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# Economic competitiveness vs. green competitiveness of agriculture in the European Union countries

**JEL Classification:** *C55; O44; Q51; Q56; R11*

**Keywords:** *competitiveness; green competitiveness; agriculture; green growth; sustainable development; zero unitarization method*

**Abstract**

**Research background:** Many scientists have researched the economic competitiveness of agriculture. At the same time, considerably less attention is paid to the so-called green competitiveness. Considering a global trend searching for solutions to reduce the environmental impact of the agricultural sector, it seems reasonable to explore the overlap between economic competitiveness and green competitiveness.
**Purpose of the article:** This study aims to answer the following questions: What is the level of economic and green competitiveness of agriculture in respective countries? What is the level of the comprehensive competitiveness of agriculture in EU member states? Do the economic competitiveness outcomes of respective countries coincide with their green competitiveness rankings?
**Methods:** Taxonomic methods were applied to design synthetic indices of economic, green and comprehensive competitiveness of 27 member states of the European Union, based on multi-criteria sets of specific indicators from 2018.

**Findings & value added:** The results of analyses imply that, in general, the level of green competitiveness of agriculture is higher than the level of its economic competitiveness in EU member states. Simultaneously, the developed rankings show that respective countries' economic and green competitiveness are not linked. In other words, economic competitiveness outcomes do not match green competitiveness outcomes for EU agriculture. This work is a genuine contribution to studies on the methods for measuring and evaluating the competitiveness of agriculture as it designs separate synthetic measures for economic and green competitiveness and confronts both types of competitiveness in EU member states. The research findings for the first time provide clear answers to questions about the mutual relationship between economic and green competitiveness in agriculture. Furthermore, an added value of this study is that it introduces and attempts to define the notion of green competitiveness.

## Introduction

Competitiveness is a term that is frequently present in economic literature and studies, viewed from different perspectives, assigned different meanings and analyzed using different approaches. Studies concerning the competitiveness of agriculture play a special role as this sector is essential both from the point of view of the economy and implementing the concept of sustainable development (Matkovski *et al.*, 2019, pp. 326–335). The contribution of present-day agriculture can be considered in three aspects: its impact on economic growth and development, impact on the human living environment and impact on the natural environment (Arisoy, 2020, pp. 286–295). However, the green competitiveness of agriculture has not been clearly defined and explored. These things are gaining importance in the light of present-day challenges to agriculture associated with increased competition in the area of alternative use of natural resources, preservation of biological diversity, food safety, and climate change mitigation. This prompted us to define the green competitiveness of the agricultural sector as achieving a competitive advantage based on the existing environmental potential and the ability to manage it sustainably. The environmental potential should be interpreted primarily as the general status of the environment in which agricultural activity takes place and the quality of resources obtained and/or produced using green methods.

In view of the global trend searching for solutions to reduce the environmental impact of agriculture, investigating this sector's economic and green competitiveness in countries of the European Union seems reasonable. The aim of the research was to answer the following questions: What is the level of economic and green competitiveness of agriculture in respective countries? What is the level of the comprehensive competitiveness of agriculture in EU member states? Do the economic competitiveness outcomes of respective countries coincide with their green competitiveness rankings? For the purpose mentioned above, an aggregate index was designed, including multiple variables in the form of indicators describing competitiveness in the economic and environmental aspects.

As respective economies open to the world and the economic relations become international, the interest in evaluating the international competitiveness of countries and their sectors is growing. For evaluating the competitiveness of agriculture, in addition its relationship with the natural environment needs to be taken into consideration. This is clear looking at the present-day challenges to this sector (Prandecki *et al*., 2021; Zia *et al*., 2022). Such challenges include the essential dilemma of how to accommodate the sustainable development of agriculture with the growth in its attractiveness (Czyżewski *et al*., 2021). The literature review shows that agricultural competitiveness studies are usually limited to assessing selected features of agriculture based on partial indicators of productivity or international trade (Ball *et al*., 2010), selected adequately for the research objective. A broader research context in analysing international competitiveness, taking its determinants into account, was given by Ball *et al*. (2010) and Viira *et al*. (2015). Some studies evaluated competitiveness using a synthetic measure designed based on a broader range of variables (Nowak & Różańska-Boczula, 2022). However, they did not consider features expressing the environmental competitiveness of agriculture, nor did they compare the competitiveness of this sector in light of the achieved economic and environmental objectives. By contrast, some papers evaluate climate change's effect on agriculture's competitiveness (Lee & Karpova, 2018; Zia *et al*., 2022). Finding the right measures of this sector’s competitiveness is also an issue (Bris & Caballero, 2015). This is still a challenge to researchers.

This work is a genuine contribution to studies on the methods for measuring and evaluating the competitiveness of agriculture as it designs separate synthetic measures for economic and green competitiveness and confronts both types of competitiveness in EU member states. According to our knowledge, no research has been conducted so far to provide clear answers to questions about the mutual relationship between economic and green competitiveness in agriculture. Furthermore, an added value of this study is that it introduces and attempts to define the notion of green competitiveness.

Synthetic indices were designed using zero unitarization, which is a multi-criteria comparative analysis method. The main idea behind the multi-criteria comparative analysis is to create an aggregated indicator underlining the hierarchization of the analyzed objects (here, EU countries) in view of a multi-feature phenomenon (competitiveness of agriculture).

This work is structured as follows. The following section presents methods for designing the index of Economic Competitiveness of Agriculture (ECA), the index of Green Competitiveness of Agriculture (GCA) and the index of Comprehensive Competitiveness of Agriculture (CCA). Section three contains a ranking of EU countries according to respective aggregate measures and compares their economic and green competitiveness. An essential element of the study is a deep analysis of specific indicators, which allowed identifying the factors that considerably contributed to reducing the levels of competitiveness indices. The last section presents conclusions from the analyses.

## Literature review

Competitiveness is an issue that is analyzed in micro-, meso- and macroeconomic terms (Harvey *et al*., 2017, 199–205; Liu, 2017, pp. 111–133; Vrabcova & Urbancova, 2021, pp. 165–184). These competitiveness levels constantly interact to increase national (Roszko-Wójtowicz & Grzelak, 2020, pp. 657–688). The concept is defined in a diverse way, as it derives from various strands of economic theories: theory of international trade, theory of economic growth and microeconomics (Balkyte & Tvaronavičiene, 2010, pp. 341–365; Siudek & Zawojska, 2014, pp. 91–108; Voinescua & Moisoiu, 2015, pp. 512–521). Literature mentions several definitions and measures of competitiveness. Some researchers perceive competitiveness as the ability to achieve good results (Matyja, 2016, pp. 368–381; Nowak & Różańska-Boczula, 2022). In turn, others see it as maintaining the country's comparative advantage (Latruffe, 2010, p. 7; Matkovski *et al*., 2019, pp. 326–335). According to Hatzichronoglou (1996, p. 3), competitiveness is "the ability of companies, industries, regions, nations or supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis". The European Commission (2009, p. 7) defines it as "a sustained rise in the standards of living of a nation or region and as low a level of involuntary unemployment as possible". By contrast, Latruffe (2010, p. 5) sees competitiveness as the ability to face up to competition and achieve competitive advantages. Siudek and Zawojska (2014, pp. 91–108) conducted a detailed review of definitions of competitiveness. They underlined that many authors describe competitiveness as a purely theoretical term that is multi-faceted and relative and is associated with the market mechanism. Also, Berger (2008, pp. 3–17) postulates a necessity to look at competitiveness in relative terms. Therefore, a major role is assigned to cross-national research comparing the competitiveness of various countries within specified limits A significant trend in competitiveness surveys is associating it with the theory of business relations, which suggests that national competitiveness relies on a comparative advantage (Matkovski *et al*., 2019, pp. 326–335). In this case, definitions of competitiveness refer mostly to how a specific country/ cluster performs in international exchange (Czarny & Żmuda, 2018, pp. 119–133; Mizik, 2021).

Many scientific papers emphasize the relationship between the agricultural sector and the natural environment. As agricultural production was intensified by simplifying the agroecosystems' structure and increasing production inputs, many threats to the natural environment arose (Kalaitzidis *et al.,* 2011; Godfray & Garnett, 2014; Rohila *et al*., 2017, pp. 145–148). Thus, the evaluation of the competitiveness of agriculture not only from the perspective of its productivity and economic performance, but also regarding its impact on the natural environment is an important line of research.

There are several different approaches to the issues of competitiveness, including its evaluation at the national, regional and sector-based level (Keogh *et al*., 2015, p. 7). Previous studies on the competitiveness of agriculture-focused mostly on a selected aspect of this phenomenon. For instance, Ball *et al.* (2010, pp. 611–627) evaluated the competitiveness of agriculture in 11 countries of the European Union and the United States based on relative productivity and relative prices. Other studies based on Total Factor Productivity (TFP) suggest slow progress in productivity convergence in the agriculture of EU countries (Baráth & Fertő, 2016, pp. 228–248). Many authors explored the competitiveness of agriculture through the prism of international trade, using several indicators to determine the international trade outcomes for a specific country/group (Senyshyn *et al*., 2019, pp. 130–143; Jarosz-Angowska *et al*., 2020, pp. 779–803; Pawlak, 2022). In her review of studies on agricultural competitiveness, Latruffe (2010, p. 12) noted that in addition to trade-related measures such as the Revealed Comparative Advantage (RCA), strategic management indicators including production cost or profitability ratios are also employed. Some studies concerning the competitiveness of the agri-food sector refer to competitiveness in the distribution chain, marketing, processing and retail trade, marketing margins, price transmission, as well as innovation in the supply chain (Lloyd, 2017, pp. 3–21; Materia *et al*., 2017, pp. 249–268). Also, many scientific studies tackled the existing competitive potential and results achieved by this sector. They implied that a high competitiveness potential was not always equivalent to the country's highly competitive position (Nowak & Różańska-Boczula, 2022). However, no uniform methodology was developed to evaluate the level of competitiveness of agriculture, let alone its definitions (OECD, 2011, p. 21). The term outcome competitiveness or economic competitiveness refers to the effects the agricultural sector achieves in economic competition (Jóźwiak, 2012, p. 9; Zegar, 2012, pp. 563–573). This is an approach employed in this paper. The competitiveness mentioned above is defined as the ability to perform more efficiently than the competitors. In addition, Jambor and Babu (2016, p. 25), and Tłuczak (2019, pp. 550–559), underline that an adequate competitive potential must be built to achieve a specific competitive position. Literature highlights that the main research problem is that a single generally accepted definition of economic competitiveness does not exist. Different approaches to competitiveness are mainly due to applying multiple criteria that allow capturing the multidimensionality of this phenomenon (Altomonte & Ottaviano, 2011, pp. 62–89; Roszko-Wójtowicz & Grzelak, 2020, pp. 657–688).

The competitiveness of agriculture in the environmental aspect was then evaluated more in terms of its sustainability. Such studies on EU agriculture were conducted, among other researchers, by Nowak *et al.* (2019) and Czyżewski *et al.* (2021, pp. 137–152). Schindler *et al.* (2015, pp. 1043–1057) highlight that many methods based on sets of indicators have been used in agricultural sustainability studies in recent years. However, international standards on methodologies for assessing the level of sustainability of agriculture have not been developed. An attempt at evaluating the relationship of agriculture with the natural environment was also made by Kasztelan and Nowak (2021), who — based on a synthetic index — evaluated the green performance of the agricultural sector in 20 member states of the EU. A set of agri-environmental indicators was also used by Turčeková *et al.* (2015, pp. 199–208) who assessed agri-environmental performance in EU member states. In contrast, Zia *et al.* (2022) examined the relationship between climate change and the competitiveness of agricultural markets. They underlined that a comprehensive measure for evaluating the global competitiveness of the agricultural sector does not currently exist. This is because most of the agricultural competitiveness indicators do not consider climate change's effect on the competitiveness of the agricultural market. Some authors also focus on identifying problems induced in the natural environment by the conventional agriculture model (Kalaitzidis *et al.*, 2011). Green growth is an important line of study in which the agricultural sector should be included. Souza Piao *et al.* (2021) and Stevens (2011) indicate that seeing environmental protection as a force driving economic growth is important and that the results should be measured in the long run. In addition, Yang *et al.* (2022) show that an improvement in agricultural infrastructure and the quality of human capital positively affects the increase in agricultural eco-efficiency.

Competitiveness studies use several measurement methods, from single indicators through their sets to more advanced econometric methods. One of the directions in competitiveness studies is using taxonomic methods, including Hellwig's development model. Such an approach referring to the economies of EU member states is represented, among other authors, by Roszko-Wójtowicz and Grzelak (2020, pp. 657–688). However, the set of variables used there comprised only six diagnostic features. By contrast, cluster analysis methods to assess differences and similarities between EU countries and the multi-criteria decision-making method (TOPSIS) were used by Małkowska *et al*. (2021, pp. 325–355) and by Nowak and Kamińska (2016, pp. 507–516). Studies regarding sustainable development also include those by Wang *et al.* (2021), who, using Data Envelopment Analysis (DEA), assessed the eco-efficiency of agricultural production. Thus, based on the review of literature, it can be concluded that an approach to evaluating and measuring competitiveness changed in time, which points to a need for continued research in order to present the complexity of this economic phenomenon from various perspectives (Roszko-Wójtowicz & Grzelak, 2020, pp. 657–688; Zia *et al*., 2022).

## Research method

The research used a multi-criteria analysis procedure that allows the evaluation of specific objects or phenomena described by multiple variables. Taxonomic methods constitute a division of multi-faceted comparative analysis (Aruldoss *et al*., 2013; Celata & Sanna, 2019; Dean, 2020; Kasztelan, 2021). The three types of indices discussed further were designed by the hierarchical ordering method, which uses the formula of the median and standard deviation for this purpose. This method is characterized by high robustness to extreme observations, which is particularly significant in the comparative analysis of European Union countries (Navarro *et al.,* 2014; Grzebyk & Stec, 2015, pp. 110–123; Caruso *et al*., 2018; Sulich & Sołoducho-Pelc, 2021).

Based on a review of reference literature concerning synthetic measures (OECD, 2008; Mazziotta & Pareto, 2013, pp. 67–80; Godlewska & Sidorczuk-Pietraszko, 2019; Małkowska *et al.,* 2021; Chen *et al*., 2021), the following research procedure stages were adopted for the purposes of this study:

1. Defining the objective and subjective scope of research;
2. Selecting and/or designing independent variables (partial/specific indicators) to describe the studied phenomena;

3. Standardization of partial indicators using zero unitarization method;
4. Designing synthetic indices for each EU country based on median and standard deviation values of standardized specific indicators;
5. Establish a linear hierarchy of countries based on determined indices in descending order.

Firstly, we identified the object of study and the subjects to be analyzed. The study's main objective was to evaluate the economic competitiveness and green competitiveness of agriculture in 28 EU countries (as per 2018), in particular focusing on the mutual relationship between these phenomena. Thus, a decision was made to design three types of synthetic indices: Economic Competitiveness of Agriculture (ECA), Green Competitiveness of Agriculture (GCA) and Comprehensive Competitiveness of Agriculture (CCA).

At the following stage, we focused on selecting the right independent variables, which is a key issue according to Walesiak (2011) and Roszko-Wójtowicz and Grzelak (2021). The selection of explanatory variables determines the accuracy of the final evaluations and the appropriateness of decisions based on them. Usually, the list of indicators is long, so selecting them for a specific issue is necessary. In creating sets of explanatory variables for designing synthetic indices, we mostly relied on the experience of international institutions that investigate the competitiveness of agriculture on a daily basis, such as the FAO, the European Environment Agency (EEA) and the OECD. In this way, 10 specific indicators describing economic competitiveness and 12 indicators describing green competitiveness of agriculture were initially delimited. The indicators selected for assessing economic competitiveness were the outcome categories of agriculture, including partial indicators of productivity. Their selection was dictated by the fact that they (and, in particular, labor productivity) are deemed to be among the most appropriate measures of long-term competitiveness (Giannakis & Bruggeman, 2018, pp. 94–106; Kijek *et al*., 2020, pp. 391–401). Magrini (2022) also emphasizes that productivity is the ability of the agricultural sector to allocate resources to produce goods and services efficiently. In turn, total productivity indices are widely applicable in economic analysis thanks to their comprehensive nature, as shown by the aggregate analysis of expenditure (Kijek *et al*., 2019, pp. 1–9; Magrini, 2022). By contrast, the share of respective countries in the gross value added (GVA) of the EU agriculture determines their position in the EU agricultural sector. In their studies, Nowak and Różańska-Boczula (2022) adopted this measure to determine the competitiveness of agriculture. The indicators of environmental competitiveness consist of variables describing both positive and negative relationships between agriculture and the natural environment.

Thus, land and water resources were taken into account, along with their quality and intensity of use. An indicator describing emissions from agriculture and production of renewable energy from agriculture and organic farming potential was also included. Most of these indicators were used for evaluating the level of sustainability of agriculture (Nowak *et al.*, 2019; Magrini, 2022). The selected indicators were verified in terms of data availability for all the 28 EU countries. Finally, 16 indicators (73%) met this condition and were used to construct the indices (Tab. 1). In addition, given a large gap in information about the key study indicators, Croatia was excluded from analyses. Here, the latest data available were included.

The third stage of the research procedure was the standardization of partial indicators. The set of explanatory variables included stimulants, positively affecting the phenomenon under study (the higher the value, the better), and destimulants, negatively affecting the phenomenon under consideration (the lower the value, the better) (Kasztelan, 2020). For example, GHG emissions are undesirable for agricultural competitiveness, so this indicator is a typical destimulant. In other words, the higher the emissions, the lower the green competitiveness of agriculture (lower GCA index). On the other hand, from the point of view of economic competitiveness, high soil productivity is desirable, so the $x_1$ indicator is a typical stimulant.

The values of variables ($x_j$, j=1,2,…,m) describing the EU countries ($o_i$, i=1,2,…,n) are presented as a matrix of observations in the following form:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \tag{1}$$

As the set of detailed indicators contains variables that cannot be directly aggregated, they were normalized using the zero unitarization method (Kukuła, 2000; Fura*, et al.*, 2020; Sompolska-Rzechuła, 2021):
for stimulants:

$$z_{ij} = \frac{x_{ij} - \min{(x_{ij})_i}}{\max{(x_{ij})_i} - \min{(x_{ij})_i}} \tag{2}$$

for destimulants:

$$z_{ij} = \frac{\max{(x_{ij})_i} - x_{ij}}{\max{(x_{ij})_i} - \min{(x_{ij})_i}} \tag{3}$$

Only this method meets all seven postulates formulated for the procedure of standardisation of variables. The values of variables $z_{ij}$ are in the range [0; 1], they are devoid of physical units, so they can be added and compared (Jarocka, 2015; Kiselakova *et al.*, 2020; Kasztelan, 2021).

Then, the normalized values of each indicator were used as the basis for calculating the median (equations 4 and 5) and standard deviation (equation 6) (Grzebyk & Stec, 2015, pp. 110–123; Kasztelan & Nowak, 2021):

$$Me_i = \frac{z_{\left(\frac{m}{2}\right)i} + z_{\left(\frac{m}{2}+1\right)i}}{2} \tag{4}$$

$$Me_i = z_{\left(\frac{m}{2}+1\right)i} \tag{5}$$

$$Se_i = \sqrt{\frac{1}{m}\sum_{j=1}^{m}(z_{ij} - \overline{z})} \tag{6}$$

Next, based on the following formula (7), ECA, GCA and CCA indices were calculated for 27 EU member states:

$$w_i = Me_i(1 - Se_i) \tag{7}$$

Index values closer to 1 mean relatively higher levels of various competitiveness categories. Estimation of synthetic measures allowed a linear hierarchisation and comparative analysis of EU countries. Respective member states were also assigned to four groups featuring similar economic competitiveness, green competitiveness and comprehensive competitiveness levels, using the following key:

| | | |
|---|---|---|
| group I: | $w_i \geq \overline{w} + S$ | high level |
| group II: | $\overline{w} + S > w_i \geq \overline{w}$ | medium-high level |
| group III: | $\overline{w} > w_i \geq \overline{w} - S$ | medium-low level |
| group IV: | $w_i < \overline{w} - S$ | low level |

## Results and discussion

The diagnostic variables adopted for analyses varied greatly from country to country in the EU (Table 2). The coefficients of variation ranged from about 14% to more than 152%. The greatest variation was observed for Final energy consumption by agriculture/forestry (x15), Soil organic matter (x12) and GVA from agriculture (x7). By contrast, Total factor productivity (x5) and UAA managed by farms with high input intensity (x10) were the least varied.

The rankings of 27 EU member states, based on synthetic index calculations (stage 5 of the research procedure), are presented in Table 3. Figure 1 is a graphic representation of the results of the evaluation for comprehensive competitiveness of agriculture (CCA) in the analyzed countries, and Figure 2 presents the mutual relationship between economic competitiveness (ECA) and green competitiveness (GCA). Colors on Figure 1 signify respective groups, delimited according to the adopted classification methods to which the countries belong.

The mean CCA for the EU countries was 0.2605, which means that the overall level of comprehensive competitiveness of agriculture in the 27 EU member states is very low considering its possible development range (0.1). Furthermore, the standard deviation of CCA testifies to a large differentiation in comprehensive competitiveness in respective member states. In terms of the CCA index, the best result was recorded in Spain (0.5006), while the worst in Bulgaria (0.0865). Group I — characterized by the highest competitiveness level — consisted of only three member states: Spain, France, and Germany and the Group IV, apart from Bulgaria, comprised Romania, Ireland, Estonia and Malta. Member states were most numerously represented in group II (11), featuring average high ranks of comprehensive competitiveness of agriculture.

A separate analysis of ECA and GCA in the studied countries leads to the conclusion that the overall level of green competitiveness of agriculture in EU countries is definitely higher (0.4503) than the level of economic competitiveness (0.1992). The country ranked best for green competitiveness was Austria (0.5893), while the Netherlands scored the worst (0.1062). In turn, with reference to economic competitiveness, the highest index was noted for Spain (0.4732) and the lowest for Lithuania (0.0236).

Out of 27 EU member states, Austria was the only one included in the group with the highest green competitiveness, whereas 18 countries formed the most numerous group II (with average high competitiveness levels). Only eight countries were classified in groups that ranked low for green competitiveness of agriculture. By contrast, looking at economic competitiveness (ECA), the distribution of countries between groups ranked high (I and II), and those ranked relatively low (III and IV) was more even (13/14).

The results of the study also imply significant disparities between evaluations of economic competitiveness and evaluations of green competitiveness in respective countries. Given the rankings of EU member states, the largest difference was observed for the Netherlands (2nd for ECA and 27th for GCA), Belgium (6/23), Estonia (21/4) and Bulgaria (22/6). In turn, the lowest difference was noted in Italy (11/14), Finland (15/12), Malta (19/24) and Romania (26/21). It is worth emphasizing that out of the 27 countries analyzed, as many as 19 (more than 70%) were at least 10 ranks apart. This concludes that the economic competitiveness of agriculture in EU countries is not equivalent to their green competitiveness. Even if the agricultural sector of a specific country features high economic competitiveness, this usually entails more environmental impact. Conversely, a high rank for green competitiveness of agriculture often does not coincide with its economic competitiveness.

What factors determined the overall low level of economic and comprehensive competitiveness of agriculture in EU countries? In the first place, the following should be noted:

- Low land and labor productivity in agriculture – 0.1687 and 0.2485, respectively;
- Low net agricultural entrepreneurial income in real terms – 0.2605;
- Relatively low share of renewable energy produced from agriculture – 0.2627;
- Relatively low agricultural income per family worker compared to wages of workers in the whole economy – 0.2921.

A thorough analysis of specific indicators concludes that the overall low comprehensive competitiveness of agriculture in the EU member states was due to low levels of their economic competitiveness. Table 4 indicates the specific indicators for respective countries which scored low for standardized measures ($z_{ij}$<0.4000). It is clear from the table what challenges each country faces in improving agriculture's economic and environmental competitiveness. This corroborates our previous findings. In the vast majority of EU countries, the main challenge for the agricultural sector is the improvement of economic competitiveness. This mainly refers to the countries of Central and Eastern Europe. Secondly, with a few exceptions (the Netherlands, Belgium), the hitherto achievements of EU member states in green competitiveness of agriculture should be given a positive evaluation.

The study results can be compared to the findings of other authors who evaluated selected aspects of EU agriculture. Studies by Baráth and Fertő

(2016, pp. 228–248) and Pawlak *et al.* (2021) show that agriculture in EU countries varies both in terms of its potential and the efficient use of such potential. Other studies corroborate that agriculture in member states varies in terms of competitiveness. Nowak and Różańska-Boczula (2022) demonstrated a significant difference in the level of competitiveness of agriculture between new and old member states. Countries with the lowest competitiveness expressed by a synthetic measure based on sources and effects of competitiveness were Belgium, Luxembourg, France and Germany. Although Belgium was highly competitive, its competitive potential was very low. Jarosz-Angowska *et al.* (2020, pp. 779–803) conducted a separate assessment of agriculture's competitive potential and its position from the point of view of international trade. They also mentioned disparities in the agricultural competitiveness level between the old EU countries and the newly acceded countries. It was underlined that those countries' low competitive potential is largely due to the structural conditions of agriculture and relatively low productivity of the production factors. Our studies lead to a similar conclusion. The only new member state with a relatively high level of economic competitiveness is the Czech Republic. However, this country has favorable agricultural structures. Čechura *et al.* (2017), who investigated productivity trends in the EU dairy sector, found no evidence of convergence processes in the sector between old and new member states. They only observed signs of catching up in the Czech Republic and Slovakia. They also noted the size of farms favorable to implementing technical and technological progress. In addition, according to the farm accountancy data network EU FADN (2022), in 2019, the average income per farm in the Czech Republic was EUR 42 359, which was nearly twice as much as, on average, in the EU. In contrast, the average income of Slovakian farmers was EUR 16852, considerably lower than in the Czech Republic. Examining the sustainability of agriculture in the EU, Magrini (2022) identified three groups of countries, depending on the level of accomplishment of their objectives. The Czech Republic was assigned to Group Three, comprising the least sustainable countries. Guth *et al.* (2020) explain that differences in productivity between old and new member states stem from the variations in the level of support, mainly in the form of direct payments. In their opinion, agriculture in new member states still shows a high potential for increasing productivity, whereas, in the EU–15, it reached the top and, in a sense, ceased to develop in classical economic terms. The comparison of both types of competitiveness — economic and green competitiveness – is also worth noting. Many countries with highly intensive agriculture and high economic competitiveness showed low green competitiveness. Although, as underlined by Czyżewski *et al.* (2021, pp. 137–152), in

Western Europe, the intensification of agricultural production is increasingly balanced, in some countries, its load on the natural environment remains high. Such a country is the Netherlands, which — according to other authors — is classified as a country with the most competitive agricultural sector (Nowak & Kamińska, 2016, pp. 507–516). However, Gołaś (2019, pp. 22–43) reported that labor productivity in the Netherlands in 2014–2016 was the highest among 28 member states and was four times higher than, on average, in the European Union. Furthermore, Kasztelan and Nowak (2021) demonstrated that the Netherlands and Belgium featured the highest pesticide use. This certainly affects the relationship between agriculture and the natural environment. The present study reveals that as many as five partial indicators of green competitiveness for the Netherlands were unfavorable. Furthermore, as demonstrated by Bos *et al*. (2013), the stocking and population density in the Netherlands are among the highest in the world. This puts biological diversity, the environment and the landscape under strong pressure. This implies that intensive farming, which overstrains natural resources, should be abandoned. Environmental protection is currently one of the priorities in the EU policy and, at the same time, one of the major challenges for agriculture Studies dedicated to sustainable agriculture imply that it reduces certain social costs of industrial agriculture. In addition, the higher the socio-economic stability of respective countries is, the more disposed they are to demonstrate green attitudes, including participating in agri-environmental programs (Bacon *et al.*, 2012, Guth *et al.*, 2020). Organic farming is integrated within the concept of sustainable agriculture. Cristache *et al*. (2018) demonstrated that the level of investment in this management model in many member states of the European Union is still insufficient. The reasons include differences in the level of socio-economic development.

## Conclusions

For many years, improvement in the competitiveness of agriculture has been a priority of the Common Agricultural Policy (CAP). On the one hand, Europe needs competitive agriculture that will be stable and efficient and optimally fulfil the environmental functions. Agriculture, being the main keeper of the natural environment, through the production process, notably in the context of industrial agriculture, disturbs the functioning of nature. Therefore, it should be a reform leader towards sustainable growth. The competitiveness of this sector should not be determined exclusively in the aspect of economic performance but also from the point of view of the environmental function.

This paper represents an interdisciplinary approach to the problem of agricultural competitiveness as it combines economic and environmental aspects of agriculture that are relevant to sustainable development. Measuring the competitiveness of agriculture is difficult due to methodological problems. This work is a genuine contribution to the approach based on synthetic measures employing several partial indicators and comparing competitiveness in economic and environmental aspects. Moreover, through the analysis of synthetic specific indicators, it was possible to identify the strengths and weaknesses of the competitive-ness of agriculture in respective countries.

The results allowed us to formulate an answer to the research mentioned above questions. Synthetic indices were calculated based on partial indicators in response to the first question. Then, their application led to the finding that Spain, the Netherlands, France, Germany and the United Kingdom featured the highest economic competitiveness. By contrast, Austria, Slovakia, Portugal and Estonia scored the highest for green competitiveness according to the adopted measure. Afterwards, the comprehensive competitiveness index was designed, and a ranking of countries showing their position in terms of competitive advantage was developed. Spain, France and Germany turned out to be the most competitive. A significant aspect of the study was checking to what extent the results of economic competitiveness outcomes for respective countries coincided with their ranks for green competitiveness. Material disparities were identified between the value of both indices in respective member states. The highest difference was observed for the Netherlands, which ranked 2nd for economic competitiveness and only 27th for green competitiveness.

Considering the results of our study, one of the main challenges for the EU countries in the coming years should be pursuing a balance between economic and environmental objectives in agricultural production. A significant problem is an overall low level of economic and comprehensive competitiveness of agriculture in EU countries. We should particularly focus on improving the land and labor productivity ratios and on relatively low agricultural income compared to other sectors of the economy. By contrast, as regards environmental issues, measures to successively increase the share of agriculture in renewable energy production are indispensable. Future studies should also consider income inequality in agriculture in the context of assumptions of sustainable development and the effect of the instruments of the Common Agricultural Policy on reducing these inequalities. The direction in which the European agriculture develops is particularly significant in terms of solving environmental and climatic issues. Sustainable development programs have been implemented for years, but despite the desired changes initiated in agriculture, they are still insufficient for the perceived needs. At present, such opportunities should be sought in the European Green Deal, which is expected to give rise to subsequent international measures to achieve ambitious climatic and environmental goals. However, this strategy's potential impact on economic objectives is a moot point. The ecological transformation postulated by the European Green Deal throws down challenges to countries, societies, agricultural producers and institutions. These challenges refer to collaboration in research and production and to undertaking measures to increase social acceptance of environmental goals. We should also be aware that environmental protection and related environmental competitiveness is not only a European, but also a global problem, implying a need for global solutions.

The limitations that emerged during the analyses, so to speak set a potential direction for future research. The indices were based on 16 indicators, although we initially identified 10 specific indicators describing economic competitiveness and 12 indicators describing green agricultural competitiveness. This is the result of an information gap in data reporting by some EU countries. A systemic improvement in the efficiency of data collection would contribute to a more comprehensive assessment of the agricultural competitiveness of EU member states. Second, due to delays in data reporting, there is still a lack of information regarding the levels of specific indicators for 2019-2021. During this time, EU countries faced unique challenges - primarily related to the need to combat the COVID-19 virus pandemic. Therefore, a question arises about its impact on the present shape of the examined phenomena. Thirdly, European agriculture is greatly varied both in terms of agricultural structures, resources of production factors, the relationship between them, the efficiency of their use, and natural conditions. For this reason, the evaluation of competitiveness for such a non-homogeneous sector is a complex and poorly explored task, notably as regards the environmental aspect. Further thorough research is necessary to identify factors determining the competitive advantage.

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## Annex

**Table 1.** Indicators selected for the analysis

| Indicator symbol | Indicator group and name (unit of measure) | Stimulant/Destimulant |
|---|---|---|
| | **Economic/outcome competitiveness** | |
| $x_1$ | Labour productivity in agriculture (GVA in agriculture/Employed persons in agriculture (EUR/AWU) | S |
| $x_2$ | Agricultural factor income per AWU in real terms (EUR/AWU) | S |
| $x_3$ | Agricultural entrepreneurial income (net agricultural entrepreneurial income in real terms) per unpaid (non-salaried) annual work unit (EUR/AWU) | S |
| $x_4$ | The income per family worker compared to the wages of employees in the whole economy (based on EUR/hour worked) (%) | S |
| $x_5$ | Total factor productivity (TFP) compares total outputs relative to the total inputs used in the production of the output (both output and inputs are expressed in terms of volumes) (Index, 3-year moving average, 2005 = 100) | S |
| $x_6$ | Gross fixed capital formation in agriculture – Investments in assets that are used repeatedly or continuously over several years to produce goods in agriculture (%–GFCF in agriculture/GVA in agriculture) | S |
| $x_7$ | GVA from agriculture (%) | S |
| $x_8$ | Land productivity (EUR/ha) | S |
| | **Green/environmental competitiveness** | |
| $x_9$ | Utilised Agricultural Area (UAA) under Natura 2000 (% of UAA) | S |
| $x_{10}$ | UAA managed by farms with high input intensity per ha (% of UAA) | D |
| $x_{11}$ | Water quality – Gross Nutrient Balance 4-years average. (kg N/ha/year) | D |
| $x_{12}$ | Soil organic matter – total estimates of organic carbon content in arable land (tons/ha) | D |
| $x_{13}$ | Production of renewable energy from agriculture (% of the total production of renewable energy) | S |
| $x_{14}$ | Emissions from agriculture (tons of $CO_2$ equivalent per 1 ha) | D |
| $x_{15}$ | The area under organic farming (% of total UAA) | S |
| $x_{16}$ | Final energy consumption by agriculture/forestry per hectare of UAA (kilograms of oil equivalent/ha) | D |

Source: own elaboration based on the FAO, the European Environment Agency (EEA) and the OECD databases.

**Table 2.** Characteristics of the diagnostic variables

| Variable | Mean | Minimum | Maximum | Standard deviation | Coefficient of variation [%] |
|---|---|---|---|---|---|
| $x_1$ | 21820,67 | 4955,56 Romania | 72825,35 Netherlands | 15812,58 | 72,47 |
| $x_2$ | 18622,15 | 4464,68 Romania | 43772,80 Netherlands | 10255,22 | 55,07 |
| $x_3$ | 14726,46 | 2621,47 Lithuania | 49093,74 Spain | 10568,36 | 71,76 |
| $x_4$ | 61,05 | 10,49 Denmark | 183,54 Spain | 36,55 | 59,88 |
| $x_5$ | 111,16 | 62,53 Malta | 142,42 Latvia | 15,34 | 13,80 |
| $x_6$ | 47,39 | 7,36 Cyprus | 128,93 Latvia | 30,36 | 64,04 |
| $x_7$ | 3,68 | 0,03 Malta | 18,13 France | 5,29 | 143,80 |
| $x_8$ | 3034,14 | 607,64 Latvia | 14988,07 Netherlands | 3040,35 | 100,20 |
| $x_9$ | 9,13 | 0,58 Finland | 21,13 Luxembourg | 6,01 | 65,82 |
| $x_{10}$ | 40,68 | 14,6 Belgium | 77,7 Romania | 14,61 | 35,90 |
| $x_{11}$ | 65,10 | 2,00 Romania | 189,00 Cyprus | 45,59 | 70,03 |
| $x_{12}$ | 215,20 | 64,62 Hungary | 1795,39 Ireland | 319,42 | 148,43 |
| $x_{13}$ | 9,93 | 0,27 Estonia | 37,03 Netherlands | 7,92 | 79,76 |
| $x_{14}$ | 3,10 | 1,26 Bulgaria | 10,36 Netherlands | 2,11 | 68,09 |
| $x_{15}$ | 8,74 | 0,41 Malta | 24,08 Austria | 6,08 | 69,59 |
| $x_{16}$ | 240,64 | 36,53 Lithuania | 2001,27 Netherlands | 366,74 | 152,40 |

Source: own elaboration based on the FAO, the European Environment Agency (EEA) and the OECD databases.

**Table 3.** Comparison of agriculture competitiveness rankings of EU countries

| EU countries | ECA ranking | GCA ranking | CCA ranking | ECA level (group) | GCA level (group) | CCA level (group) |
|---|---|---|---|---|---|---|
| Austria | 9 | 1 | 11 | II | I | II |
| Belgium | 6 | 23 | 13 | II | IV | II |
| Bulgaria | 22 | 6 | 27 | IV | II | IV |
| Cyprus | 10 | 25 | 18 | II | IV | III |
| Czech Rep. | 7 | 18 | 4 | II | II | II |
| Denmark | 13 | 20 | 6 | II | III | II |
| Estonia | 21 | 4 | 24 | III | II | IV |
| Finland | 15 | 12 | 7 | III | II | II |
| France | 3 | 13 | 2 | I | II | I |
| Germany | 4 | 17 | 3 | I | II | I |
| Greece | 16 | 7 | 12 | III | II | II |
| Hungary | 20 | 10 | 14 | III | II | II |
| Ireland | 14 | 26 | 25 | III | IV | IV |
| Italy | 11 | 14 | 5 | II | II | II |
| Latvia | 25 | 15 | 19 | IV | II | III |
| Lithuania | 27 | 16 | 21 | IV | II | III |
| Luxembourg | 8 | 22 | 9 | II | III | II |
| Malta | 19 | 24 | 23 | III | IV | IV |
| Netherlands | 2 | 27 | 16 | I | IV | III |
| Poland | 24 | 9 | 20 | IV | II | III |
| Portugal | 18 | 3 | 22 | III | II | III |
| Romania | 26 | 21 | 26 | IV | III | IV |
| Slovak Rep. | 17 | 2 | 15 | III | II | III |
| Slovenia | 23 | 8 | 17 | IV | II | III |
| Spain | 1 | 11 | 1 | I | II | I |
| Sweden | 12 | 5 | 10 | II | II | II |
| United Kingdom | 5 | 19 | 8 | I | II | II |

**Table 4.** EU countries' challenges to improve the economic and environmental competitiveness of agriculture

| EU countries | Indicators (areas) with low values of standardised measures ($z_{ij}$ < 0.4000) | |
|---|---|---|
| | Economic | Environmental |
| Austria | $x_1, x_3, x_4, x_7, x_8$ | $x_{13}$ |
| Belgium | $x_3, x_4, x_7, x_8$ | $x_9, x_{11}, x_{14}, x_{15}$ |
| Bulgaria | $x_1, x_2, x_3, x_6, x_7, x_8$ | $x_{10}, x_{13}, x_{15}$ |
| Cyprus | $x_1, x_2, x_3, x_6, x_7, x_8$ | $x_9, x_{11}, x_{13}, x_{15}$ |
| Czech Republic | $x_1, x_2, x_3, x_7, x_8$ | $x_9$ |
| Denmark | $x_3, x_4, x_6, x_7, x_8$ | $x_9, x_{13}, x_{15}$ |
| Estonia | $x_1, x_2, x_3, x_4, x_7, x_8$ | $x_9, x_{10}, x_{13}$ |
| Finland | $x_1, x_3, x_4, x_7, x_8$ | $x_9, x_{13}$ |
| France | $x_6, x_8$ | $x_9, x_{13}, x_{15}$ |

**Table 4.** Continued

| EU countries | Indicators (areas) with low values of standardised measures ($z_{ij}$ < 0.4000) | |
|---|---|---|
| | **Economic** | **Environmental** |
| Germany | $x_3$, $x_4$, $x_8$ | $x_{15}$ |
| Greece | $x_1$, $x_2$, $x_3$, $x_6$, $x_7$, $x_8$ | $x_{13}$, $x_{15}$ |
| Hungary | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{15}$ |
| Ireland | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_9$, $x_{12}$, $x_{13}$, $x_{15}$ |
| Italy | $x_1$, $x_3$, $x_4$, $x_6$, $x_8$ | $x_9$, $x_{13}$ |
| Latvia | $x_1$, $x_2$, $x_3$, $x_4$, $x_7$, $x_8$ | $x_9$, $x_{13}$ |
| Lithuania | $x_1$, $x_2$, $x_3$, $x_4$, $x_7$, $x_8$ | $x_9$, $x_{13}$, $x_{15}$ |
| Luxembourg | $x_3$, $x_4$, $x_7$, $x_8$ | $x_{11}$, $x_{13}$, $x_{15}$ |
| Malta | $x_1$, $x_2$, $x_3$, $x_4$, $x_5$, $x_6$, $x_7$ | $x_9$, $x_{11}$, $x_{13}$, $x_{15}$ |
| Netherlands | $x_4$, $x_6$, $x_7$ | $x_9$, $x_{11}$, $x_{14}$, $x_{15}$, $x_{16}$ |
| Poland | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{13}$, $x_{15}$ |
| Portugal | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{13}$, $x_{15}$ |
| Romania | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{10}$, $x_{13}$, $x_{15}$ |
| Slovakia | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{10}$ |
| Slovenia | $x_1$, $x_2$, $x_3$, $x_4$, $x_6$, $x_7$, $x_8$ | $x_{13}$ |
| Spain | $x_6$, $x_8$ | $x_{13}$, $x_{15}$ |
| Sweden | $x_1$, $x_3$, $x_4$, $x_7$, $x_8$ | $x_9$, $x_{13}$ |
| United Kingdom | $x_6$, $x_7$, $x_8$ | $x_9$, $x_{13}$, $x_{15}$ |

**Figure 1.** Ranking of the EU countries according to the cumulative competitiveness of agriculture (CCA)

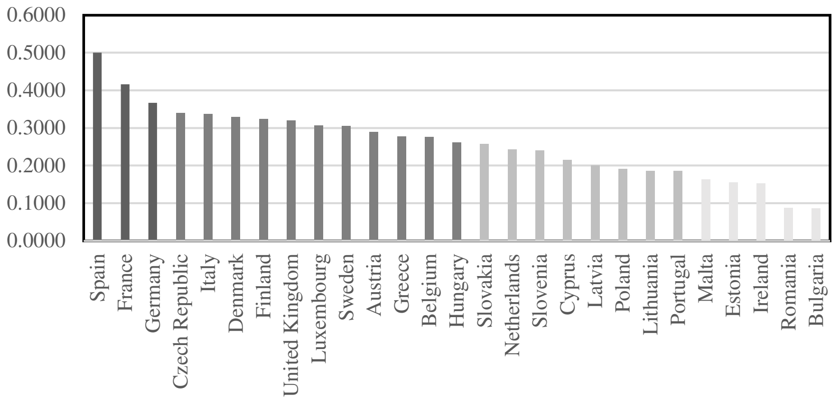
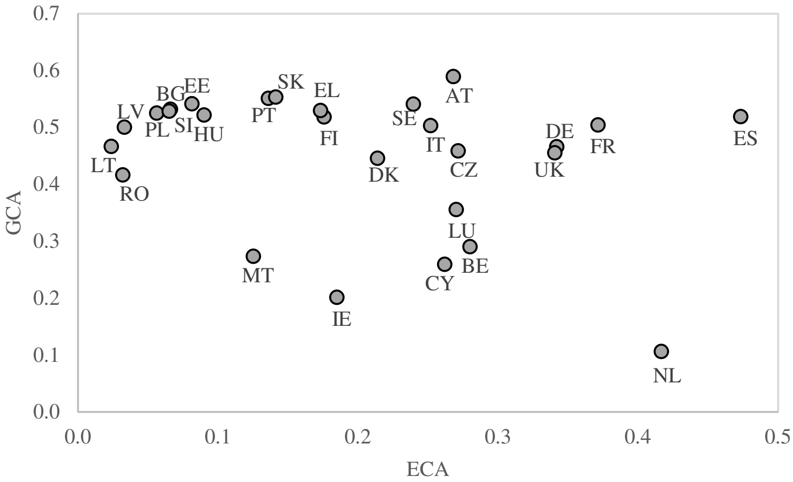


**Figure 2.** Economic competitiveness (ECA) vs green competitiveness (GCA) of agriculture in the EU countries




Note: AT – Austria; BE – Belgium; BG – Bulgaria; CY – Cyprus; CZ – the Czech Republic; DE – Germany; DK – Denmark; EE – Estonia; EL – Greece; ES – Spain; FI – Finland; FR – France; HU – Hungary; IE – Ireland; IT – Italy; LT – Lithuania; LU – Luxembourg; LV – Latvia; MT – Malta; NL – the Netherlands; NO – Norway; PL – Poland; PT – Portugal; RO – Romania; SE – Sweden; SI – Slovenia; SK – Slovakia; UK – the United Kingdom.