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CAP After 2004: Policy to Promote Development or to Elimination Differences Between Regions? Non-parametric Approach Based on Farm Efficiency in the Old and New EU Regions

Lucyna Błażejczyk-Majka

Department of Economic History, Adam Mickiewicz University in Poznań, Poland

Abstract

In the light of the Treaty establishing the European Economic Community (Treaty of Rome) of 25 March 1957, the primary aim of the Common Agricultural Policy is to provide European Economic Community citizens with adequate amounts of food at reasonable prices and to guarantee farmers a decent standard of living. That is more, the EU fund transfers were to eliminate differences between regions and promote development of individual regions. These aims proved to be particularly important following the EU enlargement in 2004. The indispensible effect of the integration process has been connected with changes in the directions of agricultural production and efficiency of utilisation of individual inputs. Nevertheless, it is difficult to evaluate the effects of the implemented policy based on univariate comparisons.

In view of the above, the aim of this paper is to assess the effects of the agricultural policy and the cohesion policy implemented in the EU, focusing on the valuation of the impact of the greatest EU enlargement on this relationship. This goal was achieved thanks to constructing multivariate rankings applying the DEA super-efficiency model for average farms specialising in plant, animal and mixed production in individual EU member countries for two period. The application of the DEA efficiency model makes it possible in the computation process to take into consideration the fact that in the course of agricultural production three groups of products are manufactured involving four basic types of inputs. The starting point for the analyses was provided by data published within the FADN agenda for average farms operating in the countries being the EU members.

The results showed that after the largest enlargement of the EU, in the case of plant and livestock production, a simultaneous increase in agricultural production and improvement in efficiency in the individual EU members was achieved, with a gradual reduction of disproportions in the efficiency of agricultural production between regions. The only area where such a relationship could not be observed was related to the production of mixed-type farms.

The novelty of the proposed in this article approach is that it allows for simultaneous analysing of changes in EU agriculture while taking into account several perspectives: changes in the assumptions of the common agricultural policy, the consequences of EU enlargement, and results of the implementation of the cohesion policy.

Keywords

EU cohesion policy, Common Agricultural Policy, supper-efficiency model, DEA.

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Introduction

The Common Agricultural Policy (CAP) is considered to be one of the most important EU policies supporting the functions of the European Single Market. It was developed in response to problems with food supply experienced in Europe after WWII (Balaceanu, 2013). The basic principles of the CAP were included already in the Treaty establishing the European Economic Community of 25 March 1957 (Treaty of Rome, 1957, Article 39). According to this document the primary aim of the CAP is to provide EU citizens with adequate amounts of food at reasonable prices and to guarantee a satisfactory standard of living to farmers. The wide scope of tasks allocated to the CAP has been realised in practice starting from 1962, when the European Agricultural Guidance and Guarantee Fund was founded (Ackrill, 2000).

Actions aiming at the assurance of food security in Europe obviously absorbed a high share of expenditure from the EC budget. As a result the agricultural policy has been this aspect of the European economic policy raising the greatest controversies among the populations of the member countries. In turn, due to the changing economic conditions from the very beginning the CAP has been one of the most frequently reformed policies. Particularly significant changes in its assumptions were introduced at the turn of the 21st century. In January 2003 the European Commission following the Mid-Term Review proposed the Luxembourg Common Agricultural Policy Reform (also referred to as the Fischler reform; Buckwell, 2003). The primary aims of this reform were connected first of all with the perspective of the greatest enlargement in the EU and the need to strengthen the bargaining position of the European Union within the WTO.

Assumptions of the CAP within the Luxembourg CAP Reform became an important element in the process aiming at the improvement of efficiency and competitiveness of the entire EU economy. In literature on the subject the Luxembourg CAP Reform is considered to be the most radical reform since the introduction of the CAP (Fischer Boel, 2005; Olper, 2008, 83-97; Swinnen, 2008). It is stated that it has led to greater simplicity and flexibility of the agricultural policy in the EU, making it more market-oriented. In the opinion of F. Fischler, the author of the reform, as well as other researchers of the EU agricultural policy, thanks to this reform the CAP is better adapted to the increasing social expectations in Europe and to the situation found on the international agricultural markets. The attempts within the CAP to attain greater marketability and competitiveness of European food products in relation to food produced in other parts of the world are to guarantee food security for the inhabitants of the EU member countries. Thus the re-defined model of the Common Agricultural Policy promotes solutions which do not disturb the directions, structure and character of the world agricultural trade (Walkowski, 2007).

However, in accordance with the concept of the European Model of Agriculture an equally essential role for the realisation of multi-functional rural development in Europe is played both by the instruments of the Common Agricultural Policy and the policy of economic, social and regional cohesion within the EU, as manifested in the Structural Funds (Barroso, 2005; Walkowski, 2007) aiming at the environmental protection and since 2013 also protection of local communities, creation of new jobs and reduction of greenhouse gas emissions (The CAP…, 2012). It needs to be stressed here that the primary aim of the cohesion policy is to ensure a higher level of regional cohesion within the EU thanks to the gradual elimination of disparity in the standard of living and living conditions for inhabitants of its individual regions.

In the case of agriculture the discrepancy between the idea of an efficient, market-oriented agriculture, sustainable, environmentally friendly development and territorial cohesion is particularly striking. The relationship between the aims of improving production efficiency and aims of the structural policy reflects dependencies between economic growth leading to disparity and the aspiration to attain territorial cohesion (Ryszkiewicz, 2013; Thematic Evaluation…, 2005; Bachtler et al., 2016). On the one hand, the EU transfers are to eliminate differences between regions in terms of their agricultural production efficiency, while on the other hand they should contribute to an accelerated development of regions in this area. Studies concerning entire economies have provided a general conclusion that a rapid economic growth of the whole country does not lead to a uniform level of development between its regions. Additionally, convergence between European regions does not progress at a rate adequate to the volume of EU funds allocated to that purpose (Pronobis, 2011).

In view of the above a question arises concerning the effect of the agricultural policy and the cohesion policy implemented in the first years after the greatest EU enlargement on the improvement of efficiency of agriculture in individual EU member countries, changes in the structure of this production as well as limitation of disparities in this respect. A particularly interesting hypothesis states that in agriculture, similarly as in the entire economies, production growth and improved efficiency in individual EU member countries do not coincide with the elimination of differences between regions. In view of the above the aim of this paper is to assess the effects of the agricultural policy and the cohesion policy implemented in the EU, focusing on the valuation of the impact of the greatest EU enlargement on this relationship.

The starting point for the analyses was provided by data published within the FADN agenda for average farms operating in individual EU member countries. Date of research should be connected not only with the availability of statistical data but also it should show the direction of changes in agriculture in the first dozen or so years after the admission of new members to the group of EU countries. In result data of research concerned 2004 and 2016. Realisation of this aim requires the application of multivariate quantitative methods, thanks to which the discussed problem may be considered in a comprehensive manner. Among the many possibilities it was decided to apply the DEA super-efficiency model, facilitating the construction of multivariate rankings for average farms in individual EU member countries. Thus this method provides a comparison of technical efficiency, which by definition to a lesser extent is burdened by the impact of various types of financial support. In this way the obtained assessments are closer to the free market principles, postulated in the assumptions of the Luxembourg CAP Reform. Additionally, the DEA methods make it possible to include several groups of agricultural products in the process of agricultural production involving many production inputs, which in turn facilitates evaluation of changes which have taken place in the structure of agricultural production over the investigated period.

The literature on the efficiency of agriculture is quite rich. It has been more detailed described in terms of the topics discussed and the methods used in the following chapters. However, it is worth emphasizing in this place, that in other publications the agriculture of individual EU countries was usually analysed from the perspective of only one a selected economic policy. From that point of view, the approach proposed in this article is really innovative because it proposes to use one numerical tool that allows analyzing EU agriculture both in terms of improving its effectiveness and the implementation of assumption of the cohesion policy.

The EU agricultural policy in view of assumptions of the cohesion policy

Already the Preamble to the Treaty of Rome contained references underlining the importance of economic cohesion in the European Community (Treaty of Rome, 1957). The primary instrument facilitating the realisation of the cohesion policy in the EU member countries was created in 1975 in the form of the European Regional Development Fund (ERDF). In the 1980s actions were undertaken to combine the cohesion policy with other economic areas. These concepts were confirmed when entering in the Article 23 of Single European Act the EC resolution on the strengthening of cohesion of its territory both in the economic and social aspects (Single European Act, 1987). Moreover, the formulation of the assumptions and implementation of the other EC policies (including the agricultural policy) had to be adapted to the conditions of economic and social cohesion. This meant that advantages resulting from the execution of other policies were considered positive on condition that their implementation does not increase regional disparities and does not lead to a deterioration of the position of poorer EU regions (Single European Act, 1987, Article 130). Such a position has been repeatedly underlined in successive years (see e.g. EU, 2004). At that time new principles were also specified for the EU cohesion policy for the years 1989-1993. The priorities for this policy included a reform of the CAP, modernisation and adaptation of the agricultural production structure as well as assistance in the development and structural changes in rural areas.

The key importance of the social and economic cohesion was also stated when the European Community decided to implement the Economic and Monetary Union, thus stressing that these actions concern also rural areas: “the community shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions, including rural areas (Treaty in European…, 1992, Title XIV). Nevertheless, it needs to be stressed that the European structural policy only complements the efforts made by the Member States, who carry the main responsibility for smoothing out regional differences. In this way, the European structural policy helps to ensure that competitiveness can be established or re-established and that there is a lasting improvement in economic development. At the turn of the new century one of the challenges for the EU cohesion policy again included actions aiming at a reduction of differences in the conservation and care of rural areas (EU, Opinion of the Committee.., 1998, 1.1.3 and 2.1.5).

The evaluation of the impact of the other EU policies on cohesion became particularly essential in relation to the EU enlargement, which took place in 2004. It was known that this change, due to its scale, would result in a decrease of mean GDP per capita in the entire European Union. As a result, this meant the exclusion from assistance for some regions, which had been receiving it before (Ryszkiewicz, 2013). In the case of the European Union particularly evident disparities were observed in terms of the level of economic development between the countries, which had formed and for many years had been operating within the EU structures and those, which became new EU members in 2004. The EU enlargement to include the 10 new members produced new challenges for the cohesion policy (European Commission, 2004).

The EU cohesion policy concerned all the economic areas. Nevertheless it was known that disparities in the efficiency of agricultural production were particularly high immediately before the greatest EU enlargement (Henning, 2008). For this reason in Agenda 2000 a significant position was assigned to problems of rural areas and agriculture (Agenda 2000…, 1997). On this basis since mid-1999 the countries of Central and Eastern Europe (CEECs) as well as Malta and Cyprus initiated the period of preparations to full EU membership. In order to reduce development disparities EU funds were allocated to actions in the candidate countries related to structural adaptations. They were executed within the framework of preaccession programmes. The most important role for agriculture was played by the Special Accession Programme for Agriculture and Rural Development (SAPARD). Its objectives, next to facilitation of integration of the agricultural sector with the EU, included also improvement of structures for processing agricultural and fishery products, and financing of integrated rural development projects aiming at improved efficiency of farms (Commission Regulation…, 2000).

In March 2000 the European Commission adopted the principles of the Lisbon strategy, aiming primarily at the establishment of possibly the most competitive and knowledge-oriented economy worldwide. Objectives of the Lisbon strategy within the CAP were finally confirmed in Luxembourg on 26 June 2003 (European Parliament, 2020). The Luxembourg CAP Reform was based on several principles. The first - the decoupling principle – assumed partial decoupling of direct payments from the volume of agricultural production, which was to weaken incentives to continuously increase its production, thus leading to a rapid increase in the EU expenditure on agriculture. In turn, the principle of cross-compliance assumed a dependence of payments to farms on their meeting specific standards, including those connected with environmental protection. In turn, the modulation principle allowed for a gradual increase in expenditure for the 2nd pillar of the CAP, i.e. the multifunctional rural development. Resolutions of the Luxembourg CAP Reform were also to eliminate the negative effects of payments in the allocation of resources. In turn, the allocation of additional funds to rural development was to contribute to an improvement of the condition of the natural environment and economic growth in structurally weaker regions.

The greatest EU enlargement to date resulted in the cohesion policy playing a key role in support for the economic regeneration of rural areas, complementing the action supported by the new rural development fund (European Agricultural Fund for Rural Development – EAFRD). In the years 2004-2006 the CAP objectives were supplemented to include further support for environmental protection and strengthening of the European Model of Agriculture (Wojtaszak, 2012). This complementary approach should seek to support the restructuring and diversification of the economy in Europe's rural areas. The synergy between structural, employment and rural development policies needs to be encouraged. In this context, the member states should ensure synergy and consistency between actions to be financed by the ERDR, Cohesion Fund, ESF, European Fishery Fund (EFF) and EAFRD on a given territory and in a given field of activity (EU, 2006; European Parliament, 2007).

Assumptions of the Luxembourg CAP Reform were implemented gradually. Nevertheless, as a result of a review of the CAP with the 2009 'Health Check': consolidation of the 2003 reform framework the effects of the CAP reform were found to be positive, particularly in the area of the complete decoupling of assistance from the volume of production, coupling of payments with actions addressing environmental protection, food safety and animal welfare, as well as making the intervention actions on the agricultural market more flexible so that they would not limit the farmers' capacity to respond to market signals (Wojtaszak, 2012). It was also stressed that the agricultural policy has to satisfy the growing world demand and to promote the model of agriculture sustainably using inputs and creating new jobs. It also has to allow for agriculture as a producer of renewable energy and biomaterials to combat climate change (European Parliament, 2009). The principles of the Common Agricultural Policy for the years 2014-2020 were finally adopted in December 2013 (EU, 2013).

The Reform of 2013 constituted the final stage in the still on-going process leading to the realisation of the Luxembourg CAP Reform assumptions. As a result of the latest step of the CAP reform was expanded to include new economic, environmental and territorial objectives. The new economic aims comprised the aspiration of the EU member countries to ensure food security thanks to sustainable agricultural production as well as increased competitiveness and better distribution of value in the food supply chain. (EU, 2013). Thanks to the realisation of these objectives, in the opinion of the European Commission the EU agriculture became more efficient, more competitive and sustainable (Overview of CAP…, 2013).

However, already in 2005 the European Council decided that the realisation of the Lisbon priorities concerning economic growth turned out to lack consistency in individual EC countries. What is more, previous challenges in the beginnings of the 21st century became even more pressing and urgent in view of the observed economic and social transformations related to globalisation and increasing competition, restructurisation processes and growing unemployment, economic migration and ageing of the populations (Barroso, 2005). On the other hand, despite the long-term actions undertaken to attain European cohesion the main aim of this policy, i.e. reduction of economic and social differences in the level of development in the European regions, might hardly be considered achieved. The European Parliament generally accepted the opinion that the cohesion policy needs to cover not only the regions requiring the support. Politicians put forward a claim that the cohesion policy is not solely a simple mechanism of solidarity, but its role is also to stimulate the internal development potential of the European regions (European Commission, 2008). Thus a question arises whether despite the actual links between the instruments adopted in the realisation of aims of the cohesion policy and the Common Agricultural Policy it is possible to simultaneously attain objectives related to improved efficiency and competitiveness of agriculture and reduce the disparity in the development levels between individual regions or member states.

As shown above in this paragraph, there are many sources and studies describing changes in the EU policy concerning the common agricultural policy or the cohesion policy. The literature on research into the efficiency of EU agriculture is also rich. Previous studies in this area are interesting due to the perspective of time taken into account (Coelli & Rao, 2005), the methods used (Baráth and Fertő, 2020; Prokopchuk et al., 2020), or the topics considered (Kusz, 2014).

The first of them (Coelly & Rao, 2005) gives us a comprehensive view of changes in productivity in the world. But they are based on data containing a substantial amount of aggregation, which relies upon the availability of comparable price information across countries, where data quality and definitions can vary substantially from one country to the next. As a result, this type of study produces fairly approximate country-level information. Baráth and Fertő (2020) also note the problem of using comparable data in cross-country analyzes, especially those relating to agricultural prices. In their research, they try to estimate a Total Factor Productivity (TFP) index for global agriculture and global agricultural regions. They show that TFP growth has accelerated in world agriculture, largely due to better performance in transition countries. What is more, Baráth & Fertő (2020) proved that TFP growth in the EU has increased, but at a slower rate in recent years. In the old EU members, the growth rate has decreased, whereas in the old EU members it has increased. In turn, Prokopchuk et al. (2020), in their research on the grain maize yield only, presented a completely different approach to determining changes in agricultural productivity. In their opinion, due to the specificity of agriculture production, it should also take into account whether factors. Thanks to the use of parametric methods, they defined the combined weather index, that can be used to estimate a weather risks at the regional level. The last one Kusz (2014) the correlation between the need to modernise agriculture and sustainable development. In his paper, he proves that in the near future, the agriculture –environment relation will be subject to the change taking into account, on the one hand, concern about the natural environment, and, on the other, pressure on increasing the efficiency of production. In his opinion, the above challenges will be addressed by the need to implement efficient and, at the same time, environmentally-friendly production technologies and relevant legal instruments which oblige agricultural producers to protect the natural environment.

However, it should be emphasized that, these researches usually analyse the efficiency of agriculture only from one or two of the above-mentioned perspectives: they concern either the analysis of changes in the assumptions of the common agricultural policy (European Parliament, 2020; Heyl et al., 2021), or the consequences of EU enlargement (Kavcic and Erjavec, 2003; Kroupová et al., 2020), the implementation of the cohesion policy (Ferry and McMaster, 2013; Mohl, 2016). The approach described in this article allows for the simultaneous consideration of the three above-mentioned perspectives.

Materials and methods

Data

Introduction of changes within the CAP, in view of their social character and the ideas promoted by the EU, requires a detailed analysis of the economic situation of farms in each of the EU member countries. For this purpose the European Commission established a system of accountancy data collection from farms: Farm Accounting Data Network (FADN, 2020), which makes it possible to determine the actual economic situation of farms. These data also constitute the basis for the evaluation of efficiency of invested EU funds and for the identification of the directions in systemic changes (Table 1).

Countries	Direction of agricultural production 2004				Direction of agricultural production 2016			
	plant	animal	mixed	total	plant	animal	mixed	total
(ITA) Italy	80%	14%	6%	854140	77%	18%	5%	532030
(FRA) France	43%	44%	13%	313920	50%	37%	13%	296620
(DEU) Germany	28%	54%	18%	210340	32%	53%	15%	186190
(NED) Netherlands	41%	54%	5%	51710	38%	60%	1%	43310
(BEL) Belgium	25%	56%	19%	32520	33%	54%	13%	25650
(LUX) Luxembourg		95%	5%	1280	5%	89%	6%	1270
(IRE) Ireland	1%	97%	2%	105730	0%	100%		77100
(UKI) United Kingdom	27%	64%	9%	100240	29%	63%	7%	95670
(DAN) Denmark	43%	41%	16%	31600	58%	34%	8%	24010
(ELL) Greece	81%	9%	10%	384250	79%	16%	5%	327620
(ESP) Spain	74%	22%	4%	577730	71%	24%	5%	421940
(POR) Portugal	49%	32%	19%	108900	54%	32%	14%	94490
(OST) Austria	21%	71%	8%	85140	24%	67%	9%	85690
(SUO) Finland	45%	54%	1%	35670	64%	36%		33080
(SVE) Sweden	24%	70%	6%	29720	37%	58%	5%	22540
(POL) Poland	27%	20%	53%	727620	45%	20%	36%	724360
(HUN) Hungary	62%	16%	22%	77860	67%	9%	24%	95390
(SVN) Slovenia		67%	33%	33470	21%	53%	26%	39300
(LTU) Lithuania	31%	33%	36%	31760	30%	43%	27%	59810
(LVA) Latvia	15%	35%	50%	21090	26%	41%	33%	21580
(CZE) Czech Republic	41%	26%	33%	13820	45%	30%	25%	15530
(CYP) Cyprus	88%	12%		9100	86%	7%	7%	7170
(EST) Estonia	39%	40%	21%	3820	47%	37%	16%	6030
(SVK) Slovakia	71%	10%	19%	2710	62%	24%	13%	2980
(MLT) Malta	76%	24%		1230	80%	20%		2260
OLD members mean	61%	31%	8%	2922890	59%	33%	7%	2267210
NEW members mean	30%	22%	48%	922480	45%	22%	33%	974410

Source: the author's study based on data published by FADN (2020)

Table 1: The number and structure of farms in 2004 and 2016 depending on the direction of agricultural production.

The starting point for the historical analysis of the effects of the CAP after 2004 was provided by the data concerning average farms in individual EU member countries in 2004 and in 2016. The selection of data, particularly for inputs, typically is problematic for researchers. In this study the selected set of variables was to reflect the participation of the four basic production factors (inputs) involved in the production process, i.e. land, labour, fixed capital and operating capital, along with three outcome variables, such as the values of plant, animal and other production.

Inputs of labour (in the FADN methodology designated as SE010) were expressed by the number of employees working full-time on the farm. The next input, land, was described in ha of utilised agricultural area UAA (SE025). The other variable used in the analysis are monetary and they are expressed in thousands of Euro (1000 €). In this way the value of operating capital involved in agricultural production was expressed (the value of SE270 less depreciation SE360) and the value of fixed capital (the total values of buildings SE450, machines SE455 and foundation stock SE460). The outcome variables were also expressed in terms of values: the volume of plant production (SE135), the volume of animal production (SE206) and the other agricultural production (SE256).

It also needs to be stressed that the example below refers to a historical assessment of changes in productivity of farms depending on the direction of agricultural production in individual EU member countries. Thus volumes of production referred to involved inputs are compared. In contrast, the profitability of production is not considered, which at the system of direct payments and subsidies provided within the Common Agricultural Policy is not a measure identical or close to the approach proposed in this study (Zhu et al., 2012). Nevertheless, it seems that such a comparison, in view of the assumptions of the Luxembourg CAP Reform presented above, would more reliably reflect changes in the efficiency of utilisation of material inputs in EU farms, resulting from the changing market situation.

The FADN agenda makes available the data concerning average EU farms at varying levels of generalisation. Among the many options in the presented study the data used were collected for eight types of farming: 1) fieldcrops, 2) horticulture, 3) wine, 4) other permanent crops, 5) milk, 6) other grazing livestock, 7) granivores, and 8) mixed. In order to distinguish the three directions of production the values of respective types of farms were totalled using the weighted means. In this aggregation, similarly as it is done within the FADN, the number of farms representing a given type of production was used, as listed in the Table 1. In this way in order to obtain the values of variables for plant production the values corresponding to the first four types of farms were aggregated. In turn, the value of animal production comprised values characterising types of dairy farms, those rearing other grazing livestock and granivores. A separate group was composed of mixed type farms. Empty fields mean that in a given year in the agriculture of a given country there were no farms specialising in a given type of production. Additionally, in order to realise the aims of this study in the same manner – using weighted means – the average values of investigated indexes were established for the countries, which until 2004 formed the EU (EU-15, or old EU members) as well as those, which within the greatest to date EU enlargement in that year joined the EU (EU-10, or new EU members).

Rankings of efficiency

One of the quantitative tools used to assess the effects of an economic policy pursued in a given period is to construct rankings of territorial units comprising a given region. A particularly important role in the case of economic problems is played by rankings taking into consideration economic efficiency of the investigated entities. On the one hand, a comparison of rankings constructed for different time points makes it possible to determine the scope of divergence between the entities, which may be a measure of economic cohesion. On the other hand, a comparison of rankings indicates changes in the position of individual entities within the ranking, thus showing improvement or deterioration of their relative efficiency. Rankings may be univariate, i.e. based on a single product and one factor of production. However, the area of the comparison is typically multivariate.

In order to objectively assess within a given timeframe the effect of the agricultural policy and the cohesion policy implemented in the first years of the greatest EU enlargement on the structure of agricultural production, it is necessary to simultaneously consider many outcomes generated in that process (or their groups) in relation to inputs. A ranking of efficiency assuming the simultaneous generation of many products in the production process based on the multiple inputs involved may be prepared thanks to the application of non-parametric methods (see e.g. Charnes et al., 1978; Farrell 1957), particularly the Data Envelopment Analysis (DEA), a method well-established in the world and Polish literature on the subject (see e.g.: Førsund and Sarafoglou, 2002; Guzik, 2009a, Kocisova et al., 2018; Scippacercola and Sepe, 2014). This method also facilitates incorporation of variable effects of scale for specific production. As any method it has numerous advantages and certain drawbacks. A review of ranking methods based on DEA was presented by Adler et al. (2002). One of the approaches discussed in that publication was the application of the super-efficiency DEA model (SE-CCR), which makes it possible to construct a ranking both for reference units and for inefficient ones. This model was described in detail e.g. by Guzik (2009a). It needs to be stressed that this approach is popular in literature on the subject (Jahanshahloo et al. 2011; Li et al., 2007; Mosbah et al., 2020). It was also presented in a study by Błażejczyk-Majka (2016).

The super-efficiency DEA model

It needs to be stressed that the Data Envelopment Analysis (DEA) is typically used to asses efficiency of entities making independent economic decisions (decision-making units, DMUs) rather than sets of entities. Nevertheless, in the case of the EU agriculture decisions concerning the volume or directions of support for farms, or the level of convergence are made at the national level. In this sense averaged farms at the national level may be treated as decision-making units. A comparison of efficiency based on DEA for aggregate units, such as average farms at the regional or national level may be found in many publications (Błażejczyk-Majka et al., 2012; Coelli and Rao 2005; Galluzzo 2016; Zhu et al., 2012). The application of non-parametric methods to compare productivity at the international level was described in detail by Coelli et al. (2005).

The DEA consists in the solution of a series of linear equations, based on which maximum technical efficiency may be determined (Debreu 1951; Koopmans 1951). This is done by comparing vectors of results - outputs q and inputs x in all investigated decision-making units (DMU_i) (i = 1, 2, …, I). A necessary conditions to be met in this analysis is to indicate the type of technology. It may be based on the constant return to scale (CRS) or variable return to scale (VRS). In this analysis it is also necessary to define the orientation of the production run by the entities, which may consist in maximisation of production (outputs maximisation) or minimisation of inputs used in the production process (inputs minimisation). A detailed description of this method may be found in publications by Coelli et al. (2005) and Thanassoulis et al. (2008).

In the case of an assumption that production generates constant effects of scale and is oriented to minimise used inputs x_n (n = 1, 2, …, N) required to generate outputs q_r (r = 1, 2, …, R), the DEA method makes it possible to determine technical efficiency by solving I linear programmes, one for each DMU (Charnes et al., 1978; Coelli et al., 2005). Efficiency of each unit is thus assessed compared to all the objects in the group:

Objective function: $\mathrm{Min}_{\theta\lambda}\, \theta_i$ (1)

subject to:
$$\boldsymbol{Q\lambda} \geq q_i,$$
$$\theta_i x_i \geq \boldsymbol{X\lambda},$$
$$\boldsymbol{\lambda} \geq 0,$$
$$\theta_i \leq 1$$

where θ_i is a scalar referred to as the multiplier of input levels (Guzik 2009b). In turn, λ is the vector of constans. A single component of this vector, reflecting the relationship between the o-th DMU, for which the programme of linear equations is solved with any j-th DMU from the tested group, will be denoted by scalar λ_{oj}. For each analysed unit its values are estimated in relation to the other units. Matrices X and Q correspond to inputs and outputs of all DMUs participating in the analysis. In turn, vectors x_i and q_i refer to incurred inputs and produced outputs in the i-th DMU. Such a formulated programme of linear equations is named after the authors of this approach Charnes et. al. (1978) and it referred to in literature on the subject as the CCR model (Førsund and Sarafoglou 2002). It should be mentioned here that this approach presents one of the methods to improve efficiency in an enterprise, such as lean management through reduction of inputs.

The multiplier of the level of inputs θi may assume values from the range of [0; 1], which define technical efficiency of the i-th DMU, also called θ-efficiency sensu Farrell (Coelli et al., 2005). All DMUs, for which $\theta_i < 1$ are considered inefficient. In turn, if $\theta_i = 1$, it means that the i-th DMU is characterised by the highest efficiency in the entire group – it is the leader, a reference unit. Typically in the course of the analysis it turns out that there are several such units, which hinders the application of this model to construct a ranking (Fried, et al., 2008).

The super-efficiency SE-CCR model is an extension of the CCR model (Andersen and Petersen, 1993). The programme of linear equations (1) is supplemented with an additional limiting condition: for the o-th DMU it is assumed that $\lambda_o = 0$. In order to distinguish the results of both methods the multiplier of the level of inputs, denoted in CCR as θ_i, in SE-CCR is described as ρ_o. Moreover, in SE-CCR the assumption that the multiplier of the level of inputs $\rho_o \leq 1$ is rejected. Thanks to such changes, efficiency of the o-th DMU is considered in relation to the group of the other DMUs excluding the o-th DMU and values of ρ-technical efficiency provided by the solution of the system of linear equations may assume values greater than 1. The value of $\rho_o \geq 1$ indicates a relative advantage of the o-th unit over the other units in the investigated group. The greater the multiplier ρ_o, the more efficient a given object is, since a smaller input provides assumed outputs (Guzik 2009a). In turn, if $\rho_o < 1$ then its value is equal to values θ_i determined by the CCR model. Such a situation means that competitors of the o-th DMU would have reached the same level of production at a smaller input. Thus the object is not efficient.

In the case of DEA it is assumed that the set of objects has to be homogeneous. This results from the postulate that the reference for an inefficient unit needs to be a technology feasibly attainable for this unit. Results provided by DEA are dependent on the number of analysed DMUs and the number of analysed variables. When the super-efficiency model is used then multivariate comparative analysis methods may be applied. In turn, Guzik (2009a) proposed testing of homogeneity of the set of units based on subjective adopted limits of homogeneity. In this study an intermediate solution is proposed: those units will be considered as failing to meet the condition of homogeneity, which may be considered as exhibiting insufficient or excessive efficiency in relation to the typical transformation of inputs into outcomes, i.e. those found outside the limits of homogeneity. The univariate quartile criterion (Tukey 1977) was adopted as the definition for limits of homogeneity, with the lower (ρ_D) and upper limits of homogeneity (ρ_U) assuming the form:

$$\rho_D = Q_1 - 3(Q_3 - Q_1),\ \rho_U = Q_3 + 3(Q_3 - Q_1). \qquad (2)$$

where Q_1 and Q_3 are the first and third quartile of values of ranking indicators ρ_o of all DMUs participating in the test. An identical solution is applied to determine extreme values in box-plots. Due to the fact that the values of estimated ranking indicators may change depending on the number of units in the analysed group (Guzik 2009b), the testing procedure for the homogeneity of the set of objects will consist in (stage 1) the determination of ranking indexes for all the units and the elimination of these units, which proved to be excessively or insufficiently effective. In stage 2 ranking indexes are determined for units from the already reduced set and again the homogeneity of the results is tested. The procedure is repeated until a homogeneous set is obtained, when all the units are found within the limits of homogeneity.

It also needs to be mentioned here that the DEA analysis is made available in many commercial statistical programmes. An open-source version of the DEAP programme developed specially for this method may be downloaded from the website of the Centre for Efficiency and Productivity Analysis (CEPA; 2020). Apart from the software an extensive description and a user's manual are also provided. In this study for the SE-CCR model the options of the Solver function of Excel were applied.

Results and discussion

The construction of a ranking for efficiency of average farms specialising in agricultural production within individual EU member countries, at the involvement of the four basic inputs and taking into consideration three groups of products, is made possible by the application of the super-efficiency SE-CCR model. In the proposed approach in this manner six rankings were constructed, separately for each of the investigated types of agricultural production, in both analysed years. Table 2 gives values of ranking indexes ρ_0 obtained at the application of this method, focused on input savings. The table comprises only the effect of the final calculations, which were preceded by several stages related with the identification of excessively efficient units (cf. formulas (2)). All the testing stages for the homogeneity of the set of investigated objects may be followed based on a publication by Błażejczyk-Majka (2016). What is more, the Table 2 shows in bold the results of these DMUs, which in the understanding of the SE-CCR model proved to be efficient, while the last two rows contain weighted mean values of ranking indexes ρ_0, determined for the EU15 and the EU-10 (i.e., the countries, which became full members in 2004). Similarly as above, the weights in the aggregation were the numbers of farms representing a given type of production, as listed in Table 1.

As a result of testing of the homogeneity in the set of investigated units, among the average farms in individual EU countries in 2004 farms specialising in plant production in Denmark and the Netherlands were considered excessively efficient. After over a decade this group was joined by Belgian agriculture, while Dutch farms showed the highest plant production, although this technology was already available for the other EU countries. In turn, in 2016 the technology of mixed agricultural production of average Dutch farms was considered to be excessively efficient. In the case of animal production the excessively efficient technology, feasibly unattainable for the other countries was found for the average Maltese farms in both years of the study.

When analysing the research results concerning plant production it may be observed that the lowest technical efficiency in the group of the EU-15 countries in 2004 was recorded for the Portuguese and Finnish agriculture. In 2016 this group was joined by Greek agriculture. However, it needs to be stressed that in the case of Portuguese agriculture an increase in average productivity through a reduction of inputs involved in the production process by 10% in 2004 and by 7% in 2016 would

Country	Crop production		Animal production		Mixed production	
	2004	2016	2004	2016	2004	2016
(ITA)	(12) **1.125**	(10) **1.214**	(7) 1.662	(7) 1.395	(8) 1.326	(8) 1.319
(FRA)	(13) **1.111**	(13) **1.094**	(22) 0.827	(21) 0.828	(21) 0.847	(17) 0.950
(DEU)	(3) **1.842**	(14) **1.063**	(14) 1.057	(15) 0.976	(10) 1.298	(9) 1.254
(NED)	*	(1) **1.952**	(1) 2.263	(2) 2.173	(2) 2.126	*
(BEL)	(1) **2.609**	*	(11) 1.116	(13) 1.012	(3) 1.519	(2) 1.981
(LUX)		(6) **1.483**	(9) 1.231	(10) 1.095	(12) 1.184	(16) 0.971
(IRE)	(9) **1.277**		(20) 0.882	(22) 0.810	(22) 0.847	
(UKI)	(6) **1.462**	(7) **1.377**	(16) 1.030	(19) 0.884	(13) 1.170	(12) 1.109
(DAN)	*	*	(3) 1.885	(4) 1.714	(16) 1.095	(1) 2.001
(ELL)	(7) **1.427**	(19) 0.860	(10) 1.217	(16) 0.974	(5) 1.388	(11) 1.151
(ESP)	(8) **1.419**	(8) **1.293**	(12) 1.085	(14) 1.004	(9) 1.299	(10) 1.233
(POR)	(17) **0.900**	(18) 0.934	(21) 0.846	(20) 0.838	(20) 0.889	(6) 1.416
(OST)	(10) **1.273**	(3) **1.675**	(2) 2.152	(3) 1.715	(1) 2.204	(4) 1.542
(SUO)	(21) 0.660	(21) 0.761	(24) 0.714	(24) 0.783	(23) 0.646	
(SVE)	(2) **1.912**	(2) **1.696**	(8) 1.477	(6) 1.478	(4) 1.435	(7) 1.330
(POL)	(18) 0.835	(17) 0.970	(19) 0.906	(18) 0.891	(17) 1.037	(20) 0.712
(HUN)	(16) 0.909	(12) **1.130**	(4) 1.713	(8) 1.200	(6) 1.382	(14) 1.011
(SVN)		(11) **1.171**	(17) 0.969	(5) 1.596	(15) 1.097	(13) 1.047
(LTU)	(15) 0.911	(20) 0.806	(6) 1.670	(9) 1.190	(11) 1.239	(18) 0.832
(LVA)	(14) **1.026**	(22) 0.733	(5) 1.697	(11) 1.044	(14) 1.101	(19) 0.822
(CZE)	(4) **1.542**	(15) **1.004**	(13) 1.076	(17) 0.891	(18) 0.959	(15) 0.987
(CYP)	(20) 0.695	(9) **1.262**	(18) 0.967	(23) 0.801		(5) 1.531
(EST)	(19) 0.750	(16) 0.979	(15) 1.044	(12) 1.013	(7) 1.346	(21) 0.698
(SVK)	(11) **1.142**	(5) **1.487**	(23) 0.753	(1) 2.447	(19) 0.910	(3) 1.606
(MLT)	(5) **1.466**	(4) **1.631**	*	*		
OLD members mean	(9.9) 1.254	(12.0) 1.121	(13.6) 1.049	(14.5) 1.261	(11.2) 1.215	(10.4) 1.221
NEW members mean	(17.2) 0.867	(16.1) 0.966	(16.5) 0.988	(14.8) 1.080	(16.3) 0.979	(19.1) 0.758

Note: * excessively efficient production technology, considerably exceeding the capabilities of the other countries. Source: the author's calculations based on FADN data.

Source: The author's calculations based on FADN data.

Table 2: Positions in ranking and ranking indexes ρ_0 obtained using SE-CCR of average farms in individual EU countries in 2004 and 2016.

have made it possible for that country to join the group of leaders. Analysis of efficiency of farms specialising in plant production in the countries, which accessed the EU in 2004 indicates that the position of leaders was only attained by the Czech and Maltese, Slovak and Latvian agriculture. However, it needs to be stressed that the most efficient among the new EU member countries, i.e. farms specialising in plant production in the Czech Republic – turned out to be over 1.5-fold less efficient than Belgian farms specialising in plant production, belonging to the group of "old" EU member countries (EU-15). In turn, in 2016 a considerable deterioration in the ranking of efficiency was recorded for plant production in average German, Greek and Czech farms. Generally it may be stated that in 2016 diversification in terms of plant production efficiency between both groups of countries was markedly reduced. This is manifested both in the average efficiencies and positions in the ranking presented in the last rows of Table 2 as well as the differences between efficiencies of the best average farms in both analysed groups.

In contrast, a different situation was observed for animal production. In 2004 among the fifteen average farms specialising in animal production in the EU-15 only four were characterised by an inefficient production technology. These included Finnish, Portuguese, Irish and French agriculture. In 2016 this group was composed of as many as seven countries. The above-mentioned were joined by Greek and British agriculture. Particularly in the case of Greek agriculture the reduction in efficiency of farms specialising in animal production in the investigated period was considerable. In turn, among the countries, which became full EU members in 2004, a situation was observed, which may be interpreted as almost opposite: only in relation to four countries – Slovakia, Cyprus, Slovenia and Poland – animal production may have been run more efficiently (cf. Kocisova et al., 2018). These results correspond to studies carried out separately for the production of pigs or milk (Błażejczyk-Majka and Kala, 2015b; Havlíček et al., 2020; Kroupová et al., 2020). Nevertheless, it needs to be stressed that except for Slovakian agriculture reaching full efficiency of farms specialising in animal production was connected with the limitation of the consumption of inputs by max. 10%. A comparison of the results concerning efficiency of plant and animal production in 2004 indicates that the gap between efficiency of animal production in the "old" and "new" EU member countries was much smaller than in the case of plant production. This result can be a voice in the discussion to the conclusions of Kusz (2014) or Heyl et al. (2021) who argued that modernization in modern agriculture is limited by environmental requirements, finiteness of natural resources, alongside the "rights" of farm animals as well as the social and cultural consequences, such as those related to the viability of rural areas. What is more, after over a decade of operation with the CAP and the realisation of the Luxembourg CAP Reform assumptions the gap between the "old" and "new" EU member countries in terms of animal production was greatly reduced. In the case of animal production we may even talk about its elimination. Of course, it is difficult to decide at this stage of the research to what extent this situation had been determined by the EU and national funding of EU cohesion policy (Ferry & McMaster, 2013).

As was shown in the analysis concerning farm structure in the EU (cf. Table 1) since the greatest to date EU enlargement in 2016 the number of farms specialising in mixed production was markedly reduced. This trend was particularly evident in the countries, which became full EU members in 2004 and was observed in another research too (Lucyna Błażejczyk-Majka and Kala, 2015a). In turn, based on the results of the SE-CCR model (cf. Table 2) it may be stated that efficiency of this type of farms in the "new" EU countries deteriorated. In 2004 six new EU countries ran agricultural production efficiently. In the next investigated year this number decreased to four. Only mixed farms in Slovakia (similarly as in the case of plant and animal production) recorded a considerable increase in efficiency. In turn, in the case of the EU-15 as many as six countries showed an increase in the ranking position, while in the case of Danish agriculture it was an extreme improvement of agricultural production efficiency.

Conclusion

The agricultural policy of the European Communities, and later the European Union has always aimed at reaching food self-sufficiency for its population. In turn, the beginning of the 21st century has marked the need for free agricultural markets and face strong external competition, which has been connected with an almost complete rejection of the Common Agricultural Policy instruments related with direct support for agricultural production. In such a situation the aim connected with the maintenance of food self-sufficiency of the EU member countries has become practically equivalent to the need for improvement of production efficiency in individual EU countries. On the other hand, since the very beginning the European Community has been striving to reduce the differences existing between the various regions and the backwardness of the less favoured regions (Treaty of Rome 1957). At the turn of the 20th and the 21st century the cohesion policy became a priority in relation to the other policies. Agriculture and rural areas are currently supported indirectly by eliminating barriers for convergence processes, particularly by strengthening the economic, social and cultural as well as the institutional and business environments (Kudełko et al., 2011). An especially interesting aspect is connected with the coupling of this trend with the CAP assumptions, which was manifested in the Luxembourg CAP Reform introduced in 2003.

The conducted analyses show that agricultural production in the EU is characterised by certain diversification, although in most cases efficiency of farms is comparable. In the case of the EU agriculture in 2004 only three countries ran agricultural production in technologies, which efficiency may not have been attainable for agriculture of any other EU country investigated in this study. In this respect the technology of plant production applied in the Netherlands and Denmark as well as the technology of animal production used in specialist farms in Malta. In 2016, the group of these countries was joined by Belgium (plant production). In the case of Dutch agriculture after over a decade of the CAP operation the plant production technology in that country became attainable, but it was the most efficient among all those used in the EU. In turn, efficiency of mixed farms in the Netherlands in the last investigated year was considerably different from the potential of farms in the other EU member countries.

In the first months of the realisation of the Luxembourg CAP Reform assumptions and in the year of the greatest EU enlargement it was shown that the "old" EU countries while far from homogeneous in terms of the outcomes, nevertheless showed on average higher efficiency in each of the three types of agricultural production. The most evident disparities were recorded in the case of plant production, while they were smallest in mixed production. Analysis of the outcomes conducted analogously for the year 2016 indicated that the gap between the "old" and the "new" member countries has narrowed, although these changes were not uniform. these results can be considered as complementary and detailed to the conclusions of (Baráth and Fertő, 2020).

Study results confirmed the necessity to conduct such comparisons taking into consideration the type of agricultural production. The most evident improvement was recorded in the case of animal production. In that area even a gradual unification may be observed in the level of agricultural production efficiency. This situation may have been influenced by the high environmental standards in animal production, common and equal for all the EU member countries, which have to be met by agricultural producers, and which in accordance with the Luxembourg CAP Reform assumptions are an indispensable element of support for agriculture.

A particularly important aspect is related with changes in farms specialising in mixed production. Firstly, the quantitative analysis for the structure of the EU farms indicated that the Luxembourg CAP Reform in the area of agriculture led to changes in farm structure. Especially marked changes may have been observed in the case of the "new" EU countries, with a marked farm specialisation. It was manifested in the reduced share of mixed farms at an increase in the number of farms specialising in plant production. Changes in that direction seem simpler and cheaper to implement than those towards the more input-intensive animal production.

Based on these conclusions the preliminary research hypothesis presented in the Introduction may be partly rejected. It turned out that in the EU agriculture in the case of plant and animal production, in contrast to the situation observed in the other branches of the economy in the years 2004 – 2015, a simultaneous growth of production and improvement of efficiency could be attained in individual EU member countries, along with a gradual reduction of disparities in the efficiency of agricultural production between the regions. However, this process was not uniform and it is necessary to distinguish the differences in the rate of changes in individual types of farms. The only area, in which no such dependence could be observed, is connected with production of mixed-type farms.

The presented approach allows for a comprehensive and multidimensional evaluation of changes in agricultural productivity in agriculture of individual EU members, and, consequently, for a macroeconomic assessment of the effects of the constantly implemented reforms of the CAP and the cohesion policy. However, the presented results have been established for selected years. To establish the trend of changes in this area, analyses should be made for each year of the period under examination. This is the direction of further research.

Corresponding authors:
Lucyna Błażejczyk-Majka
Department of Economic History, Adam Mickiewicz University in Poznań
ul. Uniwersytetu Poznańskiego 7, 61-614 Poznań, Poland
Phone: +48 61 829 15 26, E-mail: majkal@amu.edu.pl
ORCID: 0000-0002-4439-8351

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