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Technical efficiency and farm size in the context of sustainable agriculture

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Abstract: This article aims to highlight the importance of climate and environmental challenges for agricultural economics and policy. Empirical research based on the Data Envelopment Analysis (DEA) method determined the average technical efficiency and scale efficiency of farms in the European Union in total and in economic size classes in the period 2004–2020. The results indicate that agriculture is generally characterised by high technical efficiency and scale efficiency. Analysis by economic size classes of farms, defined by the standard sum of their agricultural output, shows that the relationship between the scale of production and technical efficiency of farms is U-shaped. The highest technical efficiency and scale efficiency are characterised by small, large and very large farms economic classes. Economies of scale shift the burden of food production to large farms, which provide food security and are technically efficient but excessively burdensome for the climate and the environment. Small farms produce environmentally friendly food but on a small scale. Therefore, increasing the technical efficiency of medium-sized farms can contribute to more sustainable food production that meets both food security and climate and environmental objectives. The Common Agricultural Policy 2023–2027 provides greater access to financial support for moderate-scale farms and farms undertaking ecosystem restoration activities. This may affect the strength and direction of the relationship between farm scale and productivity, including technical efficiency.

Keywords: economies of scale; European Green Deal; European Union; farming; sustainable development

Agriculture plays a key role in providing food to an increasing number of people, as its primary goal is to ensure broadly understood food security. Ensuring food security for the population means ensuring access to food: firstly, of adequate quantity and quality, and secondly, affordable food (Roetter and Van Keulen 2007). This approach to food security emphasises the need to combine agricultural technical efficiency and the idea of sustainable use of resources and economics.

Demographic forecasts shed new light on the problem of food security and indicate the challenges facing agriculture in the context of observed structural changes, as well as climate and environmental changes. The Food and Agriculture Organization estimates

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that in 2050, the world population will increase to 9.1 billion, which means that food production will have to increase by about 70% compared to food production in 2005 (FAO 2009). Similarly, the 2017 Revision of the World Population Prospects (UN 2017) presents a demographic forecast in which the world population was estimated at approximately 8.4–8.7 billion people in 2030, was expected to be 9.4–10.2 billion in 2050 and between 9.6 to 13.2 billion in 2100. The latest UN report confirms that the world's population is growing, although slightly slower than initially expected – the current population is 8.2 billion people (UN 2024). To ensure the appropriate quantity and quality of food, it is necessary to gradually shift agriculture towards more efficient but, at the same time, more sustainable methods of food production. Moving away from intensive food production at the level of agricultural policies will require the development of new financing mechanisms.

Providing an adequate quantity of food is not a big challenge for the agricultural sector because, currently, agriculture is technically efficient (Bibi et al. 2021; Dokić et al. 2022), and food production methods allow for the efficient transformation of inputs into outputs. The use of intensive farming methods, specialisation and concentration of farms have significantly increased the world's food supply. Currently, a much more difficult task is to ensure the adequate quality of food, which involves food production in accordance with the principles of sustainable development (Sanyé-Mengual et al. 2018). In addition, in the past, agriculture was the basis for the development of other sectors; however, with the development of the industry and services sector, its importance has been systematically decreasing (Allen 2000). Countries have historically gone through stages of transition where a typology of countries can be distinguished based on the role of agriculture in creating GDP and employment (Serenčéš et al. 2018). These changes shaped the economic situation of farmers. In many regions of the world, agriculture has ceased to be a source of capital and tax revenues and has become a recipient of public transfers (Anderson et al. 2010). In light of the challenges agriculture is facing, it is necessary to review the mechanisms for financial support for agricultural activities adapted to ensure sustainable and affordable food.

Ensuring food security and climate and environmental challenges prompt a return to the discussion on the size of farms, their technical and economic efficiency and their impact on the climate and environment. Existing literature describing the relationship between farm size and efficiency leads to ambiguous conclusions. Some analyses indicate that this relationship is clearly negative (Sen 1962; Dagar et al. 2021), while others prove the existence of a positive relationship (Key 2019; Bokusheva and Čechura 2017). There are also studies in the literature indicating that the relationship between farm size and its efficiency is U-shaped (Bhatt and Bhat 2014; Foster and Rosenzwieig 2017; Xu et al. 2021; Bayav 2023). The impact of the scale of agricultural production on the climate and environment has been emphasised since the 1980s, but now it has become a hot topic again. Without systemic changes in agricultural techniques and promotion of the development of sustainable agriculture, this impact seem irreversible. The research was inspired by discussions around the scale of activity, technical and economic efficiency of agriculture and sustainable agriculture, which are currently taking place in parallel in scientific literature and political debate around the world.

The aim of this article is to determine the importance of the size of farms in their technical and scale efficiency with regard to climate and environmental challenges. The research question that was attempted to be answered concerns the validity of shifting agriculture from mass agricultural production on large farms to agricultural production on smaller farms. To achieve the aim of the article, an empirical research was planned. The aim of the empirical research was to determine the relationship between the economic size of farms in the European Union (EU) and the achieved technical and scale efficiency, and an indication of the size classes of farms in which farms achieve the highest technical efficiency. The analysis attempted to answer the question of whether agriculture in the EU is characterised by high technical and scale efficiency, whether farm efficiency increases with the scale of production, and how the scale of production affects efficiency, climate and the environment. The background to the discussion was the assumptions of the Common Agricultural Policy 2023–2027 (CAP 2023–2027; EC 2021) based on the European Green Deal (EGD; EC 2019). The measurement of the scale efficiency of EU agriculture in total and in economic size classes was estimated using the non-parametric data envelopment analysis method.

Literature review. The scale of farm production is directly related to their economic efficiency, but choosing the optimal scale is a complex issue. Determining the optimal scale of production results from the need to rationally use resources in specific technological conditions. The scale of farms is determined based on the volume of their production expressed, among

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others, according to the cropped area in ha, number of animals, and value of production (Čechura et al. 2022; Koç and Uzmay 2022). The search for the optimal scale of production is based on the calculation of economies of scale, which has its theoretical basis in the theory of the enterprise. The concept of economies of scale explains how average unit cost changes as farm output increases (Varian and Varian 1992). The search for the optimal production level is shown in Figure 1.

The issue of scale of production is related to the concepts of advantages and disadvantages of scale (economies and diseconomies of scale). The advantages of scale are specialisation, which allows for more efficient use of management methods, work specialisation and better use of machines. The disadvantages of scale are situations in which an increase in production inputs results in a less-than-proportional increase in output. In the agricultural sector, there is an economic motivation to increase the scale of production, often promoted by agricultural policy. On the other hand, environmental challenges shed new light on the relationship between production scale and the efficiency of agricultural production.

Sen (1962) found that land productivity decreased on Indian farms with increasing farm size, which initiated a discussion on the nature of the relationship between farm size and productivity. Due to its controversial implications for agricultural policy, it was later subjected to numerous analyses. As a result, an attempt was made to examine in detail the direction of the relationship between the size of farms and their efficiency. Lower efficiency of small farms and an increase in farm efficiency with an increase in the scale of production were discovered by, among others, Bokusheva and Čechura (2017) or Key (2019). Key (2019) estimated total factor productivity for five size classes of U.S. corn farms and found a strong positive

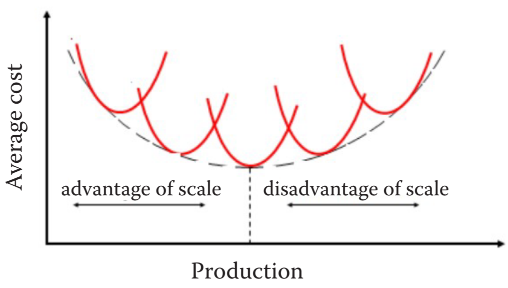

Figure 1. Advantages and disadvantages of scale

Source: Own elaboration based on Varian (1992)

relationship between production scale and total farm productivity. Similarly, Bokusheva and Čechura (2017) showed a positive relationship between the size class and the technical efficiency of farms in selected EU countries. Still, other analyses have shown that the relationship between farm size and its efficiency is U-shaped (Foster and Rosenzwieig 2017; Helfand et al. 2017; Sheng et al. 2019) – very small and very large farms were characterised by the highest technical efficiency. In a review article, Rada and Fuglie (2019) compared the relationship between the scale of farm operations and their technical efficiency in selected countries around the world. The main findings in this regard concern significant differences in the results achieved depending on the stage of the country's economic development. Generally, in developing countries it can be seen that small farms are characterised by higher technical efficiency than medium-sized and large farms. On the other hand, this relationship is positive in developed countries.

However, Xu et al. (2021), based on empirical studies of Chinese agriculture, showed that the results do not provide clear indications of what farm size guarantees the highest technical efficiency. The experience and conditions of the Chinese agricultural sector, i.e. land resources, social conditions and the level of economic development, indicate that striving to absolutely increase the technical efficiency of small farms should not be blindly based on increasing the scale of their production, a better solution is to support the development of their production to the so-called moderate scale, as also emphasised by Yan et al. (2019).

It is worth remembering that small farms are an element of the landscape of the rural agro-social sector and cannot be attributed solely to the role of a brake on agricultural development. In some regions, including Africa, Asia and South America, the agricultural sector based on production on small farms dominates and its development is promoted because of its role in reducing poverty (Eastwood et al. 2010).

Supporters of large farms emphasise the positive aspects of running a large-scale production. The most important include the impact on the technical efficiency of farms and the strong competitive position. On the other hand, large-scale production is met with numerous criticisms, primarily due to its negative impact on the climate and environment, including greenhouse gas emissions through the use of fertilisers and plant protection products (Smith et al. 2008; Selbonne et al. 2022). The increase in the scale of agriculture increases the mechanisation of agriculture, which has negative

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consequences for local natural systems and communities (Camanzi et al. 2011; Datta and Behera 2022).

MATERIAL AND METHODS

The aim of the empirical research was to determine the relationship between the economic size of farms in the EU and the achieved technical and scale efficiency, and to indicate the size classes of farms in which they achieve the highest technical efficiency. The analysis sought to check whether agriculture in the EU is characterised by high technical and scale efficiency, whether farm efficiency increases with the scale of production, and how the scale of production affects efficiency, climate and the environment.

The literature review allowed the formulation of the research hypothesis as follows:

H_1: There is a U-shaped relationship between the economic size of a farm in the EU and its technical and scale efficiency.

The subject scope of the research includes the analysis and assessment of the relationship between the economic size of farms and their technical and scale efficiency. The research covers farms from EU countries, determining the object and spatial scope of the research. The research covers the period 2004–2020.

To estimate the technical efficiency and scale efficiency of EU farms in total and in the economic size classes of farms in the years 2004–2020, the non-parametric data envelopment analysis (DEA) method was used.

The DEA method is a method of relative efficiency based on Debreu (1951) and Farrell's (1957) concept of productivity, adapted by Charnes et al. (1978) to a multidimensional situation. Assuming the presence of s outputs and m inputs, the efficiency is estimated according to the formula (1):

$$efficiency = \frac{\sum_{i=1}^{s} \mu_{i,j} output}{\sum_{i=1}^{m} \nu_{i,j} input} \quad (1)$$

where: j – object number from a group of n objects (j = 1, ..., n); s – number of outputs (i = 1, ..., s); m – number of inputs (i = 1, ..., m); μ_i – weights of j-object's i-outputs; ν_i – weights of j-object's i-inputs.

The objects of analysis in the DEA method were the so-called decision-making units (DMUs). The variables subject to optimisation were the weights of outputs and inputs, while the empirical values were the values of outputs and inputs (Charnes et al. 1978). If for a DMU technical efficiency (TE) = 1, it means that the object is technically fully operational, while if TE < 1, it means that there is a more favourable combination of inputs that would enable the same outputs to be achieved, or the object is technically defective.

The DEA methodology requires making assumptions about the objective function: minimising inputs for given outputs (input-oriented model) or maximising outputs for given inputs (output-oriented model) (Coelli et al. 2005). Second, assumptions about the nature of economies of scale are also required (Charnes et al. 1997). Depending on the type of economies of scale, technical efficiency at constant returns to scale (TE_{CRS}), technical efficiency at variable returns to scale (TE_{VRS}) and technical efficiency at non-increasing scale effects (TE_{NIRS}) are calculated. On the basis of the comparison of technical efficiency measures TE_{CRS} and TE_{VRS}, conclusions can be drawn about the level of efficiency of the scale (SE_{VRS}) of the DMU. The scale efficiency was defined as follows (Lothgren and Tambour 1999):

$$SE_{VRS} = \frac{TE_{CRS}}{TE_{VRS}} \quad (2)$$

When SE_{VRS} = 1, the DMU is efficient in relation to the scale effect; when SE_{VRS} < 1, the DMU is inefficient in relation to the production scale. The efficiency measure obtained in this way informs about the relative scale efficiency of the object, but it does not determine whether the DMU works within the advantages or disadvantages of the scale.

Scale advantages or disadvantages are helpful in determining the optimal production volume and can be identified using a second DEA tool, i.e. scale efficiency (SE_{NIRS}).

$$SE_{NIRS} = \frac{TE_{CRS}}{TE_{NIRS}} \quad (3)$$

An approximation of the economies of scale is provided in Table S1 in the Electronic Supplementary Material (ESM).

Using the input-oriented DEA model, the technical efficiency of TE_{CRS}, TE_{VRS} and TE_{NIRS} was calculated. The level of farm scale efficiency in the EU was inferred on the basis of the SE_{VRS}. The SE_{NIRS} was used to identify the type of farm operation area.

The technical efficiency of EU farms in total and in economic size classes was estimated on the basis of aggregated data for one output and eight inputs. The main production of EU farms in total and economic size classes was determined by total output. In turn, the inputs were as follows: total utilised agriculture area, fertilisers, crop protection, total livestock units, feed for grazing

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Table 1. Size of farms according to the FADN Common Typology of Agricultural Holdings

Farm size	Sum of the standard output obtained from all sources expressed in EUR
Very small	2 000–7 999
Small	8 000–24 999
Medium-small	25 000–49 999
Medium-large	50 000–99 999
Large	100 000–499 999
Very large	≥ 500.000

Source: Own elaboration based on FADN (2023a)

livestock, labour input, machinery and equipment, and gross investment on fixed assets. A description of the dataset used is presented in Tables S2 and S3 in the ESM.

The source of data on output and inputs was the Farm Accountancy Data Network database (FADN 2023b), which collects annual data on farms in total and e.g. in economic size classes separately for each EU country. The size of a farm was defined by classes of economic size of farms, in accordance with the Common Typology of Agricultural Holdings, presented in Table 1. The structure of EU farms in selected years is described in Table S4 in the ESM. The EMS (Efficiency Measurement System) program (Scheel 2000) was used to calculate the measures of technical efficiency of EU farms.

RESULTS AND DISCUSSION

In the first stage of the analysis, the total technical efficiency of farms in the EU in the years 2004–2020 was estimated; the research results are presented in Figure 2. The average technical efficiency was high and amounted to 0.9024 (standard deviation of S_{TE} = 0.0210). It was not strongly differentiated over time, V_{TE} (coefficient of variation) = 2%. It was observed that the technical efficiency of EU agriculture strongly reacted to changes during the 2008 financial crisis (Ionescu et al. 2010; Zawalińska et al. 2022).

The presented results confirmed that the average technical efficiency of EU farms has achieved high technical efficiency since 2004. In 2020, the average technical efficiency of EU farms was 0.9047 (S_{TE} = 0.1278). The lowest technical efficiency was achieved by farms in Romania; farms in 13 countries operated technically efficiently (TE = 1). In order to present the general relationship between the scale of production and the technical efficiency, Figure 3 presents the results of the average technical efficiency achieved by EU farms, taking into account their economic size classes.

The highest level of average technical efficiency was characteristic for very small, large and very large farm classes. The lowest results of technical efficiency characterised farms from the small, medium-small and medium-large classes, and their average technical efficiency was the most varied (Table 2). This finding confirmed the assumption about the relationship between the scale of production on farms and their technical efficiency. This relationship takes the U-shape.

In the second stage of the analysis, it was determined in detail whether farms in all economic size classes function efficiently in terms of the scale of their operations and which economic size class guarantees the highest scale efficiency for EU farms. Taking into account the structure of the EU agricultural sector, in which the largest group of farms was characterised by the lowest technical efficiency (small, medium-small and medium-large farms), it seems particularly useful in the search for the optimal size of farms. Determining the production level by farms is a complex decision, because increasing production affects sales revenues and operating costs at the same time, and requires taking into account technological, natural and economic factors as well as the size and structure of inputs. Moreover, the objectives of the CAP 2023–2027, require efficient agriculture both in terms of technology and scale of production, because technology and the scale of agricultural production should be an element of agriculture's transition toward sustainable agriculture.

The use of the DEA method allowed us to assess the scale efficiency SE_{VRS} and determine whether the DMUs operate of the advantages or disadvantages of scale (see Table S1 in the ESM). Table 3 presents the overall results of the scale efficiency of the EU farms in 2004–2020 in total and by economic size classes of farms.

The increase in the scale of EU agriculture initially causes, as in the case of its technical efficiency, a decrease in the efficiency of scale, as shown in Table 4. Farms in the small economic size class achieve lower scale efficiency than farms in the very small class. The increase in the economic size of farms, i.e. the increase in the sum of standard production of farms in the EU, causes a decrease in the efficiency of scale. This situation lasts until the farm reaches the sum of total production of EUR 25 000. A further increase in the total production of farms cause an increase in the efficiency scale.

The analysis of the scale efficiency of individual SE_{VRS} showed that the scale inefficiency characterised agricultural sectors in almost all EU countries and oc-

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Figure 2. Average technical efficiency of EU farms in 2004–2020

Source: Own elaboration based on FADN database (FADN 2023b)

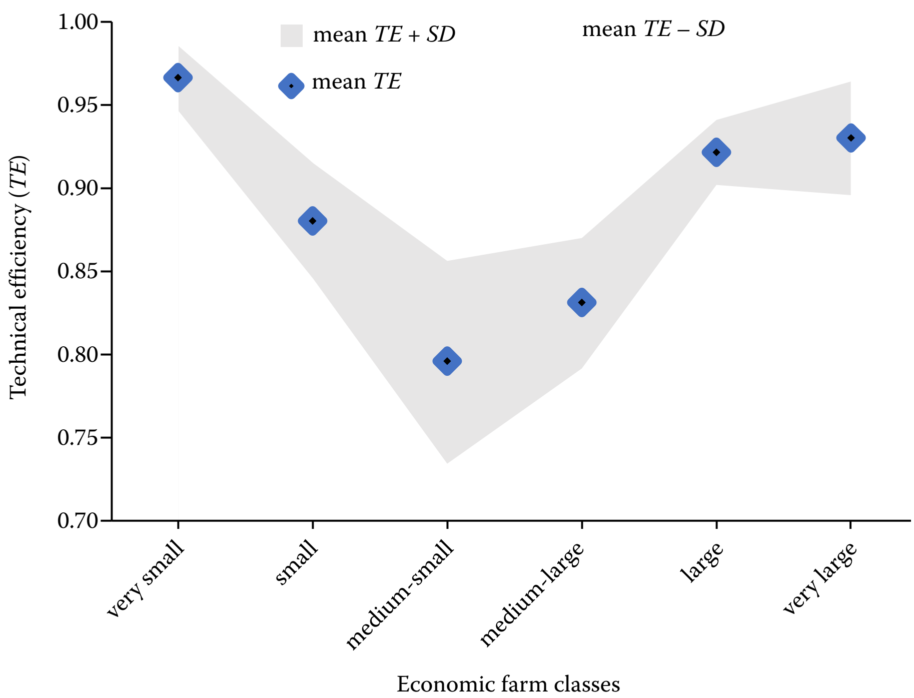

Figure 3. Technical efficiency of EU farms in economic size classes 2004–2020

Source: Own elaboration based on FADN database (FADN 2023b)

Table 2. Description of technical efficiency (*TE*) in EU farms (2004–2020) total and in economic size classes

2004–2020	Farms by size classes:					
	very small	small	medium-small	medium-large	large	very large
Mean *TE*	0.9658	0.8801	0.7955	0.8308	0.9214	0.9299
SD	0.0194	0.0346	0.0610	0.0394	0.0195	0.0340
Coefficient of variation (%)	2	3	7	4	2	3
Max – min	0.0705	0.1443	0.2015	0.1415	0.0781	0.1361

Source: Own elaboration based on FADN database (FADN 2023b)

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Table 3. Description of scale efficiency (*SE*) in EU farms (2004–2020) total and in economic size classes

2004–2020	Farms by size classes:					
	very small	small	medium-small	medium-large	large	very large
Mean *SE*	0.9772	0.9041	0.8393	0.8870	0.9570	0.9529
SD	0.0176	0.0300	0.0673	0.0362	0.0164	0.0228
Coefficient of variation (%)	2	3	8	4	2	2
Max – min	0.0599	0.1201	0.2196	0.1375	0.0741	0.0926

Source: Own elaboration based on FADN database (FADN 2023b)

Table 4. Scale efficiency and type of scale effect of agricultural production in EU countries in economic size classes of farms in 2020

Country	Very small farms		Small farms		Medium-small farms		Medium-large farms		Large farms		Very large farms	
	SE_{VRS}	SE_{NIRS}	SE_{VRS}	SE_{NIRS}	SE_{VRS}	SE_{NIRS}	SE_{VRS}	SE_{NIRS}	SE_{VRS}	SE_{NIRS}	SE_{VRS}	SE_{NIRS}
EL	1.00	1.00	**0.81**	1.00	**0.91**	1.00	**0.82**	1.00	1.00	1.00	–	–
CY	1.00	1.00	**0.95**	1.00	1.00	1.00	**0.91**	1.00	1.00	1.00	–	–
SI	1.00	1.00	**0.96**	1.00	**0.94**	1.00	1.00	1.00	**0.76**	1.00	–	–
BG	1.00	1.00	**0.72**	1.00	**0.98**	1.00	**0.89**	1.00	1.00	1.00	1.00	1.00
EE	1.00	1.00	1.00	1.00	**0.76**	1.00	**0.83**	1.00	**0.83**	1.00	**0.91**	**0.91**
HR	**0.98**	**0.98**	1.00	1.00	**0.96**	1.00	**0.80**	1.00	**0.60**	1.00	**0.66**	1.00
LV	1.00	1.00	1.00	1.00	**0.90**	1.00	1.00	1.00	**0.99**	1.00	**0.86**	**0.86**
LT	**0.93**	1.00	**0.77**	1.00	**0.77**	1.00	**0.88**	1.00	**0.96**	1.00	**0.98**	**0.98**
HU	1.00[a]	1.00	**0.78**	1.00	**0.93**	1.00	**0.90**	1.00	1.00	1.00	**0.92**	**0.92**
MT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PL	**0.99**	1.00	**0.78**	1.00	**0.69**	1.00	**0.72**	1.00	1.00	1.00	1.00	1.00
PT	1.00	1.00	**0.81**	1.00	**0.82**	1.00	**0.77**	1.00	**0.90**	1.00	**0.68**	1.00
RO	1.00	1.00	1.00	1.00	**0.96**	1.00	**0.95**	1.00	1.00	1.00	1.00	1.00
AT	–	–	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	–	–
CZ	–	–	**0.94**	1.00	**0.64**	1.00	**0.78**	1.00	**0.97**	1.00	**0.91**	**0.91**
FI	–	–	1.00	1.00	**0.82**	1.00	**0.98**	1.00	1.00	1.00	1.00	1.00
SE	–	–	1.00	1.00	**0.67**	1.00	1.00	1.00	**0.97**	1.00	**0.99**	1.00
UK	–	–	1.00	1.00	**0.92**	1.00	**0.99**	1.00	**0.96**	1.00	**0.93**	1.00
IE	–	–	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ES	–	–	**0.96**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FR	–	–	1.00	1.00	**0.97**	1.00	**0.87**	1.00	1.00	1.00	1.00	1.00
IT	–	–	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DK	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BE	–	–	–	–	1.00	1.00	**0.85**	1.00	**0.91**	1.00	1.00	1.00
GE	–	–	–	–	1.00	1.00	**0.83**	1.00	**0.92**	1.00	**0.90**	1.00
NL	–	–	–	–	**0.95**	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SK	–	–	–	–	**0.98**	1.00	**0.97**	1.00	1.00	1.00	1.00	1.00
LU	–	–	–	–	–	–	**0.93**	1.00	**0.97**	1.00	**0.90**	1.00

EL – Greece; CY – Cyprus; SI – Slovenia; BG – Bulgaria; EE – Estonia; HR – Croatia; LV – Latvia; LT – Lithuania; HU – Hungary; MT – Malta; PL – Poland; PT – Portugal; RO – Romania; AT – Austria; CZ – Czechia; FI – Finland; SE – Sweden; UK – United Kingdom; IE – Ireland; ES – Spain; FR – France; IT – Italy; DK – Denmark; BE – Belgium; GE – Germany; NL – Netherlands; SK – Slovakia; LU – Luxembourg; *SE* – scale efficiency; *VRS* – variable returns to scale; *NIRS* –non-increasing returns to scale; SE_{VRS}, numbers in regular font – farm class efficient in relation to the scale of production; SE_{VRS}, numbers in bold – farm class inefficient in relation to the scale of production; SE_{NIRS} numbers in regular font – farm class operating in the advantages of scale; SE_{NIRS} numbers in bold – farm class operating in the disadvantages of scale

Source: Own elaboration based on FADN database (FADN 2023b)

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curred in all economic classes of farm size. The highest inefficiency of the scale was characteristic of farms from the medium-small and medium-large classes. The SE_{NIRS} analysis showed that farms in the EU countries in the class large functioned at advantages of scale. The analysis of changes in the scale efficiency SE_{VRS} and SE_{NIRS} over time confirmed the durability of the observed trends. Throughout the analysed period, very small farms functioned with higher technical efficiency and more often in the advantages of scale. The increase in the size of farms initially resulted in a decrease in the technical efficiency of agriculture in most EU countries and a lower efficiency of scale. Farms in the small, medium-small and medium-large economic size classes were characterised by a less efficient transformation of inputs into output compared to farms in the very small class and were less efficient in terms of scale.

CONCLUSIONS

The structure of farms in the European Union is shaped by the Common Agricultural Policy implemented in 1962. Initially, the CAP focused its activities on achieving high agricultural productivity, ensuring safe supply chains and availability of agricultural products (EC 2012), developing farm specialisation and intensifying agricultural production. The economic justification was the pursuit of scale effects and high efficiency of agricultural production. The implemented financial support system conducted under the CAP supported the development of intensive agriculture and led to the unification of practices throughout the EU. As a consequence, however, the increase in the scale of agricultural production led to an excessive burden on nature, which is why the objectives of the CAP have now been linked to the assumptions of the European Green Deal (EC 2019), which sets the direction of agricultural policy in the EU. Furthermore, the discussion on food production in the EU touches on the Sustainable Development Goals (General Assembly 2015).

The CAP 2023–2027 (EC 2021) implements a common set of objectives integrating the interests of farmers, society and the climate, describes a set of tools necessary to achieve the assumed objectives and a common set of indicators monitoring their implementation. The actions are aimed at a more fair allocation of funds, i.e. increasing support for smaller farms, greening payments and increasing the flexibility of Member States in the division of direct payments and interventions that are intended to lead to the implementation of the European Union's ecological ambitions, in including the implementation of the Strategy from field to table (EC 2020b) and the EU Biodiversity Strategy for 2030 (EC 2020a).

The CAP 2023–2027 once again raises questions about the relationship between the scale of agricultural production and the technical efficiency of agriculture, focusing on the fact that the agricultural efficiency account should take into account not only economic considerations but, above all, include climate and environmental activities in the calculations. This means minimising the use of fertilisers, plant protection products in plant cultivation or hormones, or antibiotics in animal breeding, but also with the restoration of ecosystems and the increase in biodiversity. The prospect of stopping climate and environmental changes is to replace intensive agriculture with sustainable agriculture; one of its manifestations may be the transition from large farms with high production specialisation to smaller farms or with greater crop diversification, which, combined with the other postulates of the EGD, could be one of the steps to rebuild Europe's agricultural ecosystems.

Small farms flexibly adjust production inputs, which allows them to achieve high technical efficiency. They use more labour-intensive techniques to produce food that is environmentally and climate-friendly, but the supply of their products is limited and often expensive. Large farms, on the other hand, supply food in mass quantities, use machines for production and gain a cost advantage thanks to production specialisation. However, the production of homogeneous food over a large area interferes with natural systems, reducing the biodiversity of fauna and flora. The analysis of the technical efficiency and scale efficiency of agriculture, taking into account farm size classes, may therefore constitute a valuable voice in discussions on the future direction of changes in the production structure of the agricultural sector and facilitate the promotion of selected directions of changes in agricultural policy.

In the presented empirical research based on aggregated FADN data for the years 2004–2020, the technical and scale efficiency of farms in the EU were estimated in total, and taking into account the economic size classes of farms, using the DEA method. The overall results of the agricultural sector in the EU in 2004–2020 indicated that the average technical efficiency of farms was high and amounted to TE = 0.9024, although they still had the potential to increase their technical efficiency. Analyses in economic size classes, however, showed a significant diversification of their technical and scale

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efficiency. The results of the average technical and scale efficiency of EU farms divided into economic size classes divided farms into two groups: farms characterised by high technical and scale efficiency and farms characterised by average technical and scale efficiency. The first group consists of farms from the very small, large and very large classes. In general, these farms operated within the advantages of economies of scale, achieved optimal production volumes, and an increase in the production level of these farms would result in a decline in technical and scale efficiency. The second group of farms, i.e. farms of the small, medium-small and medium-large classes, were characterised by relatively average technical and scale efficiency, but still had the potential to increase the scale of production, because it functioned at the disadvantage of the scale.

Activities carried out under the CAP 2023–2027 emphasise the need to take into account climate and environmental changes in the current calculation of the efficiency of agricultural farms. Financial support for the CAP 2023–2027 focuses on developing mechanisms to promote production on smaller farms, using sustainable methods and taking actions to restore biodiversity. In the context of these considerations, food production on small farms seems to meet the requirements of the Common Agricultural Policy; however, food production on small farms may require a significant increase in their number. Large-scale production causes negative effects, i.e. the use of fertilisers, plant protection products, hormones, antibiotics, greenhouse gas emissions, reducing the occurrence of plant and animal species, but it meets the need to provide affordable food (at acceptable prices).

REFERENCES

Allen R.C. (2000): Economic structure and agricultural productivity in Europe, 1300–1800. European Review of Economic History, 4: 1–25.

Anderson K., Cockburn J., Martin W. (2010): Agricultural Price Distortions, Inequality, and Poverty. Washington D.C., World Bank Publications: 514.

Bayav A. (2023): Does farm size affect technical efficiency in apple-producing farms? A case study from Turkey. Erwerbs-Obstbau, 65: 1153–1161.

Bhatt M.S., Bhat S.A. (2014): Technical efficiency and farm size productivity – micro level evidence from Jammu and Kashmir. International Journal of Food and Agricultural Economics (IJFAEC), 2: 27–49.

Bibi Z., Khan D., Haq I.U. (2021): Technical and environmental efficiency of agriculture sector in South Asia: A stochastic frontier analysis approach. Environment, Development and Sustainability, 23: 9260–9279.

Bokusheva R., Čechura L. (2017): Evaluating Dynamics, Sources and Drivers of Productivity Growth at the Farm Level. OECD Food, Agriculture and Fisheries Papers, No. 106. Paris, OECD Publishing: 64.

Camanzi L., Malorgio G., Azcárate T.G. (2011): The role of producer organizations in supply concentration and marketing: A comparison between European countries in the fruit and vegetable sector. Journal of Food Products Marketing, 17: 327–354.

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

Charnes A., Cooper W., Lewin A.Y., Seiford L.M. (1997): Data envelopment analysis theory, methodology and applications. Journal of the Operational Research Society, 48: 332–333.

Coelli T.J., Rao D.S.P., O'Donnell C.J., Battese G.E. (2005): An Introduction to Efficiency and Productivity Analysis. New York, Springer: 349.

Čechura L., Žáková Kroupová Z., Lekešová M. (2022): Productivity and efficiency in Czech agriculture: Does farm size matter? Agricultural Economics – Czech, 68: 1–10.

Dagar V., Khan M.K., Alvarado R., Usman M., Zakari A., Rehman A., Murshed M., Tillaguango B. (2021): Variations in technical efficiency of farmers with distinct land size across agro-climatic zones: Evidence from India. Journal of Cleaner Production, 315: 128109.

Datta P., Behera B. (2022): Factors influencing the feasibility, effectiveness, and sustainability of farmers' adaptation strategies to climate change in the Indian Eastern Himalayan Foothills. Environmental Management, 70: 911–925.

Debreu G. (1951): The coefficient of resource utilization. Econometrica: Journal of the Econometric Society, 19: 273–292.

Dokić D., Novaković T., Tekić D., Matkovski B., Zekić S., Milić D. (2022): Technical efficiency of agriculture in the European Union and Western Balkans: SFA method. Agriculture, 12: 1992.

Eastwood R., Lipton M., Newell A. (2010). Farm size. In: Pingali P., Evenson R. (eds): Handbook of Agricultural Economics, Volume 4. Amsterdam, Elsevier: 3323–3397.

EC (2012): Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union (2012/C 326/01), Official Journal of the European Union, C 326, vol. 55, 26 October 2012. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2012:326:FULL (accessed Apr 10, 2024).

EC (2019): The European Green Deal, Communication From The Commission, COM(2019) 640 final, Brussels, 11.12.2019. Available at https://eur-lex.europa.eu/legal-

https://doi.org/10.17221/158/2024-AGRICECON

content/EN/TXT/HTML/?uri=CELEX:52019DC0640 (accessed Apr 10, 2024).

EC (2020a): EU Biodiversity Strategy for 2030. Bringing Nature Back Into Our Lives, Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Brussels, European Comission: 22.

EC (2020b): Strategy "from field to table". For a Fair, Healthy and Environmentally Friendly Food System, Communication From the Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee Of The Regions. Brussels, European Comission: 20.

EC (2021): The Common Agricultural Policy: 2023–27. Available at https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27_en (accessed Apr 10, 2024)

FADN (2023a): 2021 Standard Results of Polish FADN agricultural holdings, Institute of Agricultural and Food Economics, Warsaw. Available at http://fadn.pl/wp-content/uploads/2023/01/SR_2021_ang_www.pdf (accessed Apr 10, 2024)

FADN (2023b): The Farm Accountancy Data Network database. Available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html (accessed Apr 10,2024)

FAO (2009): How to Feed the World 2050. High Level Expert Forum – How to Feed the World in 2050. Office of the Director, Agricultural Development Economics Division, Rome 12-13 October 2009. Available at https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf (accessed Apr 10, 2024)

Farrell M.J. (1957): The measurement of productive efficiency. Journal of the Royal Statistical Society Series A: Statistics in Society, 120: 253–281.

Foster A.D., Rosenzweig M.R. (2017): Are There Too Many Farms in the World? Labor-Market Transaction Costs, Machine Capacities and Optimal Farm Size. NBER Working Paper No. 23909. Cambridge, National Bureau of Economic Research. Available at https://www.nber.org/system/files/working_papers/w23909/w23909.pdf (accessed Apr 10, 2024).

General Assembly (2015): Resolution adopted by the General Assembly on 19 September 2016. A/RES/71/1. Available at https://www.refworld.org/legal/resolution/unga/2016/en/112142 (accessed Apr 10, 2024).

Helfand S.M., Rada N.E., Magalhães M.M. (2017): Brazilian agriculture: Is it all about the large farms? EuroChoices, 16: 17–22.

Ionescu R.V., Moga L.M., Antohi V.M. (2010): Modelling of the technical progress impact on the Romanian agriculture. Journal of Food Agriculture and Environment, 8: 1081–1085.

Key N. (2019): Farm size and productivity growth in the United States Corn Belt. Food Policy, 84: 186–195.

Koç G., Uzmay A. (2022): Analyzing the effects of livestock policies on farm-level efficiency in Turkey; Thrace Region Case. Tekirdağ Ziraat Fakültesi Dergisi, 19: 515–528.

Lothgren M., Tambour M. (1999): Testing scale efficiency in DEA models: A bootstrapping approach. Applied Economics, 31: 1231–1237.

Rada N.E., Fuglie K.O. (2019): New perspectives on farm size and productivity. Food Policy, 84: 147–152.

Roetter R.P., Van Keulen H. (2007): Food security. In: Roetter R.P., Keulen H., Kuiper M., Verhagen J., Laar H.H. (eds): Science for Agriculture and Rural Development in Low-Income Countries. Dordrecht, Springer Netherlands: 27–56.

Sanyé-Mengual E., Gasperi D., Michelon N., Orsini F., Ponchia G., Gianquinto G. (2018): Eco-efficiency assessment and food security potential of home gardening: A case study in Padua, Italy. Sustainability, 10: 2124.

Scheel H. (2000): EMS: Efficiency Measurement System User's Manual. Available at https://www.holger-scheel.de/ems/ (accessed May 31, 2023)

Selbonne S., Guindé L., Belmadani A., Bonine C., Causeret F.L., Duval M., Sierra J., Blazy J.M. (2022): Designing scenarios for upscaling climate-smart agriculture on a small tropical island. Agricultural Systems, 199: 103408.

Sen A.K. (1962): An aspect of Indian agriculture. Economic Weekly, 14: 243–246.

Serenčéš P., Strápeková Z., Tóth M. (2018): Value-added, net income and employment in farms in Slovakia. In: Horská E., Kapsdorferová Z., Hallová M. (eds): International Scientific Days 2018. Towards Productive, Sustainable and Resilient Global Agriculture and Food Systems. Conference Proceedings. Prague, Wolters Kluwer ČR: 1413–1425.

Sheng Y., Ding J., Huang J. (2019): The relationship between farm size and productivity in agriculture: Evidence from maize production in Northern China. American Journal of Agricultural Economics, 101: 790–806.

Smith P., Martino D., Cai Z., Gwary D., Janzen H., Kumar P., McCarl B., Ogle S., O'Mara F., Rice C., Scholes B., Sirotenko O., Howden M., McAllister T., Pan G., Romanenkov V., Schneider U., Towprayoon S., Wattenbach M., Smith J. (2008): Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences, 363: 789–813.

UN (2017): World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248. New York, United Nations: 53.

https://doi.org/10.17221/158/2024-AGRICECON

UN (2024): World Population Prospects 2024: Summary of Results (UN DESA/POP/2024/TR/NO. 9). New York, United Nations: 69.

Varian H.R. (1992): Microeconomic Analysis (Vol. 3). New York, Norton: 506.

Xu C., Kagatsume M., Yu J. (2021). Effect of farmland size on land productivity and production cost and its intertemporal change in China's major grain producing provinces. Journal of International Development Studies, 30: 77–91.

Yan J., Chen C., Hu B. (2019): Farm size and production efficiency in Chinese agriculture: Output and profit. China Agricultural Economic Review, 11: 20–38.

Zawalińska K., Wąs A., Kobus P., Bańkowska K. (2022): A framework linking farming resilience with productivity: Empirical validation from Poland in times of crises. Sustainability Science, 17: 81–103.

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