



Primary Sector Economics

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STOCHASTIC FRONTIER MODELLING OF ORGANIC SECTOR EFFICIENCY ACROSS EUROPEAN NATIONAL ECONOMIES

Abstract

The purpose of this study is to assess the efficiency of national organic sectors across European countries by distinguishing among export, retail, and consumer market performance. The methods involve separate panel stochastic frontier models with Cobb–Douglas function, an integrated domestic market efficiency index combining retail and consumer dimensions, and a quadrant-based classification of national development patterns. The main results show that processing infrastructure is the principal factor supporting domestic organic market efficiency, whereas a strong domestic market position does not necessarily coincide with high export efficiency. The organic sectors of European countries generally exhibit decreasing or near-constant returns to scale, suggesting that expansion of the resource base alone does not ensure proportional improvements in market outcomes. The scientific novelty of

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the study lies in developing a multidimensional country-level SFA framework that separately evaluates the export, retail, and consumer-market efficiency of national organic sectors. The study further introduces an integrated domestic market efficiency index and combines it with export efficiency to construct a quadrant-based typology of national organic sector development patterns. The authors' contribution is to extend efficiency analysis beyond the conventional farm-level perspective by applying three SFA models and combining their results to identify distinct patterns of organic sector development across European countries.

Key Words:

domestic market efficiency, European countries, organic exports, organic sector, stochastic frontier analysis, SFA, technical efficiency.

JEL: C23, C51, Q13.

5 formulas, 7 figures, 7 tables, 49 references.

Problem Statement

Over the past few decades, Europe's organic agricultural sector has expanded rapidly and undergone substantial structural change. By 2024, the area of organically certified land in the EU had reached 18.1 million hectares, accounting for 11.1% of total agricultural land. In several countries, the share already exceeded 25%; Austria, for instance, recorded 27.3%, thus surpassing the Farm to Fork target of 25% by 2030 set out by the European Commission (2021). The European organic retail market also continued to grow, reaching EUR 58.6 billion in 2024. These aggregate figures, however, conceal pronounced cross-country differences. Per capita consumption ranged from approximately EUR 2 in Romania to more than EUR 481 in Switzerland, where organic products accounted for around 12% of total retail food sales, the highest share worldwide (Willer et al., 2026).

Technical efficiency is a central measure of agricultural performance, reflecting the ability to transform available inputs, such as land, labour, and capital, into the maximum attainable level of output. Technical efficiency is commonly assessed using SFA or DEA. SFA was introduced independently by Aigner et al. (1977) and Meeusen & van Den Broeck (1977), who separated stochastic shocks from inefficiency. DEA, developed by Charnes et al. (1978), constructs a non-parametric frontier from observed data but treats all deviations from it as inefficiency. By contrast, SFA decomposes the error term into random noise and a one-sided inefficiency component (Nowak et al., 2015).

Comparative assessments of agricultural sector efficiency using SFA remain relatively uncommon in the European context. The specific characteristics of organic production should also be taken into account. Available evidence suggests that the transition to organic farming may initially be accompanied by some loss of productivity, which can result in lower technical efficiency than in conventional production systems.

The purpose of this study is to assess the efficiency of the organic sectors of European countries using stochastic frontier analysis, while distinguishing between two dimensions of market performance: external, or export, efficiency and internal, or domestic market, efficiency. In line with this objective, the specific characteristics of the European organic sector, and the analytical structure of the SFA models, four research hypotheses are formulated:

H1. Processing infrastructure plays a key role in the development of the domestic market for organic products.

H2. Countries with high domestic market efficiency are not necessarily leaders in export efficiency.

H3. The organic sectors of European countries exhibit decreasing or near-constant returns to scale.

H4. During the period analysed, export efficiency in the organic sectors of European countries improved more markedly than domestic market efficiency.

Literature Review

Empirical research reveals substantial cross-country differences in agricultural efficiency, although their magnitude and determinants vary with methodology. Studies of EU agriculture link efficiency to structural characteristics and trade openness (Nowak et al., 2015; Hart et al., 2015; Lyzun et al., 2024; Kostetska et al., 2026), while DEA applications identify persistent disparities within Serbia and between Western Balkan and EU agricultural systems (Marcikić Horvat et al., 2019, 2020). Comparable heterogeneity is reported using SFA (Đokić et al., 2022). More recent studies identify systemic efficiency reserves through slack-based DEA (Kyshakevych et al., 2025b) and assess the transformation of agricultural resources into factor income across the EU and Ukraine using SFA (Kyshakevych et al., 2025a). However, these studies largely treat agriculture as an aggregate sector rather than examining specialised organic markets.

Evidence on organic farming is less consistent. Efficiency estimates depend on methodology, production system, and performance criteria (Lakner & Breustedt, 2017; Lishchynskyy & Lyzun, 2024), while studies of conversion and certification report heterogeneous effects across countries and farm types (Latruffe & Nauges, 2014; Grovermann et al., 2021; Martín-García et al., 2024; Letort & Ridier, 2025). Blockeel et al. (2025) identify differing effects on costs, labour, and income across the EU, whereas Cimpoeș & Coșalić (2025) reveal substantial variation in organic farm efficiency in Moldova. Technical efficiency, productivity, income, and environmental performance may also follow different trajectories (Madau et al., 2017; Fusco et al., 2026), questioning the adequacy of a single efficiency criterion.

This multidimensionality is reinforced by resource and environmental studies. Smith et al. (2015) show that energy-efficiency conclusions depend on the selected denominator, while Seufert & Ramankutty (2017) stress the context-dependent performance of organic farming. Technological improvements may enhance agronomic and economic outcomes (Hetmanenko et al., 2021; Kundius, 2024), yet organic expansion also involves environmental and land-use constraints (Gensch et al., 2025). Thus, greater production capacity does not necessarily imply higher market efficiency.

Policy research reaches a similar conclusion. Although organic expansion is an EU strategic priority (European Commission, 2021), its effects vary across

contexts. European support measures influence farm efficiency (Casolani et al., 2021; Sokółowicz & Lishchynskyy, 2018), while organic adoption depends on economic, institutional, and structural conditions (Möhring et al., 2024). Financial factors also affect certification decisions (Tennhardt et al., 2026), and alternative pathways towards EU organic targets may produce different economic and environmental outcomes (Kremmydas et al., 2025). Hence, larger acreage or higher certification rates do not automatically generate proportional efficiency gains.

Market performance also depends on the wider organic value chain. Sanders et al. (2016) emphasise the distribution of value added, while Jensen et al. (2011) and Katt & Meixner (2020) highlight consumer demand and willingness to pay. Institutional and market barriers remain important (Góralaska-Walczyk et al., 2025; Kostetska et al., 2026), as do spatial enabling and constraining factors (Sandström et al., 2025). Cömert Acar & Aksoy (2025) likewise conceptualise organic farming as an interaction of economic, environmental, technological, and organisational dimensions, indicating that production efficiency alone provides an incomplete measure of sector performance.

Cross-country evidence confirms that production and market development may diverge. Kociszewski & Szubska-Włodarczyk (2023) identify differences in organic farming productivity, while Willer et al. (2026) document wide disparities in organic land, production, consumption, and market size across Europe. Von Witzke (2025) similarly reports uneven recovery of national organic markets. Information and distribution channels may further facilitate commercialisation and producer–consumer links (Arfyanti et al., 2026). A strong production base may therefore coexist with weak market performance where processing, distribution, demand, or market access remain constrained.

A critical analysis of the existing literature points to a clear research gap. Frontier studies mainly assess farms, regions, or aggregate agriculture, whereas organic-sector research focuses largely on production efficiency, certification and environmental performance. Relatively little attention has been paid to how effectively national organic sectors transform their resource base into distinct export, retail, and consumer-market outcomes, or to whether performance across these dimensions develops consistently across countries. The present study addresses this gap through three complementary SFA models of export, retail, and consumer-market efficiency. The framework shifts attention from production efficiency alone towards the market realisation of organic-sector potential and enables the identification of balanced, export-oriented, domestic-market-oriented, and limited-potential-realisation patterns.

Methodology

The research methodology was designed in line with the stated objective and involves a step-by-step assessment of the main dimensions of organic sector performance across European countries. At the first stage, a panel dataset covering 2022–2024 was compiled, and a set of indicators was selected to characterise both the resource and production capacity of the organic sector and its outcomes in domestic and external markets. At the second stage, three panel SFA models were estimated, each capturing a distinct dimension of organic sector efficiency. At the final stage, the resulting technical efficiency scores were used for cross-country comparisons, trend analysis, and hypothesis testing. To summarise the findings from the two domestic market models, an integrated index was constructed by combining the efficiency of

organic retail sales with the efficiency of consumer demand formation. Comparing this index with export efficiency makes it possible to distinguish between the external-market and domestic-market orientations of national organic sectors.

Table 1 presents the variables used to specify the SFA models for assessing national organic sector efficiency.

Table 1

Variables used in the SFA models

Variable	Definition
ORG_PROD	Number of agricultural producers operating under organic production standards
ORG_LAND	Agricultural land managed under organic farming practices [ha]
ORG_PROC	Number of enterprises engaged in the processing of organic products
PROD_DENS	Number of organic producers per 100,000 inhabitants
LAND_PC	Organic agricultural land per inhabitant [ha/person]
PROC_DENS	Number of organic processing enterprises per 100,000 inhabitants
CONS_PC	Annual consumer expenditure on organic products per inhabitant [€/person]
RET_SALES	Total value of organic product sales in the domestic retail market [€ million]
EXP_VALUE	Total value of organic products supplied to foreign markets [€ million]

Source: compiled by the authors based on data from Eurostat (n.d.), OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

Table 2 presents three SFA models, which differ in their combinations of input and output variables. This design makes it possible to assess distinct dimensions of national organic sector efficiency: export performance in Model 1, domestic retail market performance in Model 2, and consumer market performance in Model 3.

Table 2

Input and output variables used in the SFA models

Variable group	Model 1 Organic export efficiency	Model 2 Organic retail market efficiency	Model 3 Organic consumer market efficiency
Input variables	ORG_PROD	ORG_PROD	PROD_DENS
	ORG_LAND	ORG_LAND	LAND_PC
	ORG_PROC	ORG_PROC	PROC_DENS
Output variable	EXP_VALUE	RET_SALES	CONS_PC

Source: compiled by the authors based on data from Eurostat (n.d.), OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

In Model 1, the value of a country's organic product exports is used as the output variable. Countries with negligible export values, such as Cyprus and Luxembourg, were excluded from the model because zero or near-zero observations cannot be accommodated in the logarithmic function. The model assesses the export efficiency of each country's organic sector by estimating how effectively its resource and production capacity is converted into export value. This capacity is represented by the number of organic producers, the area of organically managed agricultural land, and the number of organic processors.

In Model 2, the output variable is the value of domestic retail sales of organic products. This indicator captures the size and degree of development of the national organic market. The SFA Model 2 evaluates how efficiently the resource and production potential of the organic sector is converted into a market outcome represented by organic retail sales. More specifically, the model assesses the extent to which a country, given its number of organic producers, area of organically managed agricultural land, and number of organic processors, is able to generate retail sales in the domestic organic market.

In Model 3, the output variable is average expenditure on organic products per capita. Model 3 is intended to assess the efficiency of organic consumer market development. It captures how effectively the relative resource and production capacity of the organic sector is transformed into per capita consumption of organic products.

For each of the three models, a separate Cobb–Douglas stochastic frontier function was estimated in double-logarithmic form. Since the empirical dataset covers the organic sector of the countries under study for 2022, 2023, and 2024, the model was specified in a panel-data framework. The general form of the SFA model is expressed as follows:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \cdot \ln(\text{ORG_PROD}) + \beta_2 \cdot \ln(\text{ORG_LAND}) + \beta_3 \ln(\text{ORG_PROC}) + v_{it} - u_{it} \quad (1)$$

where Y_{it} – denotes the output of country iii in year t , represented by organic exports, retail sales, or per capita consumption, depending on the model; v_{it} – is a symmetric random error term capturing stochastic noise; and u_{it} – is a non-negative inefficiency component. The standard distributional assumptions were adopted: $v_{it} \sim N(0, \sigma_v^2)$ and $u_{it} \sim N(0, \sigma_u^2)$ implying a half-normal distribution of inefficiency. The parameter vector β was estimated using the maximum likelihood method.

The Cobb–Douglas functional form was selected as the baseline specification because its log-linear structure is parsimonious and allows the coefficients to be interpreted directly as elasticities, which is important for assessing returns to scale. This choice also reflects the relatively short panel, comprising 63 observations in Model 1 and 84 observations in Models 2 and 3. With three inputs, a Translog specification would require six additional second-order parameters, increasing model complexity and the risk of parameter instability and multicollinearity.

The SFA models were estimated using FRONTIER 4.1, which supports the estimation of stochastic frontier functions for panel data (Coelli, 1996). The empirical dataset for Model 1 consists of a balanced panel of 21 countries observed over three years, yielding 63 observations. Models 2 and 3 cover 28 countries over the same period and therefore comprise 84 observations each.

The smaller sample used in Model 1 reflects both the limited availability of comparable data on organic product exports and the requirements of the logarithmic Cobb–Douglas function. For a number of European countries, organic exports are either absent, negligible, or not reported separately in the available statistical sources.

Based on the estimated variance components, the parameter

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad (2)$$

was calculated. It was statistically significant in all three models, confirming the presence of technical inefficiency and supporting the use of the SFA framework. Accordingly, the null hypothesis $H_0: \gamma=0$ was rejected.

Country- and year-specific technical efficiency scores were then obtained as

$$TE_{it} = \exp(-u_{it}) \in (0,1] \quad (3)$$

The panel specification with a time-varying inefficiency component makes it possible to estimate individual technical efficiency scores for each country in every year of the study period (Fusco et al., 2026).

In the Battese–Coelli panel SFA model with time-varying inefficiency, the inefficiency component is specified as follows (Battese & Coelli, 1995):

$$u_{it} = u_i \exp[-\eta(t - T)] \quad (4)$$

To summarise the results of Models 2 and 3, an integrated index of organic domestic market efficiency IE was constructed as the geometric mean of the corresponding SFA efficiency scores:

$$IE_{it} = \sqrt{TE_{it}^{Model1} \cdot TE_{it}^{Model2}} \quad (5)$$

This approach combines two complementary dimensions of the domestic organic market: the efficiency of generating retail sales and the efficiency of developing consumer demand, measured through per capita consumption of organic products.

We further propose classifying countries according to the relationship between the SFA-based efficiency of organic exports and the integrated domestic organic market efficiency index IE_{it} . For this purpose, a two-dimensional quadrant diagram (Fig. 7) is constructed, with export SFA efficiency plotted on the horizontal axis and IE_{it} on the vertical axis. A threshold value of 0.7 is used to distinguish relatively high efficiency, thereby dividing the analytical space into four quadrants.

Quadrant I comprises countries with high values for both indicators and represents a balanced model of organic sector development. Quadrant II includes countries with high domestic market efficiency but lower export efficiency, corresponding to a domestic-market-oriented model. Quadrant III consists of countries for which both indicators fall below 0.7, indicating a limited realisation of the organic sector's potential. Quadrant IV includes countries with high export efficiency but a comparatively underdeveloped domestic market and therefore represents an export-oriented model.

Research Results

Using the Battese–Coelli specification, technical efficiency scores for organic exports were estimated for 21 countries under Model 1 (Table 3). The parameter estimates indicate a positive relationship between the main resource and production characteristics of the organic sector and the value of organic exports. Organic agricultural land and number of organic processors also had a positive effect, although its contribution was smaller than that of the number of producers. The sum of the estimated elasticities is $0.384+0.291+0.247=0.922$, indicating returns to scale that are close to constant but slightly decreasing. In practical terms, a proportional increase in all three resource inputs is associated with a less than proportional increase in organic exports.

Table 3

Parameters and diagnostic statistics of the panel SFA model 1 for organic product exports

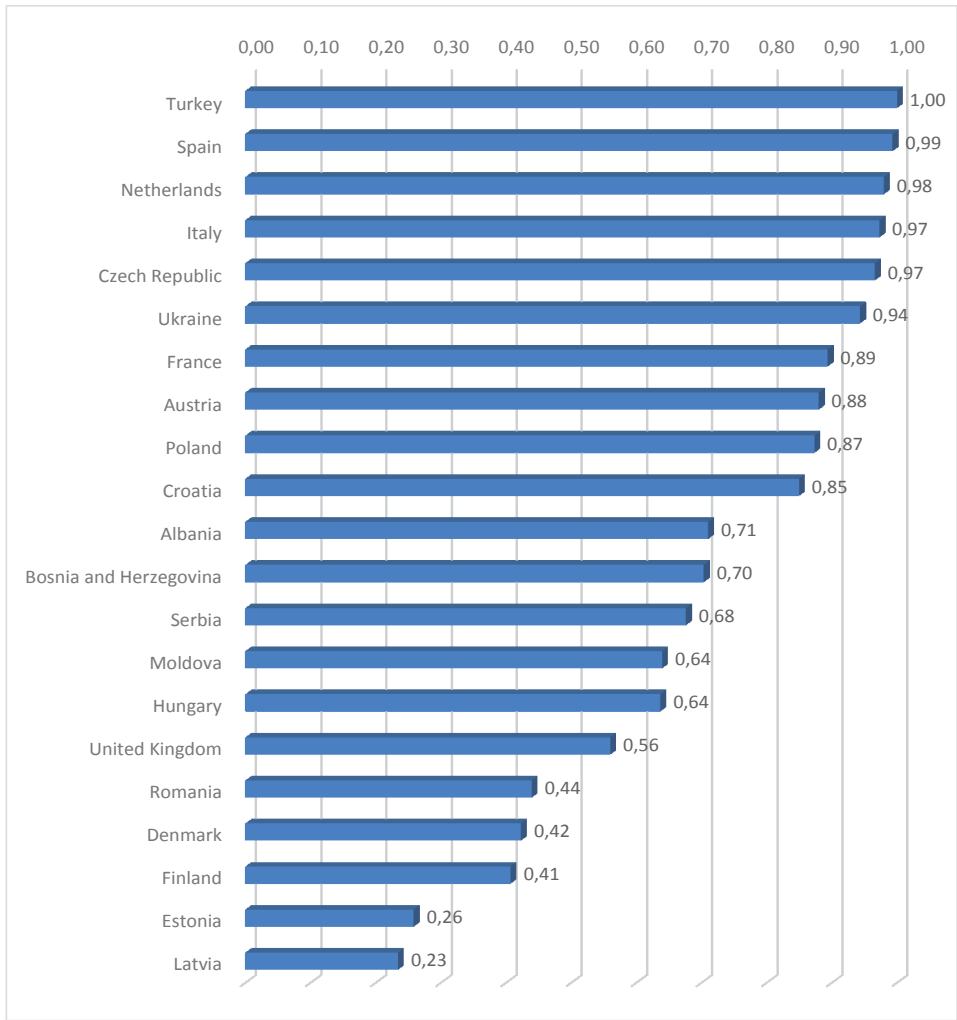
Parameter	Symbol	Coefficient	Standard error	t-statistic/comment
Constant	β_0	-1.842	0.713	-2.58
Organic producers	β_1	0.384	0.118	3.25
Organic area	β_2	0.291	0.087	3.34
Organic processors	β_3	0.247	0.096	2.57
Sigma-squared	σ^2	0.046	0.014	3.29
Gamma	γ	0.821	0.137	5.99
Eta	η	0.027	0.011	2.45
LR test of one-sided error	LR	12.284	—	$H_0: \gamma=0$, rejected
Number of countries	N	21	—	cross-sections
Number of observations	NT	63	—	balanced panel

Source: authors' calculations using FRONTIER 4.1 based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

The country ranking reveals substantial heterogeneity in export efficiency, with Turkey, Spain, the Netherlands, Italy, the Czech Republic, and Ukraine forming the leading group (Figure 1 and 2). Rather than reflecting the scale of organic production alone, these positions indicate differences in countries' ability to convert their production and processing capacity into commercially viable export flows. A broad producer base may support larger and more stable export volumes, while processing capacity facilitates product differentiation and access to higher-value foreign market segments. Countries located further from the frontier therefore appear to face constraints not only in resource availability but also in the market realisation of that resource potential.

Figure 1

Mean SFA efficiency scores for organic sector export performance across European countries

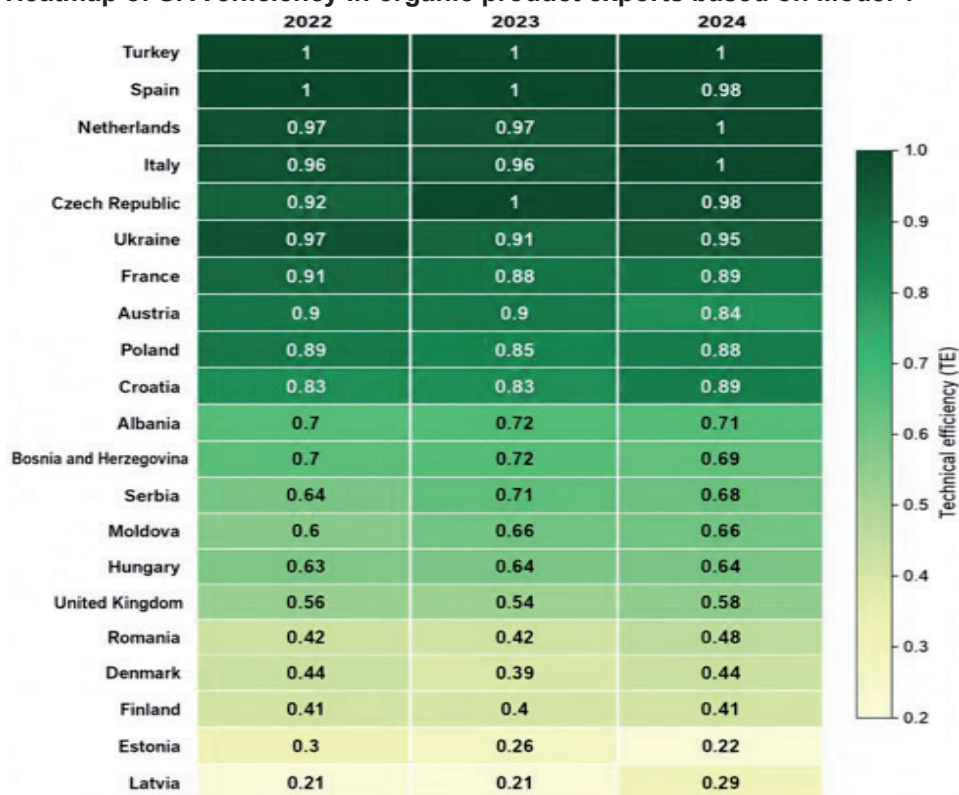


Source: compiled by the authors based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

Obtained results point to only partial realisation of the European organic sector’s export potential and suggest the presence of constraints related to export scaling, processing capacity, or integration into international markets. Overall, the parameter estimates for Model 1 suggest that export performance is shaped by both the scale of the organic sector’s resource base and countries’ ability to combine production capacity, land resources, and processing infrastructure effectively in accessing external markets.

Figure 2

Heatmap of SFA efficiency in organic product exports based on Model 1



Source: authors' calculations using FRONTIER 4.1 based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

For Model 2, stronger organic retail performance is associated with the development of processing capacity, retail infrastructure, and domestic demand, rather than with the scale of primary organic production alone (Table 4).

The positive estimate of η in Model 2 indicates a modest reduction in inefficiency over time, suggesting that European countries gradually improved their ability to convert the existing resource and production base of the organic sector into domestic retail sales during 2022–2024. Economically, this may reflect better integration between producers, processors, and retail networks, broader market access, and a more effective commercialisation of organic products. Higher efficiency is therefore characteristic not simply of countries with larger organic sectors, but of those where production capacity is more effectively matched with domestic demand and retail distribution (Figure 3).

Table 4

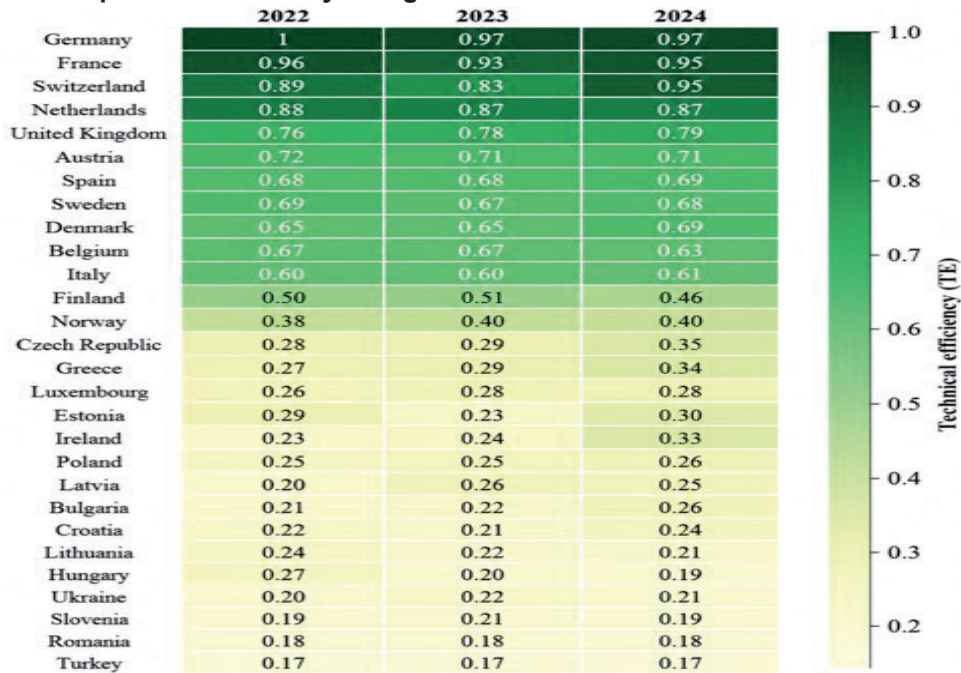
Parameters and diagnostic statistics of panel SFA Model 2 for assessing the efficiency of organic retail sales

Parameter	Symbol	Coefficient	Standard error	t-statistic/comment
Constant	β_0	-1.215	0.621	-1.96
Organic producers	β_1	0.312	0.091	3.43
Organic area	β_2	0.184	0.074	2.49
Organic processors	β_3	0.468	0.103	4.54
Sigma-squared	σ^2	0.071	0.019	3.74
Gamma	γ	0.862	0.108	7.98
Eta	η	0.018	0.009	2.00
LR test of one-sided error	LR	15.642	—	$H_0: \gamma=0$, rejected
Number of countries	N	28	—	cross-sections
Number of observations	NT	84	—	balanced panel

Source: calculated by the authors using FRONTIER 4.1 based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

Figure 3

Heatmap of SFA efficiency in organic retail sales based on Model 2

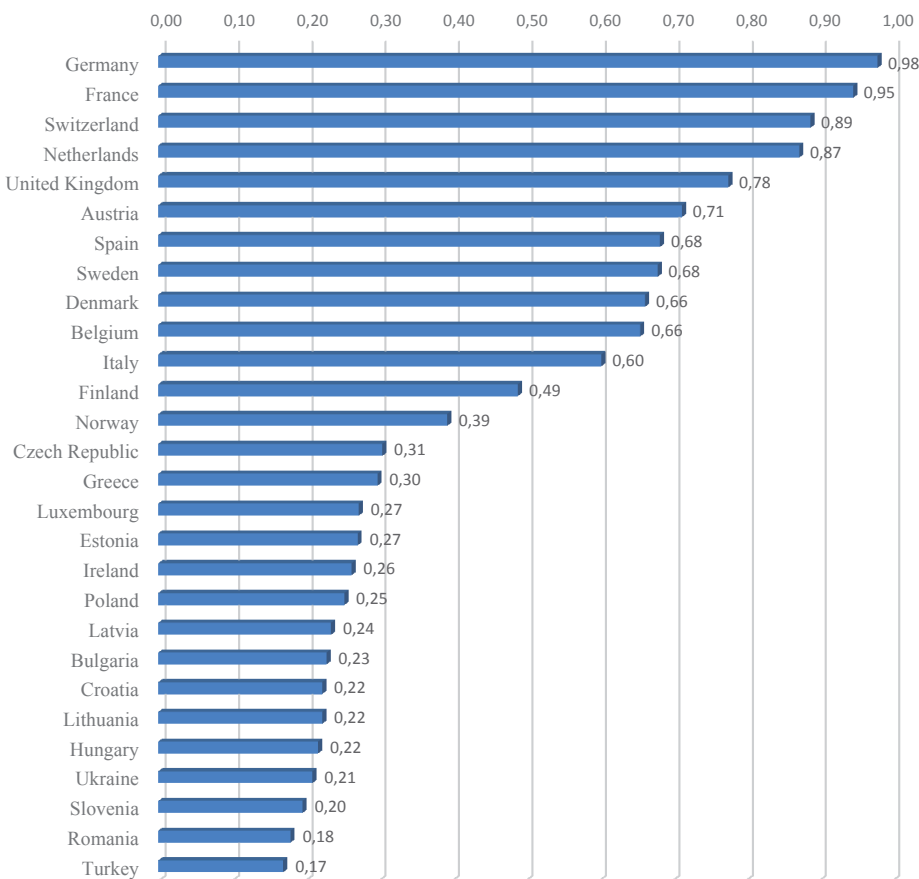


Source: authors' calculations based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

The ranking of countries by their mean SFA efficiency scores reveals a clear polarisation within the sample (Figure 4).

Figure 4

Mean SFA Efficiency Scores for Organic Retail Sales under Model 2, 2022–2024



Source: authors' calculations based on data from OrganicInfo (n.d.) and the Research Institute of Organic Agriculture FiBL (2026).

Model 3 assesses how effectively the relative resource and production capacity of the organic sector is translated into per capita organic consumption rather than absolute market size. All input coefficients are positive, with organic processors exerting the strongest effect (Table 5), indicating that consumer-market development depends particularly on the availability of processed, diversified, and market-ready organic products.

Table 5

Parameters and diagnostic statistics of panel SFA Model 3 for assessing the efficiency of organic consumer market development

Parameter	Symbol	Coefficient	Standard error	t-statistic/comment
Constant	β_0	-0.936	0.548	-1.71
Producers_p	β_1	0.286	0.084	3.40
Area_p	β_2	0.213	0.069	3.09
Processors_p	β_3	0.411	0.097	4.24
Sigma-squared	σ^2	0.058	0.016	3.63
Gamma	γ	0.837	0.112	7.47
Eta	H	0.015	0.008	1.88
LR test of one-sided error	LR	14.726	—	$H_0:\gamma=0$, rejected
Number of countries	N	28	—	cross-sections
Number of observations	NT	84	—	balanced panel

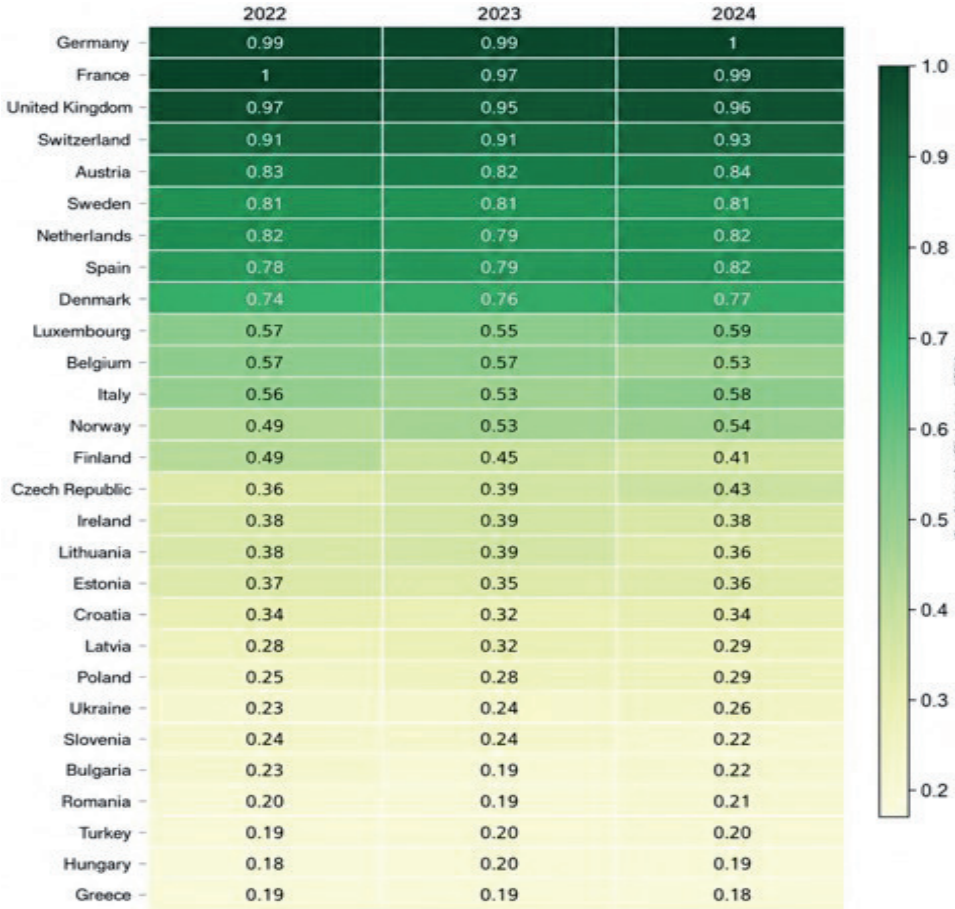
Source: authors' calculations using FRONTIER 4.1 based on data from OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

Germany, France, the United Kingdom, and Switzerland form the leading group (Figures 5 and 6), whereas the overall distribution reveals persistent cross-country disparities. These differences suggest that consumer-market efficiency depends not only on production capacity but also on the ability to connect organic supply with effective processing, distribution, and domestic demand.

Overall, Model 3 suggests that developing an organic consumer market is a more complex process than expanding production or exports. The consumer-market results further suggest that supply-side capacity alone is insufficient to generate high organic consumption in European national economies. Once a basic production and processing infrastructure is in place, additional increases in producers or organic land yield progressively smaller market effects because consumer expenditure is constrained by purchasing power, price premiums, established consumption habits, trust in certification, and access to organic products. This provides an economic explanation for the decreasing returns identified in Model 3 and for the persistent gap between countries with similar resource endowments but markedly different levels of consumer-market efficiency.

Figure 5

**Heatmap of SFA efficiency in the development of the organic consumer market
based on Model 3**

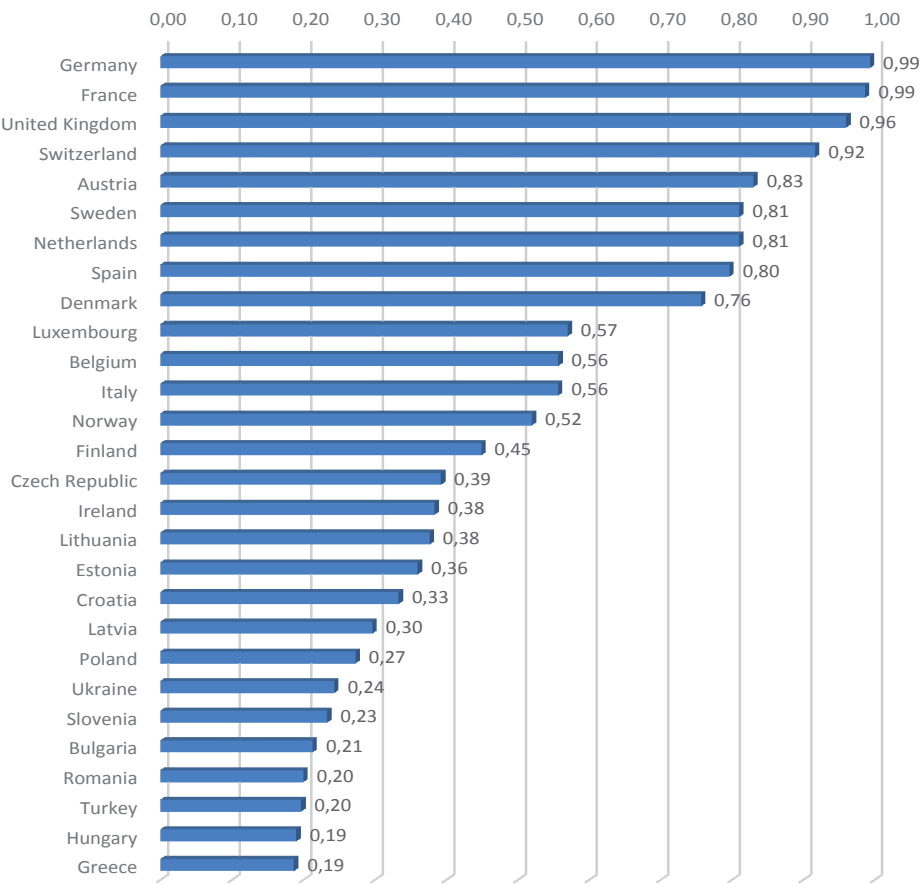


Source: authors' calculations using FRONTIER 4.1 based on data from Eurostat (n.d.), OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

The stronger contribution of European organic processors to domestic market performance has a clear economic interpretation. Processing transforms primary organic output into differentiated, packaged, and retail-ready products, increases product variety, and facilitates their distribution through conventional retail channels. A country may therefore possess a substantial organic land base and a large number of producers without generating proportionately high domestic sales if value-added processing and market intermediation remain underdeveloped. This helps explain why differences in domestic market efficiency are more closely associated with the maturity of the organic value chain than with primary production capacity alone.

Figure 6

Mean SFA efficiency scores for the development of the organic consumer market based on Model 3



Source: authors' calculations based on data from OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

Using Equation (5), the annual organic domestic market efficiency index IE was calculated for each country as the geometric mean of the SFA efficiency scores obtained from Models 2 and 3 (Table 6). The Pearson correlation coefficient between export efficiency and the integrated internal market efficiency index is relatively low ($r=0.18$), indicating that countries with high export efficiency do not necessarily demonstrate a similarly high level of domestic market efficiency, which supports the methodological relevance of analyzing external and internal market performance as separate but complementary dimensions.

Table 6

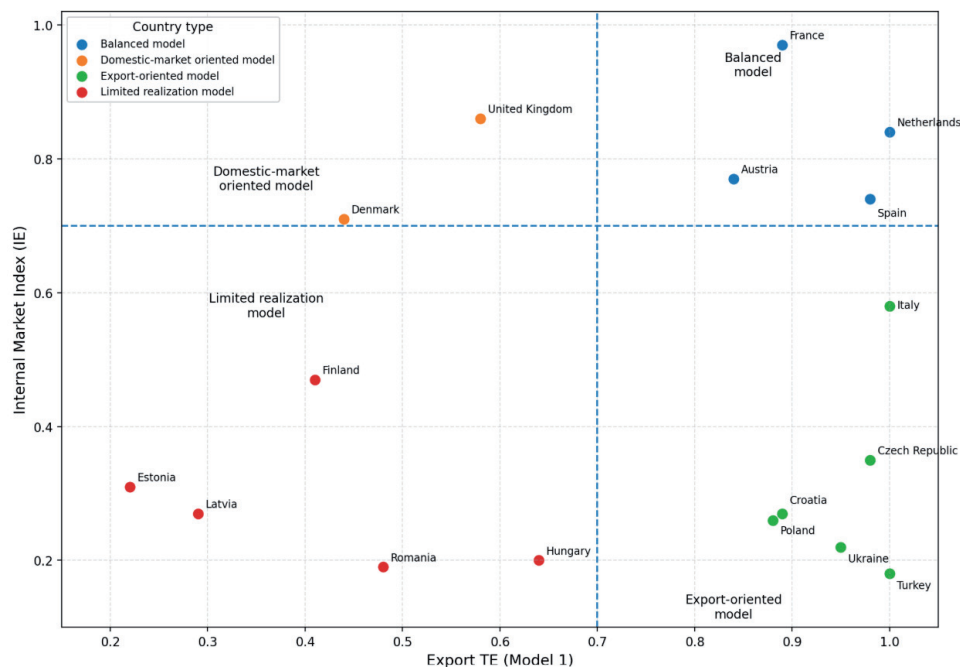
Dynamics of the organic domestic market efficiency index (IE)

Country	2022	2023	2024	Avr.
Germany	0.99	0.98	0.98	0.98
France	0.98	0.95	0.97	0.97
Switzerland	0.9	0.87	0.94	0.90
United Kingdom	0.86	0.86	0.87	0.86
Netherlands	0.85	0.83	0.84	0.84
Austria	0.77	0.76	0.77	0.77
Sweden	0.75	0.74	0.74	0.74
Spain	0.73	0.73	0.75	0.74
Denmark	0.69	0.7	0.73	0.71
Belgium	0.62	0.62	0.58	0.61
Italy	0.58	0.56	0.59	0.58
Finland	0.49	0.48	0.43	0.47
Norway	0.43	0.46	0.46	0.45
Luxembourg	0.38	0.39	0.41	0.39
Czech Republic	0.32	0.34	0.39	0.35
Ireland	0.3	0.31	0.35	0.32
Estonia	0.33	0.28	0.33	0.31
Lithuania	0.3	0.29	0.27	0.29
Croatia	0.27	0.26	0.29	0.27
Latvia	0.24	0.29	0.27	0.27
Poland	0.25	0.26	0.27	0.26
Greece	0.23	0.23	0.25	0.24
Ukraine	0.21	0.23	0.23	0.22
Bulgaria	0.22	0.2	0.24	0.22
Slovenia	0.21	0.22	0.2	0.21
Hungary	0.22	0.2	0.19	0.20
Romania	0.19	0.18	0.19	0.19
Turkey	0.18	0.18	0.18	0.18

Source: authors' calculations based on data from OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

The quadrant diagram (Figure 7) shows that European countries differ substantially not only in the overall efficiency of their organic sectors, but also in the way this potential is realised through external and domestic markets.

Figure 7

Quadrant classification of European countries by export SFA efficiency and the Internal Market Efficiency Index (IE)

Source: authors' calculations based on data from Eurostat (n.d.), OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

The cross-country differences reveal that organic sector efficiency is shaped by the way production potential is integrated into national and international value chains rather than by resource endowment alone. France, the Netherlands, Austria, and Spain combine high export and domestic market efficiency, suggesting a relatively balanced interaction between primary production, processing capacity, access to external markets, and domestic demand. A different pattern is observed in Ukraine, Turkey, the Czech Republic, Poland, and Croatia, where production capacity is converted more effectively into export performance than into domestic market outcomes. This profile is consistent with an export-oriented development path in which international market access advances faster than domestic demand and retail market maturity. By contrast, the United Kingdom and Denmark show stronger domestic-market performance, indicating that an established consumer base and developed distribution channels can support organic market efficiency even without comparable export efficiency. Countries with relatively low scores in both dimensions appear to face a broader problem of transforming available organic resources into market outcomes. These differences indicate that expanding organic land or the number of producers alone is unlikely to eliminate efficiency gaps; the development of processing, distribution, consumer demand, and market access is equally important.

A sensitivity analysis was conducted to assess whether the main results depend on the aggregation procedure used for the domestic market efficiency index or on the threshold applied in the quadrant classification. First, the integrated domestic market efficiency index was recalculated using the arithmetic mean of the efficiency scores from Models 2 and 3 instead of the geometric mean adopted in the baseline approach. This alternative aggregation produced only minor changes in the index values and did not alter the allocation of countries across the four development patterns.

The robustness of the quadrant classification was then examined using alternative threshold values of 0.65 and 0.75. As shown in Table 7, lowering the threshold to 0.65 left the classification unchanged. When the threshold was increased to 0.75, 15 of the 17 countries retained their original development pattern. Spain shifted from the balanced to the export-oriented group, while Denmark moved from the domestic-market-oriented to the limited-potential-realisation group.

Table 7

Sensitivity of the quadrant classification to alternative efficiency thresholds

Sensitivity specification	Balanced	Domestic-market-oriented	Export-oriented	Limited-potential-realisation	Classification retained
Baseline threshold = 0.70	4	2	6	5	—
Threshold = 0.65	4	2	6	5	100%
Threshold = 0.75	3	1	7	6	88.2%

*Number of countries. Source: calculated by the authors based on data from Eurostat (n.d.), OrganicInfo (n.d.), Research Institute of Organic Agriculture FiBL (2026) and the State Statistics Service of Ukraine (2026).

Overall, the sensitivity analysis indicates that the proposed typology is robust to reasonable changes in both the aggregation rule and the classification threshold. The distinction between export and domestic market efficiency therefore does not appear to be driven by a particular methodological choice, while the main country development patterns remain largely stable under alternative specifications.

The comparison between export SFA efficiency and the integrated domestic market efficiency index also reveals an important structural asymmetry: a country's strong capacity to market organic products abroad does not guarantee a comparable level of domestic market development.

Hypothesis H1, which posits a key role for processing infrastructure in the development of the domestic organic market, is supported by the empirical results. In both domestic-market models, the variables representing the number of organic processors have the largest coefficients among the resource and production factors. These findings indicate that the development of processing infrastructure contributes more strongly to domestic market efficiency than the expansion of the number of producers or the area under organic farming alone.

The comparison between export efficiency and the integrated domestic market efficiency index also shows that these two dimensions of organic sector development do not fully coincide. The correlation coefficient $r=0.18$ suggests that high domestic market efficiency does not automatically translate into strong export performance. The quadrant classification provides further evidence by identifying countries with a predominantly domestic-market orientation, including the United Kingdom and Denmark, as well as export-oriented countries whose domestic market potential remains less fully realised. Hypothesis H2 can therefore be accepted.

The analysis of the summed elasticities across the three SFA models provide support for Hypothesis H3. In the export efficiency model, the sum of the estimated coefficients is 0.922; in the retail sales model, it is 0.964; and in the consumer market model, it amounts to 0.910. In all three cases, the values are below or close to unity, indicating decreasing or near-constant returns to scale in the organic sectors of European countries. This means that an expansion of the sector's resource and production capacity has a positive effect on market outcomes, but does not generate a pronounced effect of increasing returns.

A comparison of the η parameters, which capture changes in the inefficiency component over time, suggests that the export dimension of the organic sector improved relatively faster than the domestic market dimension. The lower values in the domestic market specifications reflect the slower adjustment of national organic markets, whose development depends not only on the production base, but also on purchasing power, consumer habits, distribution channels, and trust in organic products. Hypothesis H4 is therefore supported, although the relative advantage of the export dimension should be interpreted as moderate rather than pronounced.

Discussion

The findings extend previous cross-country efficiency research by showing that national organic sectors cannot be adequately assessed through production efficiency alone. Earlier DEA and SFA studies identified substantial heterogeneity in European agriculture (Hart et al., 2015; Đokić et al., 2022; Kyshakevych et al., 2025a, 2025b), whereas the present results demonstrate that such differences also concern the ability to transform organic-sector potential into external and domestic market outcomes. The stronger role of producers in export performance and processors in domestic-market efficiency supports the value-chain perspective of Sanders et al. (2016) and complements Blockeel et al. (2025), who report heterogeneous economic effects of organic farming across countries and production systems. Thus, expansion of primary production without adequate processing and commercialisation capacity may leave part of the sector's potential unrealised.

The weak relationship between export and domestic-market efficiency is consistent with international evidence showing substantial variation in organic consumption, willingness to pay, and market maturity (Jensen et al., 2011; Katt & Meixner, 2020; Von Witzke, 2025; Willer et al., 2026). It also supports the findings of Sandström et al. (2025) and Góralska-Walczak et al. (2025), who emphasise spatial, institutional, and market constraints on organic-sector development. Theoretically, these results support a multidimensional interpretation of efficiency in which production

capacity and its market realisation represent distinct dimensions. Decreasing or near-constant returns to scale further imply that simply increasing organic land, producers, or processing capacity is unlikely to generate proportional market gains, consistent with the context-dependent interpretation of organic efficiency proposed by Lakner & Breustedt (2017) and Seufert & Ramankutty (2017).

The practical implication is that organic-sector policies should be differentiated according to national development patterns rather than centred uniformly on expanding certified acreage or producer numbers. Export-oriented countries may benefit more from stronger processing, distribution, and domestic demand, whereas countries with developed domestic markets but weaker exports require support for certification, logistics, and integration into international value chains. Countries performing weakly in both dimensions require broader value-chain interventions, consistent with evidence that organic-sector outcomes depend on structural and institutional conditions (Casolani et al., 2021; Möhring et al., 2024; Kremmydas et al., 2025). For producers and processors, closer vertical cooperation, product differentiation, and alignment of production with market demand may improve the realisation of organic-sector potential. At the EU level, the proposed efficiency measures and typology can therefore serve as a benchmarking tool for targeting support according to country-specific constraints.

Conclusions

The study demonstrates that the efficiency of national organic sectors is multidimensional and cannot be inferred from production capacity alone. External and domestic market performance represent related but distinct dimensions, while the ability to transform organic-sector resources into market outcomes depends on how effectively production, processing, distribution, and demand are connected. The proposed SFA framework therefore extends conventional production-oriented efficiency analysis towards an assessment of the market realisation of organic-sector potential.

The cross-country results reveal different development trajectories rather than a single hierarchy of successful and unsuccessful organic sectors. Balanced systems combine effective participation in external markets with a developed domestic market, whereas export-oriented and domestic-market-oriented systems exhibit asymmetric realisation of their potential. The absence of pronounced increasing returns further suggests that quantitative expansion of organic production alone is unlikely to eliminate these differences. Sustainable sector development therefore requires coordination between production capacity, processing infrastructure, market access, and consumer demand.

These findings support differentiated rather than uniform organic-sector policies across Europe. The proposed typology can help identify whether national priorities should focus on export integration, domestic market development, processing capacity, or broader value-chain strengthening, while producers can use the results to align production expansion more closely with processing and market opportunities. In this sense, the study provides both an analytical framework for comparing national organic sectors and a practical basis for targeting EU and national support measures more closely to the specific constraints affecting market efficiency.

The study is limited by the short observation period, restricted availability of comparable organic export data, and the use of aggregated national indicators that do not capture regional and farm-level heterogeneity. The results may also depend on the selected functional form and distributional assumptions of the SFA framework. Future research could extend the time horizon, incorporate institutional, price, certification, and macroeconomic determinants, and examine transitions between the identified development patterns using alternative frontier specifications.

References

- Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21–37. [https://doi.org/10.1016/0304-4076\(77\)90052-5](https://doi.org/10.1016/0304-4076(77)90052-5)
- Arfyanti, I., Karim, S., & Khoirunnita, A. (2026). Design of an Android-based information system for marketing organic agricultural products. *International Journal of Education and Management Engineering*, 16(1), 63–71. <https://doi.org/10.5815/ijeme.2026.01.04>
- Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20(2), 325–332. <https://doi.org/10.1007/BF01205442>
- Blockeel, J., Grovermann, C., & Finger, R. (2025). Organic crop farming in the European Union: Impacts on farm-level input costs, labour, and income. *Q Open*, 5(2), Article qoaf030. <https://doi.org/10.1093/qopen/qoaf030>
- Casolani, N., Nissi, E., Giampaolo, A., & Liberatore, L. (2021). Evaluating the effects of European support measures for Italian organic farms. *Land Use Policy*, 102, Article 105225. <https://doi.org/10.1016/j.landusepol.2020.105225>
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research*, 2(6), 429–444. [https://doi.org/10.1016/0377-2217\(78\)90138-8](https://doi.org/10.1016/0377-2217(78)90138-8)
- Cimpoieș, L., & Coșalić, D. (2025). Inefficiency amid sustainability? Evaluating technical efficiency in Moldova's organic farming sector. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 25(3), 235–242. https://managementjournal.usamv.ro/pdf/vol.25_3/Art22.pdf
- Coelli, T. (1996). *A guide to FRONTIER version 4.1: A computer program for stochastic frontier production and cost function estimation* (CEPA Working Paper No. 96/07). Department of Econometrics, University of New England.
- Cömert, M. A., & Aksoy, U. (2025). Organic farming: Concepts, principles, benefits and prospects. In L. P. Awasthi, *Advances in organic farming* (pp. 11–17). CABI. <https://doi.org/10.1079/9781800626850.0002>
- Đokić, D., Novaković, T., Tekić, D., Matkovski, B., Zekić, S., & Milić, D. (2022). Technical efficiency of agriculture in the European Union and Western Balkans: SFA method. *Agriculture*, 12(12), Article 1992. <https://doi.org/10.3390/agriculture12121992>

- European Commission (2021). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an action plan for the development of organic production* (COM(2021) 141 final). Publications Office of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0141>
- Eurostat (n.d.). *Population on 1 January* [Data set]. Retrieved July 8, 2026, from <https://ec.europa.eu/eurostat/databrowser/view/tps00001/default/table?lang=en>
- Fusco, G., Vecchio, Y., Masi, M., & Borgia, M. (2026). Productivity and emissions in Italian agriculture: A farm-level efficiency analysis. *Business Strategy and the Environment*, 1–13. <https://doi.org/10.1002/bse.70713>
- Gensch, L., Jantke, K., Rasche, L., & Schneider, U. A. (2026). Land of opportunities: aligning organic farming and conservation targets in Europe. *Journal of Environmental Planning and Management*, 69(8), 2443–2462. <https://doi.org/10.1080/09640568.2025.2504520>
- Góralaska-Walczak, R., Stefanovic, L., Kopczyńska, K., Kazimierzczak, R., Bügel, S. G., Strassner, C., Peronti, B., Lafram, A., El Bilali, H., & Średnicka-Tober, D. (2025). Entry points, barriers, and drivers of transformation toward sustainable organic food systems in five case territories in Europe and North Africa. *Nutrients*, 17(3), Article 445. <https://doi.org/10.3390/nu17030445>
- Grovermann, C., Quiédeville, S., Muller, A., Leiber, F., Stolze, M., & Moakes, S. (2021). Does organic certification make economic sense for dairy farmers in Europe? – A latent class counterfactual analysis. *Agricultural Economics*, 52(6), 1001–1012. <https://doi.org/10.1111/agec.12662>
- Hart, J., Miljkovic, D., & Shaik, S. (2015). The impact of trade openness on technical efficiency in the agricultural sector of the European Union. *Applied Economics*, 47(12), 1230–1247. <https://doi.org/10.1080/00036846.2014.993134>
- Hetmanenko, V., Skrylnyk, I., Kucher, A., Kutova, A., & Artemieva, K. (2021). Technological, agronomical and economic efficiency of new organic and organo-mineral soil amendments. *E3S Web of Conferences*, 280, Article 06004. <https://doi.org/10.1051/e3sconf/202128006004>
- Jensen, K. O., Denver, S., & Zanolli, R. (2011). Actual and potential development of consumer demand on the organic food market in Europe. *NJAS: Wageningen Journal of Life Sciences*, 58(3–4), 79–84. <https://doi.org/10.1016/j.njas.2011.01.005>
- Katt, F., & Meixner, O. (2020). A systematic review of drivers influencing consumer willingness to pay for organic food. *Trends in Food Science & Technology*, 100, 374–388. <https://doi.org/10.1016/j.tifs.2020.04.029>
- Kociszewski, K., & Szubska-Włodarczyk, N. (2023). The level of organic farming productivity in selected EU countries. *Economics and Environment*, 86(3), 417–435. <https://doi.org/10.34659/eis.2023.86.3.623>
- Kostetska, N., Lotysh, O., & Liakhovych, L. (2026). Ukraine's economic integration into the EU organic products market in the context of the green transition. *Journal of European Economy*, 25(2), 331–362. <https://doi.org/10.35774/jee2026.02.331>

- Kremmydas, D., Beber, C., Baldoni, E., Ciaian, P., Fellmann, T., Gocht, A., Hristov, J., Pignotti, D., Rey Vicario, D., Stepanyan, D., & Tillie, P. (2025). The EU target for organic farming: Potential economic and environmental impacts of two alternative pathways. *Applied Economic Perspectives and Policy*, 47(2), 602–623. <https://doi.org/10.1002/aepp.13470>
- Kundius, V. (2024). Socio-economic efficiency of the application of new technologies for the production of organic products. *Agriculture and Forestry*, 70(4), 171–182. <https://doi.org/10.17707/AgricultForest.70.4.13>
- Kyshakevych, B., Melnyk, O., Kotyk, Y., Lapchuk, Y., & Voronochak, I. (2025a). Technical efficiency of agriculture in the EU and Ukraine: A stochastic frontier analysis based on factor income. In F. Angeli *Rivista di Studi Sulla Sostenibilità*, 10(2), 231–250. <https://doi.org/10.3280/riss2025oa20053>
- Kyshakevych, B., Melnyk, O., Maksyshko, N., Maturin, Y., & Kotyk, Y. (2025b). Systemic issues and efficiency reserves in EU agriculture: A slack-based DEA approach. *Agricultural and Resource Economics: International Scientific E-Journal*, 11(1), 46–73. <https://doi.org/10.51599/are.2025.11.01.02>
- Lakner, S., & Breustedt, G. (2017). Efficiency analysis of organic farming systems – A review of concepts, topics, results and conclusions. *German Journal of Agricultural Economics*, 66(2), 85–108. <https://doi.org/10.52825/gjae.v66i2.2059>
- Latruffe, L., & Nauges, C. (2014). Technical efficiency and conversion to organic farming: The case of France. *European Review of Agricultural Economics*, 41(2), 227–253. <https://doi.org/10.1093/erae/jbt024>
- Letort, E., & Ridier, A. (2025). Economic performance of organic dairy farms during and after conversion. *Q Open*, 5(1), Article qoaf013. <https://doi.org/10.1093/qopen/qoaf013>
- Lishchynskyy, I. & Lyzun, M. (2024). Pattern of European regional creativity: Exploring endogenous sustainability. *ECONOMICS*, 12(3), 397–407. <https://doi.org/10.2478/eoik-2024-0030>
- Lyzun, M., Vitálišová, K., & Borseková, K. (2024). Transformation of trade flows between the EU and Ukraine in the conditions of increasing security risks. *Journal of European Economy*, 23(2), 289–305. <https://doi.org/10.35774/jee2024.02.289>
- Madau, F. A., Furesi, R., & Pulina, P. (2017). Technical efficiency and total factor productivity changes in European dairy farm sectors. *Agricultural and Food Economics*, 5, Article 17. <https://doi.org/10.1186/s40100-017-0085-x>
- Marcikić Horvat, A., Matkovski, B., Zekić, S., & Radovanov, B. (2020). Technical efficiency of agriculture in Western Balkan countries undergoing the process of EU integration. *Agricultural Economics*, 66(2), 65–73. <https://doi.org/10.17221/224/2019-AGRICECON>
- Marcikić Horvat, A., Radovanov, B., Popescu, G. H., & Panaitescu, C. (2019). A two-stage DEA model to evaluate agricultural efficiency in case of Serbian districts. *Economics of Agriculture*, 66(4), 965–974. <https://doi.org/10.5937/ekoPolj1904965M>

- Martín-García, J., Gómez-Limón, J. A., & Arriaza, M. (2024). Conversion to organic farming: Does it change the economic and environmental performance of fruit farms? *Ecological Economics*, 220, Article 108178. <https://doi.org/10.1016/j.ecolecon.2024.108178>
- Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review*, 18(2), 435–444. <https://doi.org/10.2307/2525757>
- Möhring, N., Muller, A., & Schaub, S. (2024). Farmers' adoption of organic agriculture – A systematic global literature review. *European Review of Agricultural Economics*, 51(4), 1012–1044. <https://doi.org/10.1093/erae/jbae025>
- Nowak, A., Kijek, T., & Domańska, K. (2015). Technical efficiency and its determinants in European Union. *Agricultural Economics*, 61(6), 275–283. <https://doi.org/10.17221/200/2014-AGRICECON>
- OrganicInfo (n.d.). *Sales of organic products in 2016-2024: export market* [Infographic]. <https://organicinfo.ua/en/infographics/export-market-2016-2024/>
- Research Institute of Organic Agriculture FiBL. (2026). *Data on organic agriculture in Europe* [Data set]. FiBL Statistics. Retrieved July 8, 2026, from <https://statistics.fibl.org/europe.html>
- Sanders, J., Gambelli, D., Lernoud, J., Orsini, S., Padel, S., Stolze, M., Willer, H., & Zanoli, R. (2016). *Distribution of the added value of the organic food chain*. Thünen Institute of Farm Economics. <https://doi.org/10.2762/678520>
- Sandström, E., Boere, E., Krisztin, T., & Verburg, P. H. (2025). Enabling and constraining factors for organic agriculture in Europe: A spatial analysis. *Environmental Research: Food Systems*, 2(3), Article 035006. <https://doi.org/10.1088/2976-601X/adf22e>
- Seufert, V., & Ramankutty, N. (2017). Many shades of gray – The context-dependent performance of organic agriculture. *Science Advances*, 3(3), Article e1602638. <https://doi.org/10.1126/sciadv.1602638>
- Smith, L. G., Williams, A. G., & Pearce, B. D. (2015). The energy efficiency of organic agriculture: A review. *Renewable Agriculture and Food Systems*, 30(3), 280–301. <https://doi.org/10.1017/S1742170513000471>
- Sokołowicz, M. E., & Lishchynskyy, I. (2018). Are Poland and Ukraine gravity centres for each other? Study on the labour migration patterns. *Comparative Economic Research. Central and Eastern Europe*, 21(1), 45–65. <https://doi.org/10.2478/cer-2018-0003>
- State Statistics Service of Ukraine (2026). Population size and structure [Data set]. Retrieved July 8, 2026, from https://stat.gov.ua/en/explorer?filter=PNMI_03&urn=SSSU%3ADF_POPULATION_STRUCTURE%28~%29
- Tennhardt, L. M., Bozzola, M., & Grovermann, C. (2026). Deep pockets needed? Financial health and organic certification adoption in the European Union. *European Review of Agricultural Economics*, Article jbag013. <https://doi.org/10.1093/erae/jbag013>
- Von Witzke, K. (2025). *EU organics market begins to recover* (GAIN Report No.

GM2025-0003). United States Department of Agriculture, Foreign Agricultural Service. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=EU+Organics+Market+Begins+to+Recover+_Berlin_European+Union_GM2025-0003.pdf

Willer, H., Schlatter, B., & Trávníček, J. (Eds.) (2026). *The world of organic agriculture: Statistics and emerging trends 2026*. Research Institute of Organic Agriculture FiBL & IFOAM – Organics International. <https://www.fibl.org/fileadmin/documents/shop/1861-organic-world-2026.pdf>

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