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DEVELOPMENT TRAJECTORIES AND TECHNICAL EFFICIENCY OF AGRICULTURE IN THE EUROPEAN UNION COUNTRIES (2007-2023) IN THE CONTEXT OF THE IMPACT OF THE COMMON AGRICULTURAL POLICY

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Purpose: This study aims to identify agricultural development trajectories across 25 EU member states, determine clusters with homogeneous development patterns, and analyse variations in technical efficiency levels and dynamics within these clusters. Furthermore, it evaluates the impact of Common Agricultural Policy (CAP) instruments and proposes a novel classification system to enhance the effectiveness of agricultural policy interventions.
Design/methodology/approach: The analysis employs a comprehensive set of variables reflecting the agricultural production business model's characteristics. The study utilizes EUROSTAT data spanning 2007-2023. Through systematic data analysis, clusters exhibiting similar development trajectories were identified. Technical efficiency measurements within these clusters were conducted using Data Envelopment Analysis (DEA) methodology.
Findings: The research reveals significant heterogeneity in European agricultural development trajectories, enabling the identification of distinct clusters with similar characteristics. These clusters demonstrate varying levels and evolutionary patterns of technical efficiency.
Practical implications: The empirical findings facilitate the formulation of evidence-based recommendations aimed at enhancing and harmonizing efficiency levels across the European agricultural sector.
Originality/value: This research contributes to the existing literature on EU agricultural efficiency by proposing a novel analytical clustering approach that transcends the traditional dichotomy between 'old' and 'new' EU member states. Additionally, it provides policy recommendations for future CAP developments.
Keywords: agriculture, agricultural efficiency, Data Envelopment Analysis, EU-25, Common Agricultural Policy.
Category of the paper: Research paper.

1. Introduction

Agriculture plays a crucial role in the European Union (EU) economy, not only as a source of food, but also as an important element in sustainable development, environmental protection and the maintenance of biodiversity. The agricultural sector in the EU is diverse, ranging from intensive farms in countries such as France and Germany to smaller, family-run farms in regions such as Central and Eastern Europe. Agriculture is also a key factor in sustaining rural communities, providing employment and supporting local economies. However, as the world grapples with the challenges of sustainability and resource efficiency, it is necessary to study agriculture in this aspect to ensure its long-term viability (Corato, Cancellara, 2019; Santos, Ahmad, 2020).

The European Union's agriculture is undergoing constant transformation, the dynamics of which intensified especially after the EU enlargement in 2004. It was the accession of ten new Member States, including Poland, that fundamentally changed the structure of the European agricultural sector, introducing significant production resources into the community, but also new challenges related to modernisation and farming efficiency. The differences in the level of technical development, agrarian structure and productivity between the countries of the "old" Union (EU-15) and the new members became the subject of intensive action under the Common Agricultural Policy (CAP), aimed at levelling development opportunities and increasing the competitiveness of the entire sector.

The Common Agricultural Policy (CAP) is one of the EU's oldest and most complex policies, aiming to support farmers, stabilise agricultural markets and ensure food security. Since its introduction in 1962, the CAP has undergone numerous reforms to adapt to the changing economic, social and environmental conditions. Key reforms such as Agenda 2000, the 2003 Fischler Reform and the 2013 Reform introduced mechanisms to promote sustainability, innovation and competitiveness in the agricultural sector. In turn, new rules related to the green transition and digitalisation of agriculture were introduced after 2020. To address the emerging challenges, the EU introduced initiatives such as the Green Deal, which aim to transform the Union into a modern, resource-efficient and competitive economy with no net greenhouse gas emissions by 2050 (Malorgio, Marangon, 2021). It also introduced greater flexibility for Member States to adapt policies to local needs.

The CAP plays a key role in shaping the agricultural policy in the EU, and its reforms after 2004 were aimed at adapting to changing market conditions and societal needs. In the context of analysing the efficiency of agriculture in the EU, changes to the payment system and the approach to sustainable rural development and, in particular, the so-called 'green transition' are particularly relevant.

In summary, between 2007 and 2023, the EU agricultural sector has undergone a significant transformation, driven by both CAP reforms and external economic, environmental and technological conditions. This period covers three EU financial perspectives, allowing for a comprehensive assessment of the impact of support instruments on changes in technical efficiency in agriculture.

Previous studies on the technical efficiency of agriculture in the EU have focused mainly on the selected aspects or shorter periods of analysis. There is a lack of comprehensive studies taking into account long-term changes in technical efficiency in the context of the CAP impact, especially in comparative terms between groups of countries selected for similarities in the shape of the changes taking place reflecting agricultural development paths in the years analysed. Most comparative studies usually analyse changes either on a regional basis or compare the ‘old’ and ‘new’ EU. After the last major enlargement of the EU, enough time has passed to try to construct a different grouping of countries with similar changes than before. This gap is important especially in light of the growing challenges of food security, climate change and the digital transformation of agriculture and the desirability and design of future agricultural policy. Particularly as modern agriculture in the EU faces many challenges that require modern solutions and adaptation. Climate change, with its consequences in the form of extreme weather events, droughts and floods, poses a serious threat to the sustainability of agricultural production. In addition, increasing consumer demands for food quality and safety, as well as pressure to reduce greenhouse gas emissions, require farmers to implement more sustainable practices. In the context of globalisation, EU agriculture must also compete on international markets, which requires increased efficiency and innovation.

The objective of this study is to analyse the technical efficiency of agriculture in the countries of the European Union from 2007 to 2023, taking into account the impact of the Common Agricultural Policy. The study aims to:

1. Identify trends and patterns of agricultural development across the EU in terms of various factors. Identify countries that have undergone similar development patterns.
2. Find differences in the level and dynamics of change in technical efficiency between the EU countries.
3. Evaluate the impact of CAP instruments on development and technical efficiency in different country groups.
4. Identify the factors determining the variation in technical efficiency over the period under review

The realisation of the above objectives will allow the verification of the hypothesis of a progressive convergence of agricultural efficiency between EU countries, together with the identification of ‘new’ groups of countries similar in terms of assessing the effectiveness of the CAP as an instrument for the modernisation of European agriculture.

The study aims to provide valuable insights for policy makers, farmers and other stakeholders, supporting them in their decision-making on the future of agriculture in the European Union.

2. Literature review

The technical efficiency of agriculture in the European Union (EU) is a critical area of research, particularly in the context of the Common Agricultural Policy (CAP) and its implications for Member States, including Poland. The CAP has undergone significant reforms since its inception, aiming to increase agricultural productivity, ensure food security and promote sustainable rural development.

This literature review synthesises key findings from various studies to clarify the relationship between CAP subsidies and technical efficiency in EU agriculture and also takes into account the research-applied divisions of European agriculture into different groups due to differences in CAP effects.

Previous research suggests that CAP subsidies play an important role in shaping farm technical efficiency across the EU. For example, Latruffe et al. highlight that while subsidies can increase technical efficiency, their effects are diverse and vary depending on the type of subsidy and the specific agricultural context (Latruffe et al., 2016). This is further supported by the meta-analysis by Minviel and Latruffe, showing that public subsidies can have both positive and negative effects on farm efficiency, depending on their structuring and implementation (Minviel, Latruffe, 2016). This is also reflected in the findings of Galluzzo, who notes that the first pillar of the CAP, which includes direct payments, has played a key role in supporting farm efficiency in the EU Member States. The findings revealed the positive impact of financial subsidies granted to disadvantaged rural areas on increasing technical efficiency and the low impact of decoupled payments paid under the first pillar of the CAP on the Romanian farms studied. He also showed that, although CAP subsidies have generally improved productivity, the benefits are not evenly distributed, with some regions experiencing greater improvements than others (Galluzzo, 2020).

Radlinska (2023) found that EU agriculture showed high technical efficiency (90.24%) between 2004 and 2020, with very small and very large farms being the most efficient. However, the relationship between farm size and efficiency is not straightforward. In turn, regional differences in agricultural efficiency in the context of cohesion policy are pointed out by (Cieślik, Rokicki, 2013; Nazarczuk, 2015). Several studies have also analysed the impact of the CAP on agricultural efficiency in Poland. For example, Wilczyński et al. conducted an empirical study on dairy farms in Poland revealing that technical efficiency is significantly affected by the level of CAP support received (Wilczyński et al., 2020). Similarly, Smędzik-Ambroży et al. analysed the sustainability of Polish farms after the EU accession, finding that CAP instruments positively influenced the sustainability and efficiency of farms (Smędzik-Ambroży et al., 2018). This is confirmed by later research by Błażejczyk-Majka who emphasises the importance of the CAP in increasing agricultural efficiency and reducing regional differences in the level of this efficiency (Błażejczyk-Majka, 2022). It can also be noted that previous studies have indicated that higher specialisation correlates with better technical efficiency. This was found in a study of the technical efficiency of specialised dairy farms in Poland by Špička and Smutka, who used regional data to assess efficiency levels. This is in line with broader findings across the EU, where specialised farms tend to show higher efficiency compared to mixed farms, especially in older EU regions (Špička, Smutka, 2014). Kocur-Bera, on the other hand, discusses how the EU membership and participation in the CAP has changed land management practices and agricultural property prices in Poland, which has also further affected efficiency scores (Kocur-Bera, 2016).

The dual structure of the CAP – comprising direct payments and rural development measures – has played a key role in shaping agricultural practices and productivity. Direct payments under the first pillar aim to stabilise farmers' incomes, while the second pillar focuses on rural development, which includes investments in technology and innovation that can increase productivity (Constantin et al., 2021). The integration of precision farming tools, discussed by Vecchio et al. is one such innovation that can significantly improve the productivity and sustainability of agriculture in the EU (Vecchio et al., 2020).

In summary, the literature shows a complex interaction between CAP subsidies and technical efficiency in EU agriculture, especially in Poland. While the CAP has generally contributed to farm efficiency, the effects depend on various factors, including the type of subsidies, farm specialisation and regional characteristics. On the one hand, the positive impact of CAP instruments on agricultural efficiency can be observed on the other hand, following A. Szerletics, who conducted a literature analysis on the impact of the CAP on agriculture, most of the literature was critical of the current direct payment system and its effectiveness in achieving income policy (Szerletics, Jambor, 2021). Future research should continue to explore these dynamics to provide policy adjustments that can further enhance agricultural productivity and sustainability across the EU. New insights are also required and the division of countries or regions into new groups at which future agricultural policy will be directed.

3. Methods

Data for the study were obtained from the EUROSTAT database. The data cover the years 2007-2023. In order to ensure consistency, variables were selected for the research that cover the main factors of production in agriculture, i.e. land, capital and labour. The data were grouped into a set of variables the combination of which reflects the specifics of the business model of agricultural production. The following set of variables was adopted for the analysis: (*Y*1) agricultural production (EUR million), (*X*1) agricultural area (thousand ha), (*X*2) labour (thousand AWU), (*X2_2*) wages and salaries (EUR million), (*X3*) direct costs (EUR million), (*X*4) business overheads and depreciation (EUR million). Agricultural production (*Y1*) includes income from crop production, animal production, services and subsidies. Direct costs (*X3*) include: seeds and seedlings, fertilisers, protection, veterinary and feed. Costs comprising the variable (*X4*) include: energy, materials, building maintenance, agricultural services, depreciation and other indirect costs. In the adopted DEA model, AWUs (variable *X2*) were used as the variable showing labour input.

The basic descriptive statistics for the selected years are presented in Table 1. Due to the large scope, statistics covering 3 years, i.e. 2007, 2015 and 2023, are given in the article.

Table 1.
Basic descriptive statistics for the years 2007, 2015, 2023

Specification	Year	N	Average	Minimum	Maksimum	Deviation std.
Y	2007	25	14133,9	648,5	65289,4	17410,4
X1	2007	25	7302,3	492,4	29385,0	7993,8
X2	2007	25	473,8	32,9	2299,3	621,0
X2_2	2007	25	1431,5	73,5	6738,2	1898,4
X3	2007	25	4738,4	256,5	22366,2	5671,4
X4	2007	25	3340,1	133,3	15003,3	3914,1
X5	2007	25	2135,5	68,0	10988,8	2970,1
Y	2015	25	15968,3	876,3	72902,0	19564,3
X1	2015	25	7141,3	476,9	29115,3	7789,6
X2	2015	25	379,1	20,3	1937,1	471,9
X2_2	2015	25	1618,6	74,1	7700,9	2192,8
X3	2015	25	5631,7	367,3	26192,8	6901,1
X4	2015	25	4064,8	214,7	17774,0	4724,5
X5	2015	25	2440,9	113,0	12026,1	3357,9
Y	2023	24	21313,6	1305,0	92194,4	26376,7
X1	2023	24	6648,7	478,5	28240,8	7544,8
X2	2023	24	316,0	16,5	1427,5	383,7
X2_2	2023	24	2065,2	92,7	9077,0	2652,5
X3	2023	24	7634,5	607,4	32263,2	9089,9
X4	2023	24	5164,5	311,7	23987,7	6229,3
X5	2023	24	3042,9	189,7	13515,8	4116,0

Source: own research based on EUROSTAT data.

In the initial phase of the research, an analysis of the development of the trajectories of the individual variables in each country was carried out. Based on this analysis, attempts were made to observe some patterns of change. As a result of this analysis, a grouping of countries with similar patterns of change was carried out.

As a result of the analysis of basic statistics and after a preliminary calculation of the models, Cyprus, Luxembourg and Malta were excluded from the study as countries whose agricultural activity patterns were too different. As a result, the pattern of variables is not sufficiently consistent and, therefore, not suitable for use in DEA models. A separate group was extracted from these countries, but was omitted from further technical efficiency studies. Also as a result of this analysis, a decision was made to use a DEA model with variable scale effects (BCC) to measure technical efficiency. This choice was dictated by the significant variation in the scale of agricultural activities between the analysed countries. The model's orientation towards input minimisation was adopted, which corresponds to the European Union's sustainable agricultural development policy, which postulates an increase in the efficiency of the agricultural sector through the implementation of innovation and resource-efficient inputs.

In this study, Data Envelopment Analysis (DEA), which is a multivariate and non-parametric method, was used to measure the technical efficiency of agriculture in the European Union countries. The DEA is widely used in efficiency analyses in the agricultural sector. The method is based on the concept of productivity proposed by G. Debreu (Debreu, 1951) and M.J. Farrell (arrell, 1957]). Farrell introduced the concept of an 'efficiency frontier' or 'production frontier' (best practice frontier), which represents the technological production possibilities available to a given decision-making unit, in this case individual EU countries. Farrell's concept was to evaluate the efficiency of a decision-making unit in relation to other units operating under similar technological conditions. The concept was initially applied to one-dimensional cases, but was developed into a multidimensional analysis by A. Charnes, W.W. Cooper and E. Rhodes (Charnes et al., 1978), who proposed a model assuming fixed effects of scale, known in the literature as the CCR model. In 1984, Banker, Charnes and Cooper extended the CCR model with the introduction of the BCC model, which incorporates variable scale effects for more precise efficiency results (Banker, Charnes, Cooper, 1984).

The efficiency measurement concept used in the CCR and BCC models is based on one of the most popular techniques described, among others, in the work Production Frontiers (Färe et al., 1995). With s effects and m inputs, technical efficiency can be calculated from equation (1):

$$\frac{\sum_{r=1}^{s} u_r y_r}{\sum_{i=1}^{m} v_i x_i} = \frac{u_1 y_1 + u_2 y_2 + \ldots\ldots + u_s y_s}{v_1 x_1 + v_2 x_2 + \ldots\ldots. + v_m x_m}, \tag{1}$$

where:

y_r - effect value,

u_r - effect weight,

x_i - input value,

v_i - input weight.

For each object, a linear programming task is solved, in which the calculated efficiency factor takes the form of a maximised objective function and the optimised variables are the effect weights and the input weights. For input-oriented models in dual form, it takes the form (2)

$$\min_{\Theta,\lambda} \Theta, \tag{2}$$

under constraints (3):

$$\begin{aligned} &\mathbf{Y\lambda} \geq \mathbf{Y_o}, \\ &\Theta \mathbf{X_o} - \mathbf{X\lambda} \geq 0, \\ &\boldsymbol{\lambda} \geq 0. \end{aligned} \tag{3}$$

where:

$\mathbf{X_o}$ - the vector of inputs of a given units (of dimension [$1 \times m$]),

$\boldsymbol{X}$ - the input matrix of all units (of dimension [$n \times m$]),

$\mathbf{Y_o}$ - vector of effects of a given units (with dimensions [$1 \times s$]),

$\boldsymbol{Y}$ - the matrix of effects of all units (with dimensions [n x s]),

$\lambda_1, \ldots, \lambda_\sigma$ - linear combination coefficients,

Θ - the efficiency measure of the unit.

The task was solved for all n objects. The aim of the optimisation performed was to find the minimum value of the efficiency coefficient for which it is possible to reduce inputs or resources without changing the effect level. When this is not possible, then $\Theta = 1$, which means that there is no more favourable combination that allows the object to achieve the same effects. The object is then said to be economically efficient. Conversely, when $\Theta < 1$, there is a more efficient combination of inputs that allows the facility to achieve the same effects. The parameter Θ determines what percentage of the inputs of the object under study is sufficient to achieve the current level of effects using efficient object technology. Information about the structure of the optimal combination of inputs and effects is provided by linear combination coefficients λ (Rusielik, 2017).

Banker, Charnes and Cooper in 1984 proposed an extension of the CCR model to the BCC model assuming variable scale effects (Banker, Charnes, Cooper, 1984). For this purpose, the CCR model can be modified by adding a convexity constraint $1' \cdot \lambda = 1$, resulting in a model of the form (4):

$$\min_{\Theta,\lambda} \Theta, \tag{4}$$

with constraints:

$$\begin{aligned} &\mathbf{Y\lambda} \geq \mathbf{Y_o}, \\ &\Theta \mathbf{X_o} - \mathbf{X\lambda} \geq 0, \\ &1' \cdot \lambda = 1\boldsymbol{\lambda} \geq, 0. \end{aligned} \tag{5}$$

Using the input-oriented BCC model and assuming variable economies of scale, the technical efficiency indicators of the 25 EU countries were calculated for the years 2007, 2015 and 2023. In the next step, an analysis of the development of the level of these indicators in each group was performed and an attempt was made to find a specific unique pattern. The results of the measurement are shown in Table 3.

4. Research results

In the initial phase of the research, a general analysis of agriculture from 2007 to 2023 was carried out. The changes that took place over the years under study were analysed on the basis of the collected variables. In particular, attention was paid to the development of the volume of agricultural production, the individual costs of this production, changes in the area of production, productivity and also labour inputs were taken into account both in terms of hourly inputs (AWU) and labour costs (EUR). This part also analysed the possible impact of the European Union's agricultural policy on individual countries and the influence on the formation of separate groups (Table 2.). In the second part of the research, an attempt was made to assess the level of technical efficiency and changes in this efficiency in the individual isolated groups of countries. As mentioned, the research used the DEA method and the BCC model.

A. Agricultural development in the context of CAP impact

Based on the analysis of the trajectory of changes in individual variables, several groups of countries were identified. A summary of these groups according to the adopted characteristics is provided in Table 2. A characterisation of each group along with an attempt to estimate the impact of CAP mechanisms is illustrated below.

Group 1. Efficient innovators

Netherlands, Denmark, Belgium, Germany, United Kingdom*[1].

These countries are at the forefront of agricultural innovation in the EU. They have achieved high levels of productivity through advanced technologies and efficient agricultural practices. Despite the stabilisation of agricultural areas, they have managed to significantly increase production with moderate to low labour force decline.

Characteristics:

- Strong production growth.
- Significant increases in productivity (both per hectare and per AWU).
- Stable or declining agricultural area.
- Moderate or low decline in labour force.

Agricultural policy impact:

- Support for innovation: the EU programmes supporting research and development (e.g. Horizon, 2020) have enabled these countries to invest in advanced agricultural technologies.

[1] Due to Brexit, data up to 2020 has been included.

- Environmental standards: Stringent EU environmental standards have prompted these countries to develop sustainable, high-performance farming practices.
- Targeted subsidies: the CAP has gradually moved away from production-related subsidies, favouring efficient, innovative farms in these countries.

Group 2. Rapid modernisers

Poland, Romania, Bulgaria, Czech Republic, Hungary

This group, consisting mainly of Eastern European countries, showed the most dramatic changes. These countries have rapidly modernised their agricultural sectors, significantly reducing labour inputs while substantially increasing productivity. This suggests a large-scale adoption of modern farming techniques and possible farm consolidation.

Characteristics:

- High production growth.
- Large increases in productivity, especially in later years.
- Significant reduction in the agricultural labour force.
- Various changes in agricultural area.

Agricultural policy impact:

- Structural Funds: Significant support from the EU funds (e.g. EAFRD) has accelerated the modernisation of agricultural and rural infrastructure.
- Adaptation programmes: EU pre-accession and post-accession policies forced rapid adaptation to EU standards, stimulating modernisation.
- Direct subsidies: The introduction of direct subsidies increased farmers' incomes, enabling investment in modern technologies.

Group 3 Stable performers

France, Italy, Spain, Germany, Austria, Ireland, Sweden

These countries, many of which are long-standing members of the EU, have shown steady but moderate growth. They have struck a balance between modernisation and preserving existing agricultural structures. Their challenges often include adapting to new EU regulations and maintaining stability and competitiveness.

Characteristics:

- Moderate but steady increase in production.
- Gradual improvement in productivity.
- Slight to moderate decline in agricultural area and labour force.

Agricultural policy impact:

- Market stabilisation: CAP mechanisms (e.g. market interventions) helped to maintain price and production stability.
- Protection of regional products: The EU policies protecting geographical indications supported the countries' traditional, high-quality products.
- Sustainability: The EU agri-environmental programmes encouraged sustainable practices, maintaining a balance between production and environmental protection.

Table 2.
Summary of EU country groups by agricultural characteristics (2007-2023)

Group	Countries	Growth in production	Changes in agricultural area	Changes in labour force	Productivity growth	Other characteristics
1. Efficient innovators	Netherlands, Denmark, Belgium, Germany, United Kingdom*	Strong	Stable or declining	Moderate to low decline	Significant (per hectare and per AWU)	Highest production per hectare and per AWU. Significant technology adoption. Focus on high value crops.
2. Rapid modernisers	Poland, Romania, Bulgaria, Czech Republic, Hungary	High	Diversified	Significant reduction	Large, especially in later years	Dramatic improvement in labour productivity. Significant structural changes. Likely beneficiaries of EU agricultural policies.
3. Stable performers	France, Italy, Spain, Austria, Ireland Sweden, Finland	Moderate but consistent	Slight to moderate decline	Slight to moderate decline	Gradual	Sustained growth. Stabilised agricultural sectors. Adaptation to changing market conditions
4. Challenging adaptors	Greece, Croatia, Portugal, Slovenia, Slovakia	Inferior or inconsistent	Challenges in governance	Challenges in transformation	Lower	Various structural or economic challenges. Some show improvement in later years. Often specific geographical or economic constraints
5. Specific cases	Estonia, Latvia, Lithuania	Differentiated	Differentiated	Differentiated	Differentiated	Baltic countries: mixed trends, characteristics of groups 2 and 4

* Due to Brexit, data up to 2020 has been included.

Source: own research based on EUROSTAT data.

Group 4 Challenging adaptors

Greece, Croatia, Portugal, Slovenia, Slovakia

Countries in this group face different challenges, such as difficult geography, economic constraints or structural issues in their agricultural sectors. Although some show signs of improvement, they generally lag behind in terms of productivity growth and sector modernisation. Some show recovery or improvement in later years.

Characteristics:

- Lower or inconsistent production growth.
- Less improvement in productivity.
- Challenges related to farmland management or labour force change.

Agricultural policy impact:

- Support for disadvantaged areas: Special EU programmes helped to maintain agriculture in mountainous or disadvantaged areas.
- Restructuring programmes: The EU offered support in restructuring inefficient sectors (e.g. vineyards in Greece).
- Rural development: Rural development funds helped to diversify the rural economy, relieving pressure on the agricultural sector.

Group 5 Special cases

Estonia, Latvia, Lithuania

The Baltic countries (Estonia, Latvia, Lithuania): Showing mixed trends, they can be considered a subgroup between rapidly modernising countries and countries adapting to challenges.

Characteristics:

- diverse and mixed trends.

Agricultural policy impact:

- The Baltic countries have benefited from adaptation and modernisation programmes.

These groups provide an insight into different trajectories of agricultural development across the EU. They reflect not only economic and technological aspects, but also the impact of the EU policies, national strategies and regional characteristics on agricultural performance. This classification also shows how diverse agricultural development trajectories in the EU countries are and how differently the EU policies affect these processes, depending on the initial situation of the country and its specific circumstances.

It is worth noting that the impact of the EU policies has not been unilateral. Member countries also influenced the shaping of the CAP, leading to an evolution of the policy over time, taking into account different needs and challenges of various EU regions.

B. Technical efficiency of agriculture in groups of the EU countries distinguished by development trajectories

As noted earlier, several groups of countries were identified based on the analysis of the trajectories of change of individual variables. In the second stage of the research, using the BCC model, technical efficiency was measured and an attempt was made to find differences in the level and dynamics of change in technical efficiency between the identified groups of countries. The analysis shown in this article covers 2007, 2015 and 2023. The calculated technical efficiency indicators are shown in Table 3.

Analysing the development of efficiency indicators, it can be concluded that the level of agricultural efficiency in the EU is increasing. Most of the analysed groups tend to increase the level of the efficiency indicator, but each one shows unique patterns of change in this indicator. This may be due to differences in agricultural policies, investment levels, technology, and economic and climatic conditions.

Group 1. Efficient innovators

Netherlands, Denmark, Belgium, Germany, UK*[2]

These countries are characterised by high and stable efficiency, with little change over time, suggesting effective implementation of innovations and maintenance of high productivity.

Group 2. Rapid modernisers

Poland, Romania, Bulgaria, Czech Republic, Hungary

In this group, there is a noticeable improvement in the level of efficiency over time. Two countries, i.e. Poland and Bulgaria, show full efficiency over the analysed period, while the other countries show a significant improvement in efficiency levels. These countries show a tendency towards rapid modernisation and efficiency improvements, which may be the result of investments in technology and restructuring of the agricultural sector.

Group 3. Stable performers

France, Italy, Spain, Germany, Austria, Ireland, Sweden

Countries in this group are characterised by varying but relatively stable levels of efficiency. France, Italy and Spain maintain full technical efficiency. The other countries show little fluctuation in efficiency levels. This may be due to well-established agricultural practices and supportive policies.

Group 4. Challenged adaptors

Greece, Croatia, Portugal, Slovenia, Slovakia

Countries in this group show a visible improvement in efficiency levels over time. These countries show the ability to adapt and improve efficiency, although they may face challenges in maintaining stability. Portugal is an example here with the index of 0.868 in 2007, rising to 1.000 in 2015 but falling to 0.986 in 2023.

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[2] * Due to Brexit, data from 2023 is not included.

Table 3.
Indicators of technical efficiency of agriculture in EU countries in 2007-2015

EU25	2007	2015	2023	Average
1. Efficient innovators				
Belgium	1,000	1,000	1,000	**1,000**
Denmark	1,000	1,000	1,000	**1,000**
Germany	0,997	1,000	1,000	**0,999**
Netherlands	1,000	1,000	1,000	**1,000**
United Kingdom	0,827	1,000	0,010	**0,914**
Average	**0,965**	**1,000**	**1,000**	**0,987**
2. Rapid modernisers				
Bulgaria	1,000	1,000	1,000	1,000
Czech Republic	0,834	0,851	0,872	0,852
Hungary	0,762	0,904	0,944	0,870
Poland	1,000	1,000	1,000	1,000
Romania	0,736	0,871	0,987	0,864
Average	0,866	0,925	0,961	0,917
3. Stable performers				
Austria	0,892	0,856	1,000	**0,916**
Finland	0,795	0,699	0,867	**0,787**
France	1,000	1,000	1,000	**1,000**
Ireland	0,854	0,959	0,896	**0,903**
Italy	1,000	1,000	1,000	**1,000**
Spain	1,000	1,000	1,000	**1,000**
Sweden	0,822	0,876	0,944	**0,880**
Average	**0,909**	**0,913**	**0,958**	**0,927**
4. Challenged adaptors				
Croatia	0,957	1,000	1,000	**0,986**
Greece	1,000	1,000	1,000	**1,000**
Portugal	0,868	1,000	0,986	**0,951**
Slovakia	0,856	1,000	1,000	**0,952**
Slovenia	1,000	1,000	1,000	**1,000**
Average	**0,936**	**1,000**	**0,997**	**0,978**
5. Special cases				
Estonia	1,000	1,000	1,000	**1,000**
Latvia	0,862	1,000	1,000	**0,954**
Lithuania	0,934	0,950	0,829	**0,904**
Average	**0,932**	**0,983**	**0,943**	**0,953**
Average total	**0,920**	**0,959**	**0,972**	**0,950**

Source: own research.

Group 5. Special cases

Estonia, Latvia, Lithuania

These countries are characterised by varying trends in efficiency, with Estonia and Latvia showing stability, while Lithuania experiencing a decline in efficiency in recent years.

Summarising the analysis of the development of the efficiency index, it can be concluded that most countries show an upward trend in efficiency. The countries in the 'High Efficiency Innovators' group show the most stable performance. The greatest improvement is seen in the 'Rapid Upgraders' and 'Challenged Adaptors' groups. The Baltic countries (group 5) show mixed trends, with the exception of Estonia maintaining stable efficiency. By 2023, the majority of countries have achieved high efficiency rates (>90%)

5. Recommendations

In order to improve the efficiency of agriculture in the different groups of countries in the European Union, different agricultural policies can be proposed to address the specific needs and challenges of each group. The recommendations for each of the identified groups are presented below:

Group 1: Efficient innovators

Netherlands, Denmark, Belgium, Germany

Recommended policies:

- Support for research and innovation: Increase funding for agricultural research to develop new technologies and practices that can increase productivity.
- Sustainability: Promote agricultural practices that are environmentally friendly, such as precision agriculture that minimises resource use. Support for projects related to a circular economy.
- Educational programmes: Training for farmers on new technologies and innovative farming practices.

Group 2: Rapid modernisers

Countries: Poland, Romania, Bulgaria, Czech Republic, Hungary

Recommended policies:

- Access to finance: Facilitate access to credit and grants for farmers to invest in modern technology and infrastructure.
- Support programmes for young farmers: Initiatives to attract young people to the agricultural sector, which can contribute to innovation and modernisation.
- Cooperation with the environment: Encourage consolidation and partnerships between farmers and technology companies to implement modern solutions.

Group 3: Stable performers

France, Italy, Spain, Austria, Sweden, Ireland, Finland

Recommended policies:

- Preserving traditional practices: Promote local agricultural traditions that can be sustainable and efficient.
- Quality certification schemes: Support for the introduction of certification schemes that promote the quality of agricultural products, which can increase their market value.
- Sustainability: Support agricultural practices that are sustainable to maintain production stability. Support for producer groups.

Group 4: Challenged adaptors

Greece, Croatia, Portugal, Slovenia, Slovakia

Recommended policies:

- Support for climate change adaptation: Programmes that help farmers adapt to changing climate conditions, such as training in sustainable water management.
- Investment in infrastructure: Improve infrastructure, such as irrigation systems, to increase production efficiency.
- Promoting crop diversity: Encourage the cultivation of a variety of crops, which can increase resilience to climate and market changes.

Group 5: special cases

Estonia, Latvia, Lithuania

Recommended policies:

- Support for the development of local markets: Initiatives to develop local markets for agricultural products, which can increase farmers' incomes.
- Education and training programmes: Training for farmers in modern farming practices and farm management.
- Increasing access to technology: Facilitate access to modern technologies and tools that can help increase production efficiency.

Each group of countries in the EU has its own unique challenges and opportunities. The implementation of appropriate agricultural policies that take into account the specificities of each group can contribute to improving the efficiency of agriculture across the EU. It is also crucial to monitor and evaluate the effectiveness of these policies to adapt them to the changing conditions and needs.

6. General conclusions

Based on the analysis of the technical efficiency of agriculture in the European Union countries from 2007 to 2023, taking into account the impact of the Common Agricultural Policy (CAP), general conclusions can be drawn:

- The analysis showed an overall increase in the technical efficiency of agriculture in the EU over the period studied. Most member countries achieved high efficiency rates, suggesting a positive impact of CAP reforms and investments in modern technologies. In particular, country groups such as the 'Productive Innovators' and 'Rapid Modernisers' showed significant progress in efficiency, which may be the result of successful implementation of innovation and adaptation to changing market conditions.

- There is a clear variation in technical efficiency levels between different country groups. Countries in the ‘Efficient Innovators’ group (e.g. Netherlands, Denmark, Germany) have achieved the highest efficiency rates, while the ‘Challenged Adaptors’ (e.g. Greece, Croatia) face a variety of structural and economic challenges, which affect their ability to improve efficiency.
- The CAP has played a key role in shaping the technical efficiency of agriculture in the EU. Policy reforms, such as the introduction of direct payments and rural development programmes, have contributed to increased investment in modern technologies and improved living conditions in rural areas. However, these effects have varied depending on the specific characteristics of the countries and their initial circumstances.
- Against the backdrop of increasing challenges related to food security, climate change and sustainability pressures, agriculture in the EU needs to adapt to new realities. The implementation of green transformation and the digitalisation of agriculture is becoming crucial for the further development of the sector. Countries that successfully implement innovative agricultural practices will be more likely to achieve long-term efficiency.
- The conclusions of the analysis point to the need for further research on the technical efficiency of agriculture in the context of changing market and policy conditions. It is important for the EU agricultural policy to be flexible and adapt to local needs and country specificities. In the future, it will also be necessary to diversify support instruments to better respond to the challenges and needs of different groups of countries.
- Investment in R&D and knowledge transfer is crucial to increasing technical efficiency in agriculture. Countries that make effective use of technological innovation and support the development of human capital are more likely to achieve high production efficiency. Cooperation between member countries in sharing experiences and best practices can further increase efficiency across the EU.
- The future of agriculture in the EU will largely depend on the ability of countries to adapt to the changing market, technological and environmental conditions. The balance between production and environmental protection will be vital, which requires innovative solutions and the involvement of all stakeholders in decision-making processes. The Common Agricultural Policy should continue its reforms to effectively support farmers in adapting to these challenges.

In conclusion, the analysis of the technical efficiency of agriculture in the EU between 2007 and 2023 shows positive trends, but also variation in performance between countries. The Common Agricultural Policy is crucial for the further development of the sector, but requires continuous adaptation and innovation to meet today’s challenges. These findings and recommendations can form the basis for shaping the future EU agricultural policy and agricultural development strategies in individual Member States.

7. Summary

The study analyses the technical efficiency of agriculture in the European Union countries for the 2007-2023 period, taking into account the development paths in each country and the impact of the Common Agricultural Policy. A set of variables was adopted that reflects the specifics of the business model of agricultural production and is also relevant to the analysis of technical efficiency. In the first stage of the research, on the basis of observations and analysis of the trajectory of the adopted variables, five groups of countries with similar development paths and efficiency were identified. An attempt was made to estimate the impact of different CAP instruments on the formation of these paths. In the second stage, the Data Envelopment Analysis (DEA) method was used, which, in the context of the adopted variables, allowed for an accurate assessment of the technical efficiency of agriculture, taking into account differences in the structure of production and the level of technological development. The results indicate a general upward trend in technical efficiency in the EU agriculture, but with marked differences between the separate groups of countries. The study also showed that the impact of the CAP on technical efficiency varies and depends on the initial conditions and development strategies adopted in each country. The results of the study made it possible to formulate recommendations aimed at raising and levelling the efficiency levels.

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