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THE LEVEL OF ORGANIC FARMING PRODUCTIVITY IN SELECTED EU COUNTRIES

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ABSTRACT: The article aims to determine the efficiency of organic crop production and the potential of organic animal production on a macroeconomic scale in selected European Union (EU) countries. Synthetic indicators were constructed and calculated using Principal Component Analysis based on Eurostat data from 2012-2020. The results allowed us to compare the economic situation of organic farming in different countries and to determine their rankings. The discussion is complemented by an analysis of key variables relating to crop and animal production. This helped to explain the reasons for changes in the ranking of individual countries and to characterise the evolution of individual types of production. In organic crop and animal production, the clear leaders were the Netherlands, Belgium and Denmark (only in animal production), i.e., countries with well-developed, modern organic farming systems. Poland is characterised by relatively low crop production efficiency and one of the lowest animal production potentials. The results of the research can be used to improve the operation of agricultural policy in order to increase the efficiency of organic production.

KEYWORDS: organic farming, synthetic indicator of organic farming productivity, productivity of organic agriculture in the European Union countries

Introduction

The European Union (EU) aims to create a resource-efficient, competitive and modern economy, as manifested in the European Green Deal (EGD), an action plan to tackle climate change and environmental degradation. Agricultural production continues to contribute to environmental degradation, including climate change, air and water pollution, loss of biodiversity, soil erosion, and food waste (Wrzaszcz & Prandecki, 2020). This negative environmental impact is mainly due to the excess of nutrients used in agriculture.

Organic farming is a pioneer for sustainable agriculture and, thus, also for a sustainable food system (European Commission, 2020). The EU action plan to support the development of organic agriculture under the EGDis based on three main priorities: stimulating demand and ensuring consumer confidence, stimulating conversion and value chain development, and increasing support for organic farming (European Commission, 2022). According to the accompanying EGD strategy 'Farm to fork', the share of organic agricultural land in total agricultural land is expected to reach 25% in 2030 (European Commission, 2020). In 2020, the share in the EU's total UAA was 9.2% (Eurostat, 2022), but this figure varies widely across member states. It is highest in Austria, with 26.5% of organic agricultural land in UAA, in Estonia, with 22.4%, and in Sweden, with 20.4%. In Poland, it is 3.5% (Eurostat, 2022; FAOSTAT, 2022). A large part of the organic agricultural land in the EU is permanent grassland and not areas directly dedicated to organic food production of plant origin. In Austria, it occupies 57.7% of organic agricultural land, in Belgium 62.2%, in the Czech Republic 81.5%, in Estonia 42.5% and in Sweden 22.7% (Eurostat, 2022; FAOSTAT, 2022). In the EU, organic permanent grassland accounts for 42.4% of total organic UAA, land devoted to cereal production accounts for only 16.3%, while permanent crops account for 11.4%. The large share of permanent organic grassland in the organic UAA can be considered a variable that is indicative of the limiting potential of organic crop production, as it translates into a smaller share in organic UAA. As permanent grassland is only partly used for grazing animals, an increase in its area does not necessarily translate into an increase in organic food supply.

Organic food contains more nutrients and minerals than conventional food (Taghikhah et al., 2020). While organic agriculture is more sustainable, it produces lower yields compared to conventional agriculture, which, coupled with higher costs, results in higher organic food prices (Seufeert & Ramankutty, 2017). Studies show that a hectare of land farmed organically can produce 20 to 50 per cent lower yields (Meemken & Qaim, 2018). In this context, some concerns may be raised regarding the implementation of the

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EGD objective, including the 'Farm to fork' strategy. Given the continuous increase in demand for food, as well as the target of achieving 25% of organic land in the total agricultural land, a change in EU agricultural land use can be expected. Some conventional land may be converted to organic, but there will additionally be a need to convert other land for organic farming production (such as forests or other natural habitats). Studies show that in such situations, the benefit of developing additional land for organic farming would be offset by the greenhouse gas emissions produced during conversion (Purnhagen et al., 2021).

Considering the findings and relationships presented above, the article aims to determine the crop efficiency and animal production potential of organic farming on a macroeconomic scale.

An overview of the literature

One of the main factors that influence the conversion of conventional agricultural production to organic production is subsidies (Rozman et al., 2013). Palšová et al. (2014) showed that the development of organic farming was noticed in Slovakia after changes in the agricultural policy pursued after its inclusion in the Common Agricultural Policy (CAP) (i.e., there was a commitment to increase the land allocated to organic farming and the possibility for farmers to receive subsidies for establishing organic agricultural production). At the same time, organic livestock production dominated organic crop production. Based on statistical data, it was found that in Denmark and Sweden, the introduced procurement programmes for organic food in public sector institutions enabled the expansion of the organic food and farming sector (Daugbjerg, 2023).

Verburg et al. (2022) pointed out that the main barrier to the uptake of organic farming is primarily the insufficient value of public support. Other authors pointed to bureaucratic barriers within the national system for using CAP funds, as well as the instability and disorder of the system (Kociszewski & Graczyk, 2021). Wiśniewski et al. (2021) showed a mismatch between the use of funds for organic farming and its environmental potential; as a result, these funds are not fully utilised, adversely affecting the effectiveness of CAP support. A better delegation of financial resources for the development of organic farming in terms of spatial differentiation is needed. Additionally, a barrier due to the problem of acquiring additional labour has been demonstrated, as organic farming is more labour-intensive (Verburg et al., 2022).

In the literature, there are various studies on the development of conventional agriculture, its environmental aspects, and organic farming. For example, using the Hellwig method, Czyżewski et al. (2018) constructed a synthetic indicator of environmental sustainability for agriculture in EU regions. Pépin et al. (2021) analysed the socio-economic factors that affect organic vegetable farms in France. They conducted an online survey, and based on the results, they developed a typology of organic farms using Factor Analysis of Mixed Data and agglomerative hierarchical clustering (AHC). Other researchers have analysed the development of organic farming based on statistical (secondary) data. For example, Jeločnik et al. (2015) determined the development in Romania. They found great potential for the development of this type of agriculture due to the high fertility of agricultural land and the low level of chemical pollution in intensively cultivated areas.

On a national level, synthetic indicators of the development of organic agriculture and environmental conditions were constructed for counties in Poland in 2017 (Smoluk-Sikorska et al., 2020) and 2018 (Smoluk-Sikorska & Malinowski, 2021) using TOPSIS (the Technique for Order of Preference by Similarity to Ideal Solution). The indicator consisted of 28 diagnostic variables that describe the structure of organic farming. They indicated a significant differentiation in the level of development of organic agriculture in Poland, with little differentiation in environmental conditions.

Antczak (2021) used a dynamic synthetic indicator to determine the status and spatial differentiation of organic farming in Poland. Factors that influence the high level of development of organic agriculture in Polish regions were natural conditions (rich soils, naturally valuable areas), subsidies from national and EU budgets, support and cooperation with local authorities, the stability and consistency of regulations, proximity to large markets (in big cities), the support of local organisations and authorities, and access to the labour force. She showed the unstable, diverse and multidirectional development of organic farming in Poland. In another paper, Antczak (2019) used a synthetic indicator of development determined using the zeroed unitisation method to determine the level of development of organic agriculture in communes of the Łódzkie Voivodeship.

Based on the literature review, a research gap can be observed regarding the lack of synthetic indicators for the efficiency and potential of organic farming on a macroeconomic scale. Thus, the following research questions were formulated: How efficient is organic crop production, and what is the potential of organic animal production in EU member states? To answer these questions and to achieve the goal of the paper, two groups of synthetic indicators were constructed, divided into organic crop efficiency production and organic animal production potential. In this way, an attempt was made to complement the way that the development of organic farming has been measured, which so far has mostly been based on indicators of the size of the organic area, its share in the EU, the number of farms, and the value of sales on the organic food market. In the case of crop production, the indicator

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relates to the volume of production from a given crop per hectare devoted to that crop. It serves to assess the efficiency of this production. It is also indirectly relevant to the creation of production potential. In the case of animal production, the indicator relates to the number of selected breeding animals per hectare of UAA and thus determines the potential of this production.

Research methods

The PCA method used to construct the synthetic indicators makes it possible to reduce the diagnostic characteristics to a few principal components, facilitating interpretation. The principal components do not lose their informative capacity as the sum of their variances equals the sum of the variances of the input variables (Panek, 2009). The eigenvector values are interpreted as the correlation coefficients of the individual principal component with the variables included (Kwiatkowski & Roszkowska, 2008). A detailed description of the principal component method can be found in Ostasiewicz (1998), Aczel (2000), Morrison (1990), Jolliffe (2002), Radhakrishna (1964), and Krzyśko (2000), among others. This method can be found in Hellwig (1968) while using the analysis of variance to construct a synthetic indicator can be found in Pluta (1974; 1976).

Synthetic indicators were determined using the Principal Component Analysis (PCA) method for as many member countries as possible (subject to data availability). The available data cover the period 2012-2020 and come from the Eurostat database. When constructing the synthetic indicator of organic crop efficiency, the total production of cereals and the areas intended for their cultivation were considered without considering their individual types. The selection of more detailed data was limited by availability. As such, Austria, Germany, France, Denmark and Portugal were excluded. The final list of countries included Belgium, Bulgaria, Croatia, Cyprus, Czechia, Estonia, Finland, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, and Sweden. Conducting a comparative analysis in both static and dynamic terms involved calculating indicators and creating a ranking based on their respective values. It compares the production potentials of the selected countries, and their ranking from one year to the next shows how production capacities and their efficiency have changed compared to other countries.

The synthetic indicator of organic crop efficiency performance includes the following diagnostic variables:

- x_1 – cereals for the production of grain (tonne)/area of organic cereals for the production of grain (ha),
- x_2 – permanent crops for humans (tonne)/area of organic permanent crops (ha),

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- x_3 – plants harvested green from arable land (tonne)/area of permanent organic grassland (ha),
- x_4 – root crops (tonne)/area of organic root crops (ha),
- x_5 – vegetables (tonne)/area of organic vegetables (ha),
- x_6 – fruit (tonne)/area of organic fruit (ha).

When constructing the synthetic indicator of organic animal production potential, the lack of statistics for some member states prevented the inclusion of variables such as the number of organic eggs produced and the amount of organic milk, cheese or organic meat production. The selected compilation of the diagnostic variables included in this indicator avoided the elimination of Germany, Belgium, Finland, Luxembourg, Slovenia, Austria, and Portugal. With the indicated limitations in data availability, the indicator was calculated for Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden. The indicator takes into account the following diagnostic variables:

- x_1 – live bovine (pcs.)/ecological utilised agricultural area excluding kitchen gardens (ha),
- x_2 – live swine (pcs.) /ecological utilised agricultural area excluding kitchen gardens (ha),
- x_3 – live sheep (pcs.) /ecological utilised agricultural area excluding kitchen gardens (ha),
- x_4 – live goats (pcs.) /ecological utilised agricultural area excluding kitchen gardens (ha),
- x_5 – live poultry (pcs.) /ecological utilised agricultural area excluding kitchen gardens (ha).

The set of diagnostic variables means that the resulting indicator mainly determines the potential of animal production rather than its efficiency.

The construction of the synthetic indicators of organic crop efficiency and the synthetic indicator of organic animal production potential based on the value of the first principal component is as follows (Bąk, 2018):

normalisation of variables:

$$z_{ij} = \frac{x_{ij} - \overline{x_{ij}}}{s_j}, \tag{1}$$

where:

z_{ij} – the normalised value of the *j*th variable (diagnostic variable after standardisation),

x_{ij} – observation of the *j*th variable for object *i,* – arithmetic mean of the observations of the *j*th variable,

s_j – standard deviation of the observations of the *j*th variable.

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- calculation of the covariance matrix **S**,
- calculation of the eigen values and eigenvectors of the covariance matrix **S**,
- calculation of principal component values based on empirical data and eigenvectors:

$$Y=XW, \tag{2}$$

where:
Y – matrix of principal components,
X – matrix of empirical data,
W – matrix of coefficients of principal components, and the principal component values are the synthetic indicators of organic crop efficiency and the synthetic indicators of organic animal production potential analysed in the paper.

- determination of a synthetic indicator based on the value of the first principal component,
- ordering of objects based on the value of the first principal component (descending).

Research results

The first principal component explains about 60% of crop efficiency in the period analysed. Table 1 shows the eigen values for the analysed diagnostic variables from 2012 to 2020.

Table 1. Eigen values of the first principal component (loads of the first principal component) for the analysed diagnostic variables of organic crop production, 2012-2020

Variable	Eigen values of the first principal component								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
x_1	0.4204	0.4603	0.4532	0.4208	0.4033	0.3531	0.4840	0.3783	0.3613
x_2	0.4823	0.5068	0.4919	0.4770	0.4861	0.4903	0.5080	0.4978	0.4986
x_3	-0.0621	-0.0586	-0.0845	-0.0737	-0.0508	-0.0759	-0.1809	-0.1075	-0.1171
x_4	0.4509	0.2696	0.3196	0.3833	0.4755	0.4600	0.3072	0.3985	0.4064
x_5	0.3954	0.4523	0.4273	0.4553	0.3657	0.4162	0.3483	0.4455	0.4470
x_6	0.4766	0.5006	0.5107	0.4855	0.4885	0.4943	0.5092	0.4902	0.4921

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Table 2. Ranking of selected EU countries according to the synthetic indicator of organic crop efficiency, 2012-2020

Country	2012		2013		2014		2015		2016		2017		2018		2019		2020	
	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**
Netherlands	1	6.54	1	6.50	1	6.35	1	7.42	1	6.70	1	6.53	1	4.10	1	6.08	1	5.72
Belgium	2	3.81	2	2.98	2	2.65	2	2.08	2	2.34	2	3.00	3	2.06	2	2.94	2	3.31
Sweden	3	1.48	4	1.72	4	0.99	4	1.07	3	1.77	3	1.88	5	0.54	4	1.60	3	1.91
Italy	4	1.43	3	0.93	6	0.45	6	0.08	6	0.90	5	0.73	4	1.65	3	1.8	4	1.75
Cyprus	5	0.73	7	0.11	9	-0.47	16	-0.83	18	-1.25	14	-0.81	18	-1.36	7	-0.11	7	0.11
Slovakia	6	0.19	6	0.21	7	0.19	11	-0.64	11	-0.52	15	-0.87	2	3.44	18	-1.45	17	-1.17
Slovenia	7	-0.20	8	-0.20	13	-0.63	12	-0.75	9	-0.45	13	-0.72	12	-0.41	14	-0.86	9	-0.05
Latvia	8	-0.49	10	-0.36	12	-0.60	14	-0.80	13	-0.73	16	-1.04	14	-0.82	8	0.08	16	-1.01
Spain	9	-0.55	8	-0.20	14	-0.86	13	-0.79	10	-0.46	8	-0.47	9	-0.25	8	-0.12	8	0.07
Greece	10	-0.58	5	0.27	3	2.23	3	1.95	5	0.91	4	0.95	6	0.44	5	1.11	5	0.78
Czechia	11	-0.59	11	-0.45	10	-0.52	10	-0.57	8	-0.38	9	-0.48	13	-0.55	13	-0.82	13	-0.87
Hungary	12	-0.60	9	-0.31	8	-0.30	9	-0.56	15	-0.91	11	-0.62	10	-0.35	10	-0.36	12	-0.71
Ireland	13	-0.75	12	-0.52	5	0.76	5	0.44	4	1.16	6	0.65	7	0.17	9	-0.31	10	-0.52
Lithuania	14	-0.96	14	-0.92	15	-1.01	19	-1.26	15	-1.05	7	-0.08	11	-0.38	6	0.08	6	0.29
Estonia	15	-0.96	17	-1.13	17	-1.30	17	-1.03	19	-1.35	19	-1.40	19	-1.52	19	-1.57	19	-1.64
Finland	16	-1.20	15	-1.00	18	-1.31	18	-1.23	14	-0.80	18	-1.26	21	-2.09	20	-1.75	20	-1.88
Romania	17	-1.22	18	-1.16	11	-0.59	8	-0.37	7	-0.22	12	-0.69	15	-0.92	16	-1.02	18	-1.47
Croatia	18	-1.25	16	-1.04	16	-1.04	7	-0.35	12	-0.65	10	-0.53	8	-0.10	11	-0.53	14	-0.94
Poland	19	-1.35	19	-1.44	19	-1.45	20	-1.30	17	-1.07	17	-1.05	16	-0.93	12	-0.69	11	-0.59
Bulgaria	20	-1.66	20	-1.60	20	-1.47	21	-1.75	21	-2.08	20	-1.72	17	-0.95	15	-0.90	15	-0.95
Malta	21	-1.81	21	-1.85	21	-2.07	15	-0.82	20	-1.93	21	-1.98	20	-1.77	21	-2.06	21	-2.13

* R – Rank; ** V – Value

Source: authors' work based on Eurostat (2022).

Using the eigen values of the first principal component, it is possible to see which diagnostic variables have a greater influence on organic crop production (Kolasa-Więcek, 2012). Throughout the analysed period, variable X_2 significantly influenced the value of the first principal component. Identical conclusions can be drawn for variable X_6. In contrast, the eigen values of the first component for variables X_1, X_4 and X_5 fluctuated, and the variable X_3 had a negligible impact.

Throughout the considered period, the first two places were occupied by the same countries, the Netherlands and Belgium. Third place alternated between Sweden and Italy. The changes are visible in the next places in the ranking.

Table 3 presents the values of the first component for the analysed diagnostic variables included in the synthetic indicator of organic animal production potential from 2012 to 2020. This potential is understood as the production capacity in animal production per ha UAA (number of animals per ha of Utilised Agricultural Area).

Table 3. Eigen values of the first principal component (loads of the first principal component) for the analysed diagnostic variables of organic animal production, 2012-2020

Variable	Eigen values of the first principal component								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
x_1	0.5585	0.5390	0.5420	0.5429	0.5333	0.5221	0.5362	0.5175	0.5339
x_2	0.5691	0.5575	0.5747	0.5541	0.5476	0.5401	0.5129	0.5126	0.5288
x_3	0.0027	0.0448	-0.0184	-0.0237	0.0071	0.0198	0.0605	0.1071	0.0903
x_4	0.1528	0.2423	0.1745	0.2126	0.2457	0.2828	0.3283	0.3552	0.3070
x_5	0.5838	0.5814	0.5875	0.5936	0.5961	0.5961	0.5813	0.5761	0.5769

Throughout the analysed period, variables X_1, X_2 and X_5 significantly influenced the level of organic animal production potential. Variables X_3 and X_4 had a negligible effect on the ranking position of the Member States.

The first four places in the ranking were occupied by the same countries: the Netherlands, Denmark, Belgium and Luxembourg. France was fifth in 2012 and tenth in 2020. Greece, on the other hand, moved up to fourth position in 2020 from eleventh in 2012. Ireland was in sixth place at the end of the period, ahead of Austria, Germany and France. Slight changes in the ranking position are visible in the middle of the ranking, by one or two positions on average. This applies to Sweden, Czechia, Cyprus, Portugal, Latvia, Italy,

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Table 4. Ranking of selected EU countries according to the value of the synthetic indicator of organic animal production potential, 2012-2020

Country	2012		2013		2014		2015		2016		2017		2018		2019		2020	
	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**
Netherlands	1	5.61	1	6.02	1	6.11	1	5.84	1	5.84	1	5.81	1	5.73	1	5.76	1	5.61
Denmark	2	3.17	2	3.03	2	2.90	2	3.09	2	2.89	2	2.97	3	2.80	3	2.38	3	2.54
Belgium	3	2.79	3	2.57	3	2.49	3	2.72	3	2.63	3	2.96	2	2.96	2	2.93	2	3.35
Luxembourg	4	0.75	5	0.51	4	0.61	4	0.83	4	0.80	4	0.46	5	0.61	5	0.55	5	0.61
France	5	0.46	4	0.52	5	0.48	7	0.24	9	0.14	10	0.07	9	0.05	10	0.07	10	0.01
Austria	6	0.35	6	0.28	7	0.32	8	0.01	7	0.35	8	0.22	8	0.22	9	0.13	8	0.20
Germany	7	0.30	7	0.25	6	0.42	5	0.38	6	0.36	5	0.44	7	-0.29	8	0.28	9	0.07
Slovenia	8	0.18	8	0.18	8	0.11	6	0.26	5	0.41	6	0.33	6	0.36	7	0.38	7	0.32
Ireland	9	0.02	10	-0.05	9	0.03	9	-0.11	10	-0.02	9	0.07	12	-0.29	6	0.43	6	0.33
Sweden	10	-0.05	11	-0.19	10	-0.16	10	-0.12	11	-0.17	12	-0.24	11	-0.21	12	-0.24	12	-0.19
Greece	11	-0.44	9	0.16	11	-0.34	11	-0.23	8	0.14	7	0.25	4	0.78	4	0.97	4	0.83
Czechia	12	-0.50	13	-0.51	13	-0.43	13	-0.38	13	-0.40	13	-0.43	13	-0.41	13	-0.48	13	-0.42
Cyprus	13	-0.50	12	-0.27	12	-0.40	12	-0.36	12	-0.20	11	-0.10	10	-0.10	11	0.06	11	-0.04
Portugal	14	-0.58	15	-0.60	15	-0.61	14	-0.53	16	-0.68	14	-0.66	14	-0.46	14	-0.67	15	-0.73
Latvia	15	-0.61	14	-0.58	14	-0.56	15	-0.61	14	-0.64	15	-0.67	16	-0.68	16	-0.72	14	-0.67
Italy	16	-0.67	16	-0.67	17	-0.73	18	-0.69	17	-0.70	18	-0.77	17	-0.75	17	-0.75	16	-0.76
Finland	17	-0.74	18	-0.79	16	-0.70	16	-0.68	18	-0.74	16	-0.76	18	-0.80	19	-0.82	18	-0.79
Croatia	18	-0.76	19	-0.85	22	-0.92	24	-1.02	20	-0.94	20	-0.89	19	-0.75	18	-0.76	19	-0.81

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Finland, Croatia, and Slovakia. At the bottom of the list were Spain, Bulgaria, Hungary, Poland, Romania and Malta.

Country	2012		2013		2014		2015		2016		2017		2018		2019		2020	
	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**	R*	V**
Slovakia	19	-0.76	17	-0.74	18	-0.81	17	-0.69	15	-0.66	17	-0.76	15	-0.67	15	-0.70	17	-0.77
Hungary	20	-0.84	22	-0.91	19	-0.82	20	-0.86	22	-1.00	24	-1.04	23	-1.09	23	-1.12	24	-1.13
Estonia	21	-0.87	20	-0.89	21	-0.84	19	-0.83	19	-0.90	21	-0.91	21	-0.92	21	-0.96	21	-0.93
Lithuania	22	-0.91	21	-0.90	20	-0.84	21	-0.93	21	-0.96	19	-0.86	20	-0.87	20	-0.91	20	-0.87
Spain	23	-1.01	23	-1.02	24	-0.99	23	-1.01	23	-1.02	22	-1.01	22	-1.02	22	-1.02	22	-1.03
Poland	24	-1.02	25	-1.09	25	-1.04	25	-1.07	26	-1.12	26	-1.11	25	-1.14	24	-1.15	25	-1.13
Romania	25	-1.06	24	-1.08	23	-0.99	22	-0.98	24	-1.07	25	-1.10	26	-1.17	26	-1.18	26	-1.22
Bulgaria	26	-1.11	26	-1.14	26	-1.12	26	-1.10	25	-1.09	23	-1.04	24	-1.09	25	-1.17	23	-1.05
Malta	27	-1.20	27	-1.24	27	-1.17	27	-1.19	27	-1.25	27	-1.24	27	-1.28	27	-1.31	27	-1.32

* R – Rank; ** V – Value

Source: authors' work based on Eurostat (2022).

Discussion

The calculation based on the methodology used showed that the variables for interrelated production of X2 (permanent crops) and X6 (fruit) mostly influenced the synthetic indicator of organic crop efficiency and the ranking of individual countries in a given year. They play an important role in shaping the rural landscape (through orchards, vineyards and olive tree plantations) and deliver environmental services. These types of production play an important role in shaping the rural landscape (through orchards, vineyards and olive tree plantations) and delivering environmental services. Taking into account all analysed countries, the average yield of permanent crop production was 3.7 tons/ha in 2012 and 3.0 tons/ha in 2020 (a decrease of 19% over this period). The average yield of fruit production decreased from 2.9 tons/ha in 2012 to 2.5 tons/ha in 2020 (i.e. 14%).

The countries at the top of the ranking, i.e., the Netherlands, Belgium, Sweden and Italy, showed significantly higher production efficiency for these variables than other countries throughout the analysed period. In the two best countries, the decline in productivity was more dynamic than the average in the entire group of countries. The highest decline was in the Netherlands, which was in first place – from 20.3 tons/ha in 2012 to 11.5 tons/ha in 2020 in production from permanent crops (by 43%) and from 20.1 tons/ha in 2012 to 14.3 tons/ha in 2020 in fruit production (by 29%). Over the same period, Belgium (second in the ranking) showed slightly smaller yield declines (39% in production from permanent crops and 31% in fruit production). Sweden recorded a 59% decrease in yield from permanent crops and an 11% increase in fruit production yield. The country is characterised by a very well-developed market for organic products, which generates strong demand impulses. In Italy, the yield from permanent crops increased by 88% (from 3.4 to 6.4 tons/ha) and fruit production by 80% (2.5 to 4.5 tons/ha) during the same period. Productivity indicators of permanent crop and fruit production show that the level does not depend on the climate that prevails in a given country. The most productive countries include countries from both the north and south of Europe. Productivity depends on the intensity of production methods and on individual spending in the market for organic products. Four countries with the highest productivity also had the biggest value of organic food sales per capita. According to FiBL & IFOAM (2022), in 2020, Sweden ranked first (212.3 EUR), the Netherlands was second (78.2 EUR), Belgium third (77.2 EUR) and Italy fourth (64.1 EUR)[1].

1 In 2020 (FiBL & IFOAM, 2022), Denmark (383.6 EUR), Luxembourg (284.6 EUR) and Austria (253.6 EUR) achieved the highest per capita sales of organic food products in the EU. However, due to a lack of data on production efficiency, these countries are not included in the part of the study related to crop production. This also applies to other

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The results also show a gradual convergence of productivity between the top two countries and the rest of the countries (Table 2), with calculations showing productivity from permanent crops increasing in countries with less developed organic farming: Cyprus (38%), Greece (51%), Spain (24%), Poland (312%), and Bulgaria (112%). In Poland, the increase in production per hectare of UAA may have resulted from changes in regulations, which were tightened in 2013. They included the requirement to supply products to the market by organic farms (Kociszewski & Graczyk, 2021). In 2012, Poland had an average fruit production capacity of 0.3 tons/ha and 2.5 tons/ha in 2020 (an increase of 733%), thanks to which so-called fictitious crops were liquidated. In previous years, the fictitious crops were officially classified as organic for the sole purpose of receiving subsidies. In practice, no production was carried out there, which reduced the productivity of Polish organic farming on a macroeconomic scale.

Variables X1 (live bovine), X2 (live swine) and X5 (live poultry) significantly influenced the indicator of organic animal production potential and, thus, the position of various countries in the ranking. The top three countries were characterised by a stable potential of animal production. In the Netherlands, the live bovine potential was 1.1 pcs/ha throughout the analysed period. Belgium's potential was similar, at 1.2 pcs/ha in 2012 and 1.1 pcs/ha in 2020. It decreased slightly in Denmark, from 1.0 pcs/ha in 2012 to 0.7 pcs/ha in 2020. It is a group of wealthy countries with a well-developed organic food market and intensive agricultural production, which translates into maintaining the possibility of animal production. Cattle breeding potential also remained stable in countries with a lower synthetic indicator of organic animal production potential. They are smaller countries but with well-developed cattle production. Ireland, Slovenia, Austria and Luxembourg maintained a potential of 0.7-0.8 pcs/ha in 2020. By contrast, Europe's two largest markets for organic production slightly reduced their potential. In Germany, it decreased from 0.6 pcs/ha in 2012 to 0.5 pcs/ha in 2020 and in France, from 0.4 pcs/ha to 0.3 pcs/ha. Bulgaria, Hungary, Poland and Spain showed the lowest potential, oscillating around 0.1 pcs/ha from 2012 to 2020.

Throughout the analysed period, the proportions of changes in cattle production potential and changes in organic cultivation areas were not related to their share in total UAA or their ranking (Table 4). In the Netherlands, which is ranked first, the cattle population increased by nearly 48%, with an increase in ecological UAA of 48%. In Belgium (second place), the increase was 54%, with an increase in ecological UAA of 66%. The situation was similar in countries with low potential for organic cattle breeding, low

well-developed markets – France and Germany. Across all EU countries, Sweden ranked fourth in terms of per capita sales, the Netherlands seventh, Belgium eighth and Italy ninth.

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positions in the ranking, and a relatively high share of organic crops in total UAA, i.e., Estonia (22.4% UAA) and Czechia (15.3% UAA). It was also visible in Italy and Germany, where the share of organic crops in UAA amounted to 10.2% (Eurostat, 2022), and the increase in that area was 54%, with an increase in the number of livestock units of 47%. The situation was slightly different in Sweden (20.4% UAA), where organic land increased by 28%, with an increase in the herd by 17%. In three other countries with well-developed organic farming, the increase in organic UAA was much faster than the increase in the number of animals. In Denmark (11.4% UAA), the increase in the herd was 24%, with a 75% increase in organic area. In Austria (26.5% UAA), it increased by 26% with a 10% increase in herds, and in France, it increased by 144% with a 93% increase in herds. These are markets where the domestic offer of products of animal origin is growing more slowly than in other product groups. In the same period, Poland showed a decrease in organic land by 25%, while the cattle breeding rate remained stable. It resulted from the tightening of the requirements for granting subsidies by Polish organisations of domestic agricultural policy (Kociszewski & Graczyk, 2021).

Over the time frame, the pork production potential (i.e., the average value of the X2 variable (live swine)) remained stable in all analysed countries. There were no dynamic changes either in the Netherlands and Denmark, which showed the highest potential (1.2-1.3 pcs/ha in 2012 and 1.4-1.5 pcs/ha in 2020), or in Belgium, which is close to the average of all analysed countries (0.2 pcs/ha in 2012 and 0.3 pcs/ha in 2020). The situation was similar in France and Luxembourg (0.2 pcs/ha over the whole period) and in Slovenia, Austria and Germany (0.1 pcs/ha).

The top two countries in 2020 (Table 4) had a great advantage in organic poultry production over the other countries. The Netherlands produced 54.3 pcs/ha (an 11% increase compared to 2012), and Belgium produced 51.6 pcs/ha (68% increase). The second group in this category includes Denmark 12.9 pcs/ha (70% growth) and France 9.5 pcs/ha, whose potential decreased by 16%. This group did not have such a big advantage in organic poultry compared to countries such as Germany (12.5% growth), Luxembourg (26% growth) and Austria (70% growth). The number of animals per hectare in France was higher than in these countries by 55-106%. The potential was much smaller but growing in Cyprus (3.4 pcs/ha (183% growth), Ireland 2.7 pcs/ha (68% growth), Sweden, 2.2 pcs/ha (10% growth), and Poland, 1.4 pcs/ha (250% growth). The remaining countries maintained very little poultry production potential. Among them, Spain can be distinguished; its potential increased from 0.1 pcs/ha to 0.8 pcs/ha (700%). The average potential for all countries increased by 31%.

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Taken as a whole, the ranking based on the synthetic indicator of animal production potential showed that the positions of individual countries did not change significantly. The reasons for France's decline from fifth place in 2012 to tenth in 2020 were the reductions in cattle and poultry production potential. The rise of Greece (from eleventh to fourth) and Ireland (from ninth to sixth) is the result of an increase in cattle and poultry production potential. The peculiarities of the production of these countries are noteworthy. Greece has the highest sheep population per hectare, amounting to 1.3 pcs/ha in 2012 and 2.7 pcs/ha in 2020. Ireland had the second highest potential of organic sheep. In 2012, it amounted to 0.7 pcs/ha, and in 2020, it was 1.1 pcs/ha.

Conclusions and limitations of the research

The synthetic indicators of organic crop efficiency and organic animal production potential make it possible to compare the economic situation of organic farming in different countries in a given year. It was possible to determine their rankings in static terms (Table 2, Table 4), but intertemporal comparisons can only be based on changes in the position of individual countries in these rankings over the years. For this reason, the discussion of the results of research on synthetic indicators was supplemented by an analysis of variables that relate to specific categories of plant and animal production each year. This made it possible to analyse the results in dynamic terms, explain the reasons for changes in the position of individual countries in the rankings, and determine the evolution of individual types of production.

The rankings showed that in both organic crop and animal production, the Netherlands and Belgium, countries with well-developed, modern production systems, were clear leaders. They are highly efficient in both conventional and organic production, gaining a significant advantage over the other countries in the study. In animal production, the same is true of Denmark, but due to the lack of available data, it could not be included in the calculation of the synthetic crop production index. The three leaders in the ranking of animal production potential achieved the greatest advantage over the rest of the countries in pig and poultry farming. Both in these categories and in cattle breeding, the Netherlands had the greatest potential. Denmark stood out from the first two countries in the potential of poultry production. Belgium was much worse in pig farming compared to the leaders. The high efficiency of crop production and the potential of livestock production in the Netherlands is partly because the large production volume comes from a relatively small area of organic farming. In 2018, it was the lowest in the EU, at 3.28% of UAA (Zieliński et al., 2022). This is linked to the intensification of organic production, which partly takes on the characteristics of conventional agricul-

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ture and reduces the provision of environmental public services. The level of productivity and production potential was also influenced by spending on organic food per capita. Factors such as the market size, the share of organic crops in the UAA, and the number of organic farms did not matter much. The results on the changes in the efficiency of particular categories of crop production also showed that there is a convergence of productivity. The average cattle and pig meat production potential for all countries did not change significantly. In most countries, however, there was an increase in poultry production potential (by an average of 31%). The exceptions were France and Italy, where there was a reduction.

In 2012, Poland, with the second lowest share of organic farming in the UAA (3.36%), was in nineteenth place in the ranking of crop production, but it moved up to eleventh place in 2020. This resulted from a significant increase in the efficiency of fruit production (by 733%) and permanent crops (by 311%), which was one of the effects of the Polish government tightening the requirements for granting subsidies to organic farms (eliminating fictitious crops with a simultaneous decrease in the area under cultivation). In animal production, Poland was close to the bottom of the ranking (Table 4) – 24th place in 2012 and 25th place in 2020. It had the lowest potential in cattle breeding, along with Bulgaria, Hungary and Spain (0.1 pcs/ha).

The synthetic indicators we developed, due to the diversity of the data categories, data availability, the complexity of the agricultural production structures of the analysed countries, and the limitations of the methodology, do not show development trends in the time frame. It is not possible to determine the rate of increase in crop production efficiency or the development of animal production potential, although it was possible based on variables for individual production categories. The indicators can form the basis for developing research based on an extended methodology for measuring the rate of productivity growth and the potential of organic production on a macroeconomic scale. A synthetic measure is needed to calculate the average value for the entire group of analysed countries and to compare the indexes from different years to determine the dynamics of change. Unfortunately, the research encounters limitations related to data availability. This makes it impossible to calculate organic crop production indicators for economies with the highest share of organic crops in UAA. It also limits an in-depth measurement of the efficiency of animal production based on the volume and value of final products. Currently, this can only be done for a small group of countries. Exploring the relationship between production potential, consumption patterns, and trade structures could be a valuable avenue for future research. In particular, analysing changes in production potential alongside shifts in consumption volume, value, and composition within individual countries and their structures of imports and exports would be worthwhile. For instance,

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comparing the economies with the greatest production potential to those with the largest markets for organic food products could yield interesting insights and help explain the reasons for changes in the efficiency and potential of organic production.

The contribution of the authors

The concept of the paper, N.S.-W.; project and the organisation of research, N.S.-W. and K.K.; analysis of results, N.S.-W.; writing – original draft preparation, N.S.-W. and K.K.; writing – review and editing, N.S.-W. and K.K.

All authors have read and agreed to the published version of the manuscript.

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