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Economic and energy efficiency of agriculture

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Abstract: Article concerns economic and energy efficiency of agriculture in European Union countries. The study period concerned 2016. For analysis and presentation of materials, descriptive, tabular and graphic methods and the Data Envelopment Analysis (DEA) method – CCR (Charnes, Cooper and Rhodes) model focused on input-oriented minimisation were used. An assessment of the socio-economic development of the EU countries was made using the following measures: Human Development Index (HDI) and Gross Domestic Product (GDP) per capita (USD per inhabitant). Modern agriculture depends on industrial energy sources and as the socio-economic development changes into more and more energy-intensive production technologies. After presenting the introduction and review of the literature, the economic and energy efficiency of agriculture in the EU countries in 2016 was examined, which was at a high level – the DEA reached 0.67. Then, the correlation between the socio-economic development of countries and their economic and energy efficiency was analysed. It was also found that along with socio-economic development in the EU countries, the economic and energy efficiency of agriculture is increasing.

Keywords: Data Envelopment Analysis (DEA) method; energy resources; European Union; socio-economic development

The present level of human life has been achieved thanks to the exploitation of natural capital on an unprecedented scale. This causes a growing interference in the state of the planet and an increase in uncertainty about its future. Currently, the most developed economies can observe trends that are based on the cult of economic growth and the consumption of goods and services whose production is based on resources obtained from the environment. The proper counterweight can be sustainable development, which requires the creation of a relationship between the economy, society, and the environment, which will not affect the ability of the environment to provide its services in the future (Svatoš 2005). It is also important to treat the environmental issues on a supranational and global level, treating the Earth's ecosystem as a common good. The negation of such an idea is, for example, the transfer by rich countries (pseudo-sustainable) of energy-intensive and "environmentally dirty" production to other areas of the globe. An important problem is also the uneven distribution of natural resources, in particular minerals that are the main sources of energy. The situation in which several countries have a good, from which one can no longer be excluded, is very dangerous. International dependencies of energy and raw materials are becoming an element of pressure and might be the cause of socio-economic crises.

Technological nature of human existence dependent on external sources of energy has become a prerequisite for the existence of any civilisation and the driving force behind every action. This confirms the contemporary dependence of mankind on energy, which deter-

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mines economic growth, the standard of living, and can be a source of international conflicts. One of the main problems is the limitation of its sources, in particular those of non-renewable.

Another problem is the negative impact of energy production from non-renewable sources on the environment. The main negative is the high emission of greenhouse gases and the interference of conventional energy into the ecosystem. Climate change and negative environmental effects are the results of a simplified understanding of economic processes, consisting of adopting economic effects as a basis for development, without taking into account external costs. Making an assessment solely using the classical measurement of economic efficiency turned out to be a wrong approach, giving incorrect information from sustainable development. Economically efficient objects are not always environmentally effective. Due to the existing conflict of economic and environmental goals, it is necessary to look for measures that would include both economic and environmental elements. The above doubts were one of the main reasons to research the presented article. Another reason was the dependence of the world economy and its growth from limited natural resources, and on the other hand, the growing demand for energy. Besides, there is a need to improve energy efficiency and reduce greenhouse gas emissions on a micro and macro scale.

One of the important sectors of the economy, where energy is an indispensable factor of production, is agriculture. Modern agriculture depends on industrial materials resources and energy sources and, along with socio-economic development, it is moving to more and more energy-intensive production technologies. A negative phenomenon is an existing dependence that along with the increase in energy consumption from fossil fuels, the unit of energy expended gives smaller production increases, which results directly from the law of diminishing revenues.

The main aim of the work was to assess the economic and energy efficiency of agriculture in the EU countries and to determine the relationship between the socio-economic development of these countries and the economic and energy efficiency of agriculture.

LITERATURE REVIEW

Since its inception, civilisation has been dependent on the use of natural resources. The first phase of human development, combined with the development of the so-called I sector (agriculture), called by Toffler (1980) "the first wave", began around 8000 BC and lasted until the eighteenth century. Civilisation has used, especially in the field of energy carriers, renewable raw materials available in general: wood, water, wind and the muscular strength of animals and humans. Nature coped with the refilling of man-made raw material. First and foremost, the changes caused by typically agricultural activities were irreversible, resulting in far-reaching soil erosion and, as a result, the process of secondary stepping and desertification. The "second wave" society (the industrial era) used primarily non-renewable resources. This accelerated the development of civilisation, which on the basis of feedback caused an increase in the demand for resources.

The basis for the philosophy of using natural resources are two questions. The first – where do natural goods come from, and the second – how to use them, on the one hand, in a decent way to bring happiness, both the person to whom it is provided and the pensioner (from Latin *bonum honestum*), on the other hand, how to use them to bring material benefits (from Latin *bonum utile*) and give us pleasure (from Latin *bonum delectabile*).

The problem of limited resources of natural resources has existed for a long time in economic theories. Already in antiquity, Plato expressed concerns about natural resources that are non-renewable. The physiocrats believed that the wealth of society depends on the natural productivity of the land. Adam Smith at the beginning of the 19th century, claimed that the environment is a natural barrier to economic growth. Thomas Malthus, David Ricardo, and John Stuart Mill played the most important role in creating modern resource theory. Malthusian paradigm (being the basis of static resource theory) forming the basis of the idea of Malthusianism always assumes an absolute boundary of resources. The Ricardo paradigm is the basis of the dynamic theory of natural resources, assuming the continuous enlargement of the resource base by assigning the new element of natural resources of the environment the possibility to use its properties to meet human needs, based on the achievements of technical progress and the development of human knowledge. The neo-classical economics is primarily Pareto efficiency, the Pigovian tax, the Hotelling's rule, and the Nordhaus theory.

Energy raw materials are an element of natural resources that are intensively exploited in the modern world. The development of civilisation and the economy causes an increased demand for energy, which is a multidimensional concept. They can be considered in various aspects:

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- Economic – energy is a good or a set of goods that are traded on global markets;
- Ecological – energy sources are classified as clean or polluting environment, and the primary goal is sustainable development;
- Social – access to energy is the basic social value resulting from the necessity of satisfying living needs, which enforces fair distribution among consumers;
- Geopolitical – energy resources and geographical location of resources (mainly fossil fuels) shape interstate relations and energy security of the state.

Energy raw materials have an impact on economic processes in the modern world, their role and importance to the economy are decisive. Every type of human economic activity requires the use of energy. Agriculture, industry, production of goods or provision of services cannot exist without the smallest portion of energy, in particular from oil, gas, and coal. The Earth without hydrocarbons would face a catastrophe. The challenge for humanity is to properly manage the resources of raw materials, which are exhausted and unevenly distributed around the world. Several countries have over 80% of global reserves (in the case of coal, the 10 countries with the largest reserves have 93% of global reserves). Such an arrangement of energy potentials causes that other countries and societies depend on energy raw materials monopolists. This is a problem, because modern civilisation is more than ever a "slave" of energy, and therefore countries having energy raw materials.

MATERIAL AND METHODS

Assessing only with the help of a classic measurement of economic efficiency has proved to be a wrong approach, giving the wrong information from the point of view of sustainable development. Economically effective facilities are not always environmentally effective. In connection with the existing conflict of economic and environmental goals, it seems necessary to search for measures that would include both economic and environmental elements. In the adopted Data Envelopment Analysis (DEA) method, several expenditures were adopted simultaneously, both in the field of economics (work, land) and the environment (energy), which should be considered innovative in research on effectiveness in agriculture. Also, a model focused on minimising inputs has been chosen, which is in line with the current needs of economic and rational management of limited resources.

To determine the economic and energy efficiency of agriculture in the EU countries, the DEA method – the CCR (Charnes, Cooper and Rhodes) model focused on input-oriented minimisation was used. The model's orientation towards the minimisation of expenditures was adopted, as following the EU legislation on environmental policies and disseminated principles of sustainable development, which assumed that the only currently accepted development option for European agriculture is the increase in agricultural production through innovation and de-intensification of inputs.

Based on the literature review, the following variables were adopted for the model:

- Effect 1 – gross value added in agriculture (EUR);
- Input X_1 – an area of agricultural land (ha);
- Input X_2 – employment in agriculture (people);
- Input X_3 – energy consumption (one thousand tons of equivalent oil).

The source material for the research was data for 2016 published in EUROSTAT databases. Data from 2016 were the last available data at the time of the study. Part of the material was obtained from data of the United Nations Development Program (UNDP 2016) and World Bank (2018). Objects for research were chosen in the way of purposeful sampling. The research was carried out in the agricultural sectors from individual the EU countries, taking into account the following conditions:

- Criterion 1 – data on agriculture in a given country were complete;
- Criterion 2 – the share of the value of agricultural production in the total the EU agricultural production was above 0.5%.

The adoption of the above criteria was dictated by the necessity of obtaining data necessary to implement the main research objective, which consists of determining the relationship between the socioeconomic growth of the country and the effectiveness of agriculture. As a result of the adopted criteria, 24 out of 28 Member States were selected. From the research sample, as a result of criterion 1, Germany was eliminated, for which there is no complete data on energy consumption in agriculture. Due to the second criterion, Malta, Luxembourg, and Cyprus were removed from the sample. The share of the production value of agriculture in Malta, Luxembourg, and Cyprus in the total the EU agricultural production is 0.03, 0.1, and 0.1% respectively, therefore these are countries of negligible importance for the EU agriculture.

The DEA method is classified as nonparametric methods for testing the effectiveness of objects. In 1978, the authors of the DEA method (Charnes,

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Cooper and Rhodes), based on the concept of productivity formulated by Debreu and Farell, defining the measure of productivity as a quotient of a single effect and single effort, applied it to a multidimensional situation, in which there are more than one effort and more than one effect (Charnes et al. 1978). Mathematically, the DEA model can be presented in the following way (Charnes et al. 1978).

Objective function:

$$\max_{u,v} \frac{\sum_{r=1}^{s} \mu_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \tag{1}$$

With the following limiting conditions:

$$\frac{\sum_{r=1}^{s} \mu_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \; \left(j = 0,1,\ldots,n \right); \mu_r, v_i \geq 0 \tag{2}$$

$$\frac{\mu_r}{\sum_{i=1}^{m} v_i x_{io}} \geq \varepsilon \; \text{ for } r = 0,1,\ldots,s \tag{3}$$

$$\frac{v_i}{\sum_{i=1}^{m} v_i x_{io}} \geq \varepsilon \; \text{ for } r = 0,1,\ldots,m \tag{4}$$

where: s – number of effects; m – number of inputs; μ_r – weights determining the importance of individual effects; v_i – weights determining the importance of individual inputs; y_{rj} – the size of the r^{th} effect (r = 1, …, R) in the j^{th} object; x_{ij} – the size of the i^{th} type (n = 1, …, N) in the j^{th} object; (j = 1, …, J).

The DEA method allows the study of the relationship between the level of many inputs and many effects. In the DEA model m inputs and s different effects boil down to single sizes of "synthetic" input and "synthetic" effect, which are then used in calculating the object efficiency index (Roll and Hayuth 1993). In linear programming, this indicator is a function of the target. In the DEA method, two variants of the objective function can be distinguished: maximisation of effects at given inputs or minimisation of inputs at given effects (Cooper et al. 2007). The μ_r and v_i coefficients are the optimised variables, which are the weights of the size of inputs and effects, and the magnitude of effects and inputs are empirical data (Cooper et al. 2007). The limitation assumes that the quotient of synthetic effect and synthetic input is to be less or equal to unity (without this limitation the task would have infinitely many solutions). Weights of inputs and effects are determined to maximise the above relation of effects to inputs, and their sizes may be equal to or greater than zero.

The solution of the objective function using linear programming allows setting the efficiency curve on which all effective units of the studied population are located (Figure 1). The graphical presentation of the efficiency curve is possible for the models: 1 input and 1 effect, 2 inputs and 1 effect or 1 input and 2 effects. For multidimensional models, the curve's reference is several interconnected fragments of different hyperplanes. Objects are considered to be technically efficient if they are on the efficiency curve (their efficiency index is 1, which in the model focused on minimising inputs means that there is no more favourable combination of inputs that allows the company (sector/country) to achieve the same effects) if while they are outside the efficiency curve, they are technically inefficient (their efficiency index is less than 1, which means that there is a more ef-

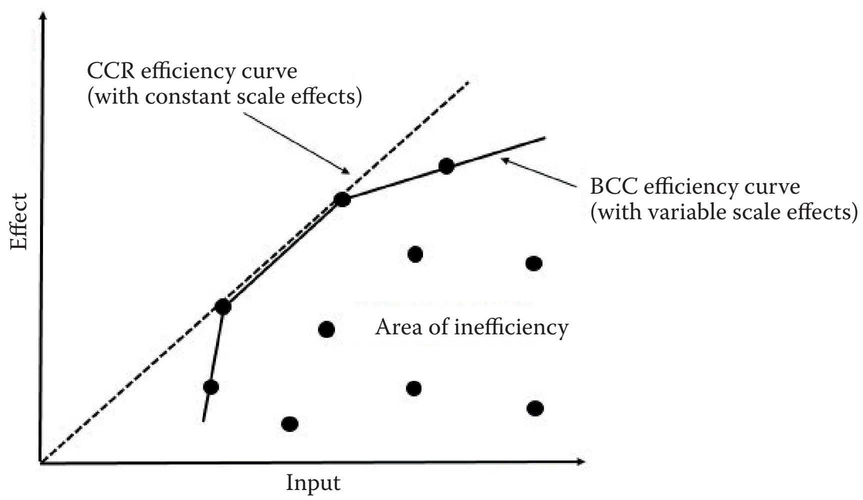

Figure 1. CCR efficiency curve (Charnes, Cooper and Rhodes; with constant scale effects) and BCC efficiency curve (Banker, Charnes and Cooper; with variable scale effects) (model: 1 effect and 1 input)

Source: Charnes et al. (1994)

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fective combination of inputs that allows achieving the same results). The effectiveness of the object is measured relative to other objects from the studied group and takes values from the interval (0,1). In the DEA method, the objects of analysis are Decision Making Units (DMU), which can be companies, sectors, countries (Charnes et al. 1994). The subject of the analysis is the effectiveness with which a given DMU transforms its inputs into results.

Nonparametric methods, including the DEA method, are used to analyse the effectiveness of various objects. The DEA method was most commonly used to investigate the effectiveness of banks (Berger and Humphrey 1997; Brockett et al. 1997), insurance institutions (Fukuyama and Weber 2001), educational institutions (Saunders 2003; Hu and Kao 2007), hospitals (O'Neil and Dexter 2005; Jacobs et al. 2006), farms (Galanopoulos et al. 2006), as well as industries of various types.

DEA models are increasingly used in economic and environmental analyses. This approach was presented in research, among others Ramanathan (2005), Zhou et al. (2007), Bian and Yang (2010) and Song and Wang (2014).

RESULTS AND DISCUSSION

In the first stage of the research, the level of agricultural productivity in particular countries in 2016 was recognised and a ranking of countries according to the index of the economic and energy efficiency of agriculture was created (Figure 2).

The average technical efficiency of agriculture in the EU in 2016 was at a high level – the DEA efficiency ratio amounted to 0.67. Agriculture in five of the twenty-four countries studied was considered fully effective, their efficiency index was 1. In the group of effective facilities, there was agriculture in Sweden, Slovakia, the Netherlands, Italy and Greece (Figure 2).

In the second stage of the research, based on the DEA method, optimal technologies were identified for inefficient agricultural sectors in individual countries, so that their efficiency could increase to uni-

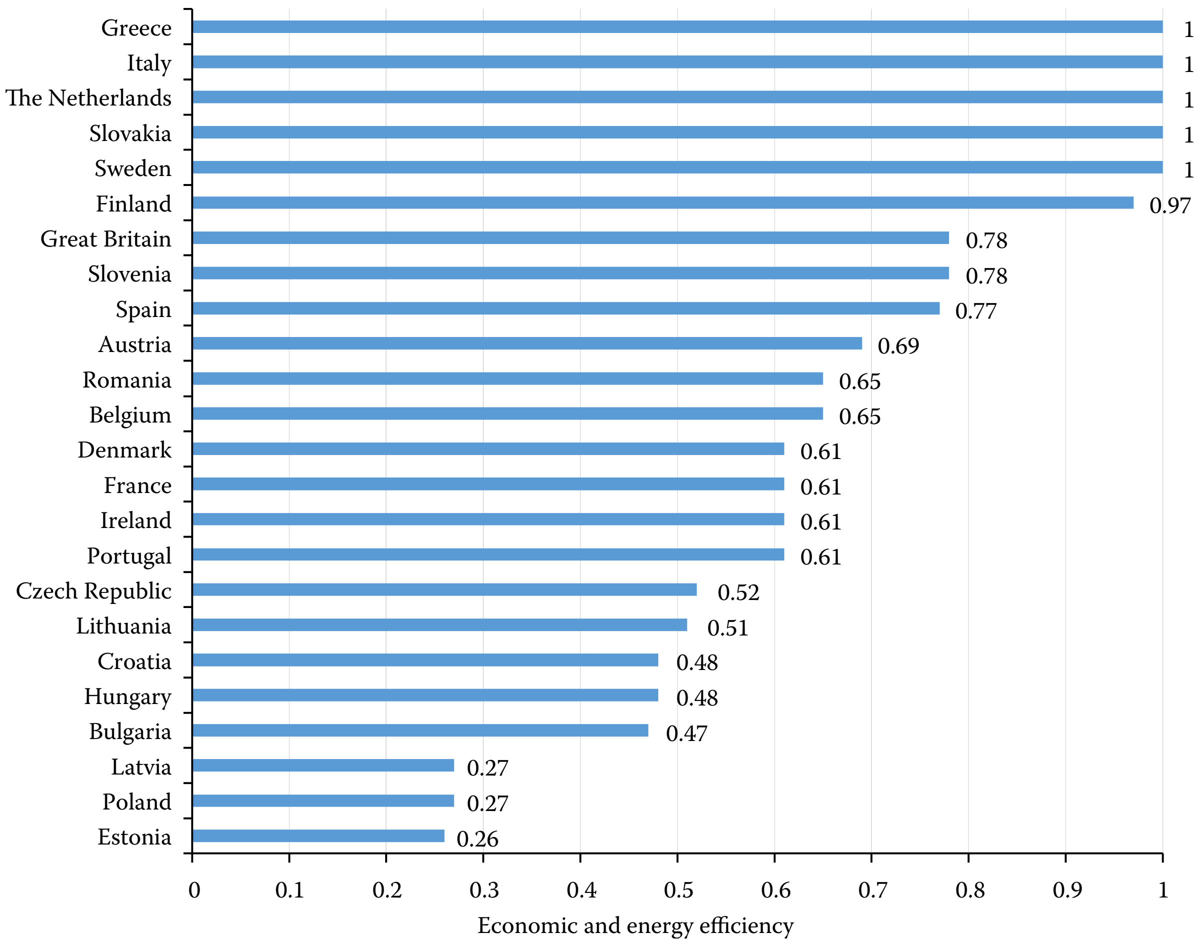

Figure 2. Economic and energy efficiency of the EU countries' agriculture based on the DEA method

Source: Authors' calculations based on EUROSTAT (2018a,b,c,d)

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ty. Following the idea of benchmarking for countries with ineffective agriculture, benchmarks have been defined. Based on these standards, a combination of technologies allowing for the same effects at lower inputs was determined for inefficient countries. Calculations can be made based on the coefficients for the combination of a common line technology – λ (Table 1).

For example, the combination of 30.3% of Italian agriculture technology and 4.2% of agriculture technology from the Netherlands is optimal for Polish agriculture. The agriculture sectors of Italy and the Netherlands (fully effective) have become benchmarks for inefficient agriculture in Poland. In other words, for Polish agriculture to become effective, it should construct technology based on agriculture from the regions that set the benchmark.

Polish agriculture could be classified as effective if, to achieve unchanged gross value added, the number of employed would be reduced by 83%, utilised agricultural area (UAA) by 73% and energy consumption by 74%. Potential changes that should be made in the field of inputs in agriculture in individual countries are presented in Table 2.

The data contained in Table 2 show that ineffective agriculture in individual countries should achieve the current level of its effects (gross value added) using fewer inputs (smaller area of agricultural land, number of employees in agriculture and lower energy consumption), which would allow them to improve their efficiency and place in the ranking.

In the next stage of the research, the hypothesis about the impact of the socio-economic development of the country on the economic and energy efficiency of agriculture was verified. An assessment of the socio-economic development of the EU countries was carried out using two measures:

i) Human Development Index;

ii) GDP per capita (USD per capita).

Using the HDI indicator, the ranking of countries presented in Table 3 was obtained. The top position was taken by 4 countries: Ireland, Sweden, Denmark and the Netherlands. The top ten also included: Great Britain, Finland, Belgium, Austria, France and Slovenia.

In the next stage, the correlation between selected indicators illustrating the socio-economic development of countries and the economic and energy efficiency of agriculture in these countries was calculat-

Table 1. Coefficients of linear combination (λ) of technology common for agriculture from individual countries

Country	Effective agricultural sectors (benchmarks)				
	Sweden	Slovakia	the Netherlands	Italy	Greece
Bulgaria	–	0.140	–	–	0.249
Czech Republic	0.468	–	0.030	0.026	–
Estonia	0.082	–	0.001	–	–
Ireland	–	0.558	–	–	0.160
Spain	4.676	–	–	0.044	0.704
France	4.911	–	0.149	0.156	–
Latvia	0.066	0.106	–	–	0.027
Lithuania	–	0.063	–	–	0.162
Hungary	–	–	–	0.093	0.232
Austria	0.383	–	0.026	0.052	–
Poland	–	–	0.042	0.303	–
Portugal	0.059	–	–	0.035	0.350
Slovenia	–	–	–	0.018	0.033
Finland	0.497	–	0.110	0.037	–
Great Britain	0.497	4.244	–	–	–
Belgium	0.182	–	0.113	0.011	–
Denmark	0.530	–	0.005	–	–
Croatia	–	–	–	0.029	0.087
Romania	–	–	–	–	1.096

Source: Authors' calculations based on EUROSTAT (2018a,b,c,d)

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Table 2. Recommendations for reduction of inputs for agriculture in the crosssection of individual countries (%)

Country	Energy consumption	Utilised agricultural area (UAA)	Number of employees in agriculture
Belgium	–34.676	–34.676	–34.676
Bulgaria	–52.435	–68.751	–52.435
Czech Republic	–47.978	–47.978	–47.978
Denmark	–69.425	–38.613	–38.613
Estonia	–74.481	–74.481	–74.481
Ireland	–39.101	–63.45	–39.101
Spain	–23.199	–23.199	–23.199
France	–38.764	–38.764	–38.764
Croatia	–51.552	–51.552	–59.825
Latvia	–72.959	–72.959	–72.959
Lithuania	–49.058	–70.689	–49.058
Hungary	–52.389	–52.389	–52.755
Austria	–30.600	–30.600	–30.600
Poland	–72.989	–72.989	–83.559
Portugal	–39.109	–39.109	–39.109
Romania	–34.536	–60.072	–69.052
Slovenia	–22.279	–22.279	–61.522
Finland	–2.961	–2.961	–2.961
Great Britain	–21.687	–43.623	–21.687

Source: Authors' calculations based on EUROSTAT (2018a,b,c,d)

ed. Based on the conducted analyses, a clear positive correlation was found (Table 4), which means that in the EU countries, along with the increase in socio-economic development, the economic and energy efficiency of agriculture is increasing. It is worth noting that in the case of GDP per capita and the HDI indicator indicated a strong correlation.

In the next stage of the research, the economic and energy efficiency of DEA in particular countries was compared with the values of the HDI (Figure 3). Four groups of countries were distinguished:

i) A group of leaders in which there are countries characterised by a higher level of socio-economic development than the average in the EU and in which was higher than average EU agricultural efficiency (Finland, the Netherlands, Sweden, Spain, Slovenia, Great Britain, Austria);

ii) A group of countries that is more than average in the EU in agricultural efficiency, despite the lower than average level of socio-economic development (Slovakia, Greece, Italy);

Table 3. Ranking of the EU countries according to socio-economic development using the HDI and GDP per capita

Country	Human Development Index (HDI; 2016)	GDP per capita (USD; 2016)
Ireland	0.934	64 100.43
Sweden	0.932	51 844.76
Denmark	0.928	53 578.75
The Netherlands	0.928	45 637.88
Great Britain	0.920	40 412.03
Finland	0.918	43 433.03
Belgium	0.915	41 260.97
Austria	0.906	44 731.01
France	0.899	36 870.21
Slovenia	0.894	21 650.21
Spain	0.889	26 616.75
Czech Republic	0.885	18 483.72
Italy	0.878	30 668.98
Estonia	0.868	17 736.80
Greece	0.868	17 881.52
Poland	0.860	12 415.04
Lithuania	0.855	14 912.68
Slovakia	0.853	16 529.54
Portugal	0.845	19 871.71
Latvia	0.844	14 070.42
Hungary	0.835	12 820.08
Bulgaria	0.810	7 469.44
Romania	0.807	9 532.16

The correlation ratio between GDP per capita and HDI was at the level of 0.91
Source: Authors' calculations based on UNDP (2016) and World Bank (2018)

iii) A group of countries with a socio-economic development greater than average in the EU, which agriculture cannot keep up with (France, Belgium,

Table 4. Correlation ratios between economic and energy efficiency of agriculture measured by the DEA method and selected measures of socio-economic development in the EU countries

Measures of socio-economic development	Correlation coefficients
GDP per capita (EUR per capita)	0.47
Human Development Index (HDI)	0.42

Source: Authors' calculations based on UNDP (2016) and World Bank (2018)

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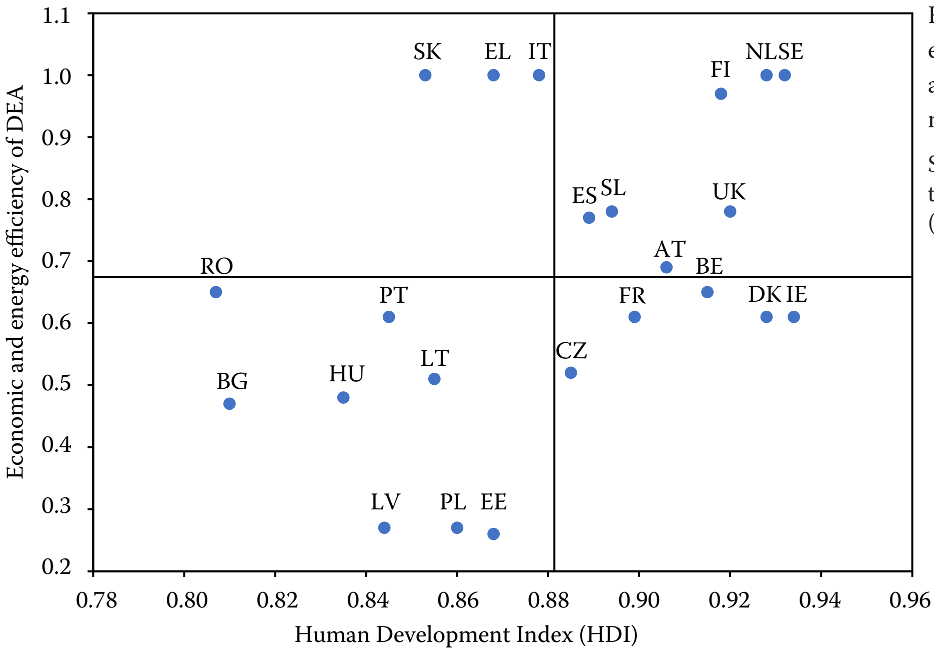

Figure 3. Economic and energy efficiency of the EU countries' agriculture based on the DEA method

Source: Author's calculation based on EUROSTAT (2018a,b,c,d) and UNDP (2016)

Denmark, Ireland, Czech Republic). It should be noted that the first four countries in this group are close to the group of leaders in both the economic and energy efficiency of agriculture and the level of socio-economic development of the country;

iv) A group of countries with smaller changes in the scope of socio-economic development as compared to the EU average, as well as the agricultural efficiency (Romania, Portugal, Bulgaria, Hungary, Lithuania, Latvia, Poland, Estonia).

Next, the correlation between the share of agriculture in generating GDP and the economic and energy efficiency of agriculture based on the DEA method was calculated. The correlation coefficient was –0.21, which means that together with the decreasing share of agriculture in the country's GDP (marginalisation of agriculture), the agricultural efficiency in the country is increasing.

CONCLUSION

Extraction of energy resources and their processing is invasive to the natural environment. The increase in the concentration of pollutants in the atmosphere as a fuel combustion effect and technological processes of many industries and transport violates the balance of energy exchange between the Earth and the cosmos. This causes global temperatures to rise and, consequently, melting glaciers and rising sea levels, ozone depletion, acid rain, smog, droughts, and other anomalies. Pollution due to gases and dust as a result of energy production disturbs the proportion of natural air composition, harming human life and health, and negatively affects the development of plants and animals. Energetics is responsible for almost 70% of global anthropogenic greenhouse gas emissions, which is a significant problem of environmental safety and global atmospheric pollution. One of the directions limiting negative impact is the development of energy based on renewable sources. The second key action limiting the negative impact of energy on the environment is the improvement of energy efficiency. This issue was also one of the most important problem areas in the study. In the context of allocative efficiency, treating energy as a resource, in particular a limited resource, has important economic consequences. Economic and energy efficiency can be understood as a concept referring to the efficiency of energy use as a resource.

In the research part of the work, calculations in the field of economic and energy efficiency of agriculture in the EU countries were made. Based on the conducted research, it was found that the average economic and energy efficiency of agriculture in the EU countries in 2016 was at a high level – the DEA amounted to 0.67. Five of the twenty-four respondents were found to be fully effective, their rate of agricultural efficiency was 1 (Sweden, Slovakia, the Netherlands, Italy and Greece). In the EU, there were clear differences both in terms of social and economic development of countries, as well as the economic and energy efficiency of agriculture.

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Comparing two variables, a group of leaders was indicated, in which there are countries characterised by a higher level of socio-economic development than the EU average, and in which agriculture reported higher than average EU economic and energy efficiency (Finland, the Netherlands, Sweden, Spain, Slovenia, Great Britain, Austria). In the group of the weakest countries – with the smallest index of socio-economic development and agricultural efficiency concerning the EU average – there were: Romania, Portugal, Bulgaria, Hungary, Lithuania, Czech Republic, Latvia, Poland and Estonia. It was also found that along with socio-economic development in EU countries, the economic and energy efficiency of agriculture is increasing. Besides, it was observed that with the declining share of agriculture in the country's GDP (agriculture's marginalisation), the economic and energy efficiency of agriculture in this country is increasing. The phenomenon of a declining share of agriculture in GDP is characteristic of highly developed countries, where agriculture is also usually at a high level of advancement.

Recognising that it is necessary to introduce a coherent environmental and energy policy in agriculture, the Common Agricultural Policy should be shaped differently by expanding it to include measures that favour the economical use of energy sources. Combining self-mutually exclusive goals, i.e. economic and energy efficiency, requires regulation and support. Food production should use energy sparingly and care for natural resources, and this requires a different policy from the current EU Common Agricultural Policy. In the context of current needs in the area of environmental protection and eco-efficiency, the obtained research results may be the basis for consideration of changes in agricultural policy and its evolution towards supporting countries with the lowest economic and energy efficiency and enabling the transfer of solutions used by leaders. The conducted research gives grounds to believe that further research on economic and energy efficiency in agricultural farms should be carried out, which would allow identifying those producers who produce food maintaining a positive energy balance and the lowest expenditure from three main categories – land, work, capital.

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