. Among these factors, the first had the greatest impact. A similar relationship between this factor and the technical efficiency of agriculture was observed by Adhikari and Bjorndal (2011). As shown by Będzik (2010), the quality of the soil is significantly positively correlated with the size of the crop.

Table 4. Parameters and test values of the Tobit regression

Variable	Coeff.	Z-value
Const.	x	–
X_1 soil productivity index	0.08342***	4.7128
X_2 average farm size in ha	x	–
X_3 percentage of farms managed by holders over 55 years	0.00613***	3.2681
X_4 percentage of farm managers with full agricultural training	x	–
X_5 subsidies on investments in euro per farm	0.00004***	3.0087
Log–likelihood = 17.49769		

x – eliminated variable, ** and *** indicate significance at the 5% and 1% level

Source: Own elaboration

However, she states that in many cases the size of the crop was influenced more by fertilization than by the quality of the soil, as indicated by her results. Similar conclusions were drawn by Świtłyk (2001), which means that in the farms in which the soil quality is not high, one can achieve yields comparable to those obtained on farms with a better soil thanks to the use of higher doses of mineral fertilizers and pesticides. As reported by Latruffe (2004), it should be emphasized that the current studies on efficiency in the Central and Eastern Europe have not taken into account the quality of soil.

As expected, the age of the farm managers had a positive effect on the technical efficiency of agriculture. Experience in the management of agricultural production on the part of individuals who run an agricultural household plays an important role, as it often substitutes for the formal education of the farmer. Hamerska and Roczkowska-Chmaj (2008) showed that the highest rates of technical progress were obtained by the farmers aged 35–50 years; however, the level of education did not influence the results obtained in their holdings. Studies conducted by Onu et al. (2000) and Idris et al. (2013) also confirm that the educational level is not associated with the technical efficiency.

A third factor positively affecting the technical efficiency of agriculture are the surcharges for investments – their impact, however, was the lowest among all variables under study. The development of farms is inseparably linked to their investment activity. Projects have a significant impact on the efficiency of the production, competitiveness and, therefore, the market power of business (Kisiel and Babuchowska 2013). An increase in farm resources enables a higher rate of production and supports the farm's long-term development. The main reason for the business investment, including farms, is the expectation of a future income higher than the costs of the investment (Babuchowska and Marks-Bielska 2012). Surcharges for investments enable the modernization of agricultural households and the improvement of their competitive position in the market, and in the longer perspective, they improve the effectiveness of management.

Among the factors under study, the size of the farm appeared to be non-significant from the technical efficiency of agriculture viewpoint. It should be noted that the results of studies undertaken by different authors are not consistent in this regard. Some indicate that larger farms achieve better results,

doi: 10.17221/200/2014 -AGRICECON

e.g. Hadley (2006), for different types of farms in the UK; Emvalomatis et al. (2008), for farms growing cotton in Greece; and Carroll et al. (2009), for farms specializing in the production of cereals and dairy cattle in Ireland.

The above results can be explained by the fact that with an increase in farm growth, the scale of production increases, which enables a more efficient use of resources, and thus an increase in efficiency. In turn, studies conducted by other authors show that smaller farms are more efficient; for example, Munroe (2001) for Polish farms, and O'Neill and Matthews (2001), for farms in Ireland. In this case, it is thought that the factor influencing the discrepancy of the results is the large diversity of agriculture in the European Union in terms of the structure of farms and their specializations.

The average size of farms in the EU in 2010 was 14.3 hectares, while in the UK, Denmark, Germany, France this exceeded 50 hectares, and in the Czech Republic the size was up to 150 hectares. In other countries, in turn, this area was much lower than the EU average, e.g. Poland (6.6 ha), and Italy (8.8 ha). Thus, depending on the country or group of countries under study, the impact of the farm size on the efficiency may be different.

The low importance of the farm size in the explanation of the level of the technical efficiency may point to the "depletion" of scale advantages in relation to the farms of the EU countries. It should also be noted that the existence of efficient farms characterized by a small-area is a desirable feature from the standpoint of the development of sustainable agriculture, which is now considered a priority in the EU (Europe 2020). Extensive production methods used in these types of farms allow for sustainable management of natural resources which favours the preservation of biodiversity. Such an approach indicates that different perspectives on agricultural restructuralisation and changes in the agrarian structures are necessary, which take into account not only the economic aspects (e.g. efficiency improvement), but also the needs of the society and the environment.

CONCLUSIONS

This study has measured the technical efficiency of agriculture in the 27 EU countries in 2010. For this purpose, the DEA method was utilized. Furthermore, we have identified factors determining the technical efficiency, and the econometric modelling of their impact on its level has been calculated with the use of Tobit model. There are three reasons why the study undertaken by our group provides a contribution to the literature in the field of agricultural efficiency. Firstly, the scope of the study covers all 27 EU countries. To our knowledge, no studies have not been conducted in this field yet. Secondly, this study focuses on the technical efficiency of agriculture. This measure allows consideration of the effect of all main factors of production in agriculture, i.e. labour, land and capital. Thirdly, the determinants of technical efficiency identified and used in the econometric analyses include, among others, the quality of land which, as noted by Latruffe et al. (2004), constitutes a factor often not taken into account in the existing studies regarding the efficiency for the Central and Eastern Europe.

The results indicate that across all the 27 EU Member States, the level of the technical efficiency of agriculture is diverse, and the difference between the countries with the highest and the lowest efficiency is estimated at 40%. Those countries with a thoroughly technically efficient agriculture have been identified as Cyprus, Denmark, Greece, France, Spain, the Netherlands, Luxembourg, Italy and Malta. In turn, the least technically efficient agriculture has been characterized for the Czech Republic, Lithuania, Hungary, Ireland, Latvia and Slovakia. Taking into account the factors determining the effectiveness of technical agriculture, it should be noted that the stimulants have proven to be such factors as: the soil quality, the age of the manager and the surcharges for investments. In turn, the size of the farm has been reported to be irrelevant when analysing the technical efficiency of the agricultural sector.

Our results allow the formulation of several recommendations with respect to the Community policies towards agriculture. Firstly, there is a need for the public support for investment in the modernization of the agricultural sector allowing for the creation of technical progress in agriculture. This applies particularly to the countries newly admitted to the European Union, in which the level of agricultural development is lower than is the case in the countries of the so-called "old 15". Such activities should be supported both at the Community level and at the level of the national policies. Secondly, a different approach to the issue of agricultural restructuralisation and changes in the agrarian structures is necessary; and this should take into account not only the economic

doi: 10.17221/200/2014 -AGRICECON

aspects (e.g. efficiency improvement), but also the social and environmental ones.

The low importance of the farm size indicates that regardless of this factor, these entities can be fully effective. The policy of seeking to increase the proportion of large farms on the grounds of improving the efficiency of smaller households should be rescinded as this would be desirable from the standpoint of the development of sustainable agriculture, which has Thanks to the extensive production methods used in this type of farm, a more efficient management of natural resources and the preservation of biodiversity are possible.

REFERENCES

Adhikari Ch.B., Bjorndal T. (2011): Analyses of technical efficiency using SDF and DEA models: Evidence from Nepalese agriculture. Applied Economics, 44: 3297–3308.

Babuchowska K., Marks-Bielska R. (2012): Investments in agricultural holdings. In: Kisiel R., Babuchowska K., Marks-Bielska R.: Farms from Eastern Poland and their Owners Propensity to Invest with an Application of the Instruments of the Common Agricultural Policy. PTE, Torun (in Polish).

Banker R.D., Charnes A., Cooper W.W. (1984): Models for estimation of technical and scale inefficiencies in data envelopment analysis. Management Science, 30: 1078–1092.

Będzik B. (2010): The role of crop producers education and soil quality in volume of yields in the Western Pomerania province. Folia Pomeranae Universitatis Technologiae Stietinensis, Seria Oeconomica, 282: 13–20 (in Polish).

Bhalla S., Roy P. (1988): Mis-specification in Farm Productivity Analysis: The Role of Land Quality. Oxford Economic Papers, 40: 55–73.

Błażejczyk-Majka L., Kala R., Maciejewski K. (2011): Data envelopment analysis in estimation of technical efficiency change of regional agriculture production EU, 1989–2007. Journal of Mathematics and System Science, 1: 43–51.

Bojnec S., Latruffe L. (2009): Determinants of technical efficiency of Slovenian farms. Post-Communist Economies, 21: 117–124.

Burja V. (2011): Regional disparities of agricultural performance in Romania. Annales Universitatis Apulensis, Series Oeconomica, 13: 115–121

Carroll J., Greene S., O Donoghue C., Newman C., Thorne F. (2009): Productivity and the determinants of efficiency in Irish agriculture (1996–2006). In: 83rd AES Conference, Dublin, Ireland, 30 Mar. 30–Apr. 1.

Charnes A., Cooper, W. W. Rhodes E. (1978): Measuring the efficiency decision making units. European Journal of Operational Research, 2: 429–444.

Coelli T.J., Prasada Rao D.S. (2005): Total factor productivity growth in global agriculture: A Malmquist index analysis of 93 countries, 1980–2000. Agricultural Economics, 32: 115–134.

Cook W.D., Seiford L.M. (2009): Data envelopment analysis (DEA) – Thirty years on. European Journal of Operational Research, 192: 1–17.

Čechura L. (2012): Technical efficiency and total factor productivity in Czech agriculture. Agricultural Economics – Czech, 58: 147–156.

Dharmasiri L.M. (2011): Measuring agricultural productivity using the Average Productivity Index (API). Sri Lanka Journal of Advanced Social Studies, 1: 25–44.

Emvalomatis G., Oude Lansink A., Stefanou S. (2008): An examination of the relationship between subsidies on production and technical efficiency in agriculture: the case of cotton producers in Greece. In: 107th EAAE Seminar Modelling of Agricultural and Rural Development Policies, Seville, Spain, Jan. 29–Feb. 1.

Europe 2020 (2010): A European Strategy for Smart, Sustainable and Inclusive Growth. Communication from the Commission, Brussels, 3. 3. 2010.

Fandel P. (2003): Technical and Scale Efficiency of Corporate Farms in Slovakia. Agricultural Economics, 49: 375–383.

Fuglie K.O. (2010): Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data.

Fuglie K.O., Wang S.L. (2013): New evidence points to robust but uneven productivity growth in global agriculture. Global Journal of Emerging Market Economies, 5: 23–30.

Greene W.H. (2003): Econometric Analysis. Prentice Hall, New Jersey.

Gul M. (2006): Technical efficiency of apple farming in Turkey: A case study covering Isparta, Karaman and Nigde provinces. Pakistan Journal of Biological Sciences, 9: 601–605.

Hadley D. (2006): Efficiency and Productivity at the Farm Level in England and Wales 1982 to 2002. Report for the Department for Environment, Food and Rural Affairs (DEFRA), London, March.

Hamerska I., Roczkowska-Chmaj S. (2008): Farmers' education and age versus scientific-technological progress index. Inżynieria Rolnicza, 11: 75–82 (in Polish).

Idris N.D.M., Siwar Ch., Talib B. (2013): Determinants of technical efficiency on pineapple farming. American Journal of Applied Sciences, 10: 426–432.

doi: 10.17221/200/2014 -AGRICECON

Kisiel R., Babuchowska K. (2013): Capital expenditures in agriculture holdings – regional approach. Roczniki Ekonomii Rolnictwa i Rozwoju Obszarów Wiejskich, 100: 62–69 (in Polish).

Kołodziejczak A. (2010): Models of agriculture and the spatial diversity of ways of farming in Polish agriculture. UAM, Poznan (in Polish).

Latruffe L., Balcombe K., Davidova S., Zawalinska K. (2004): Determinants of technical efficiency of crop and livestock farms in Poland. Applied Economics, 36: 1255–1263.

Luik H., Omel R., Viira A.H. (2011): Efficiency and productivity change of Estonian dairy farms from 2001–2009. In: EAAE 2011 Congress, Change and Uncertainty Challenges for Agriculture, Food and Natural Resources, ETH Zurich, Zurich, Aug. 30–Sept. 2.

Mahjoor A.A. (2013): Technical, allocative and economic efficiencies of broiler farms in Fars Province, Iran: A data envelopment analysis (DEA) approach. World Applied Sciences Journal, 21: 1427–1435.

Mallawaarachchi T., Walcott J., Hughes N., Gooday P., Georgeson L., Foster A. (2009): Promoting Productivity in the Agriculture and Food Sector Value Chain: Issues for R&D Investment. ABARE and BRS Report to the Rural R&D Council, Canberra, Dec.

Mathijs E., Vranken L. (2001): Human capital, gender and organization in transition agriculture: measuring and explaining the technical efficiency of Bulgarian and Hungarian farms. Post-Communist Economies, 13: 171–187.

Munroe D. (2001): Economic efficiency in Polish peasant farming: An international perspective. Regional Studies, 35: 461–471.

O'Neill S., Matthews A. (2001): Technical efficiency in Irish agriculture. Economic and Social Review, 32: 263–284.

Onu J.K., Amaza P.S., Okunmadewa F.Y. (2000): Determinant of cotton production and economic efficiency. African Journal of Business & Economic Research, 192: 24–30.

Onyenweaku C.E. Igwe K.C., Mbanor J.A. (2004): Application of stochastic frontier production functions to the measurement of technical efficiency in yam production on Nasarawa State, Nigeria. Journal of Sustainable Tropical Agricultural Research, 13: 20–25.

Picazo-Tadeo A.J., Gomez-Limon J.A., Reig-Martinez E. (2011): Assessing farming eco-efficiency: A data envelopment analysis approach. Journal of Environmental Management, 92: 1154–1164.

Rahman S., Salim R. (2013): Six decades of total factor productivity change and sources of growth in Bangladesh agriculture (1948–2008). Journal of Agricultural Economics, 64: 275–294.

Świtłyk M. (2001): Technical efficiency of fertilization in Poland in years 1975–1997. Folia Universitatis Agriculturae Stetinensis, Seria Oeconomica, 222: 361–372 (in Polish).

Zamanian Gh.R., Shahabinejad V., Yaghoubi M. (2013): Application of DEA and SFA on the measurement of agricultural technical efficiency in MENA1 Countries. International Journal of Applied Operational Research, 3: 43–51.

Ziółkowska J. (2009): Determinants of technical efficiency measured with the DEA method. Zagadnienia Ekonomiki Rolnej, 3: 124–132 (in Polish).

Yu C.H, Yoo J.C., Yao S.B. (2014): Farmers' willingness to switch to ecological agriculture: A non-parametric analysis. Agricultural Economics – Czech, 60: 273–278.

Received: 6th November 2014
Accepted: 2nd December 2014

Contact address:

Tomasz Kijek, Department of Economics and Agribusiness, Faculty of Agrobioengineering, University of Life Sciences in Lublin, ul. Akademicka 13, 20-950 Lublin, Poland
e-mail: tomasz.kijek@up.lublin.pl