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MODELLING ECONOMIC POLICY IN THE CONTEXT OF FOOD SECURITY IN EU COUNTRIES AMIDST THE TRANSFORMATION OF THE GLOBAL ECONOMY

Abstract

The article examines the theoretical and methodological foundations for assessing and forecasting food security in European Union countries against a backdrop of global economic transformation, increasing geopolitical instability, inflationary pressures, energy risks, and climate challenges. It argues that the EU's current approach to food security goes beyond the traditional understanding of providing the population with food. It is shaped by a multidimensional system of economic, social, institutional, energy, and logistical factors. The authors identify food prices, food affordability, inflationary pressures, energy costs, climate shocks, and social vulnerability as key determinants of food security. The article suggests an integrated methodological approach to analysing food security in EU countries, combining indicative analysis, cross-country clustering, the construction of a composite food

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security index, and scenario-based forecasting. A system of indicators is developed based on four key dimensions of food security: availability, affordability, stability, and quality & nutrition proxy. A matrix is also developed to cluster EU countries based on food prices, inflationary pressures, and the social affordability of food. On this basis, groups of countries with different levels of risk of food insecurity are identified. The study demonstrates the merits of using a scenario-based approach to forecast trends in food security, taking into account the inertia of food inflation, the energy-cost channel, global food prices, climate risks, and logistical disruptions. It offers baseline, optimistic, and risky scenarios for the development of food security in EU countries. The article shows that, in the current context, food security should be considered as a systemic indicator of the resilience of the agri-food system, and that effective economic policy must be based on proactive risk monitoring, the integration of macroeconomic and social indicators, and the development of adaptive mechanisms for regulating food markets.

Key Words:

agriculture, climate shocks, composite index, economic policy, EU countries, European integration, food inflation, food security, geopolitical instability, global risks, scenario forecasting.

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2 tables, 7 formulas, 31 references.

Problem Statement

Amid the transformation of the global economy, food security is becoming not only a social issue but also a strategic economic factor that determines the resilience of national and supranational development systems. This issue is particularly pressing for the EU countries due to the combined impact of several factors: geopolitical instability, climate risks, volatile energy and agricultural commodity prices, logistics disruptions, and changing consumer demand patterns. In its current policies, the European Commission explicitly emphasises the need to establish a competitive, sustainable, and innovative agri-food system that can ensure affordable and safe food supplies in times of crisis.

Contemporary academic and applied discourse on food security is shifting away from a narrow interpretation of food supply as a production-only issue. International analyses emphasise the multidimensional nature of food security, which encompasses availability, affordability, quality/safety of consumption, and supply stability over time. Meanwhile, global assessments indicate that the risks of food insecurity remain high and that the cost of a healthy diet is rising. This increases the need for systematic monitoring and forecasting, even in relatively stable regions, particularly in the EU.

An additional challenge for the EU is the significant cross-country variation in food prices, which directly impacts food affordability and leads to disparities in food security risks within the integration bloc. According to Eurostat (2026a), price levels for food and non-alcoholic beverages varied significantly between Member States in 2024, confirming the need for comparative analysis and the development of forecasting models that take into account the structural characteristics of national economies. At the same time, varying inflationary trends within the EU increase the importance of econometric tools for assessing future trends in food security.

In this context, the development of methodological approaches to the comprehensive assessment and forecasting of food security in EU countries, which would combine macroeconomic, price, resource, and institutional indicators, takes on scientific significance. The relevance of this topic stems from the need to move from a reactive approach to managing food risks to a preventive one, based on the analytical identification of trends and scenario-based planning.

The article aims to establish the theoretical and methodological foundations for assessing and forecasting food security in EU countries amidst global economic transformation, and to develop an analytical framework for improving the effectiveness of economic and agri-food policies at the supranational and national levels.

Literature Review

Several main approaches to assessing food security can be traced in recent studies, including index-based, indicator-based, multi-criteria, and econometric approaches. Drawing on international practices, Jones et al. (2013) emphasise in a seminal review that accurate measurement of food security is critical for policy targeting, early warning, and programme evaluation. However, it is complicated by the diversity of approaches, tools, and levels of analysis (from national to household level).

Cafiero et al. (2018) make a significant contribution to the methodology by justifying the use of the Food Insecurity Experience Scale (FIES) based on Rasch modelling. This approach has significantly improved the measurement of food affordability and has become a global monitoring standard. For macro-level studies, however, the FIES should be supplemented with production, price, trade, and stability indicators, which are particularly important for analysing EU countries.

Pérez-Escamilla et al. (2017) emphasise that the choice of indicators should be based on policy and governance objectives rather than on statistics alone. In this context, their proposed SMART-based approach to indicator selection is methodologically significant for developing a system of indicators for cross-country comparative studies, particularly within the EU, where it is necessary to balance data comparability with sensitivity to national characteristics.

Popadynets et al. (2024) comprehensively assess the capacity of Ukraine's domestic food market in the pre-war period, using a system of demand, production, and import dependency indicators. Their studies also analyse differences in consumer behaviour in the food markets of Ukraine and EU countries, and demonstrate that

consumption patterns are shaped by income levels, cultural factors, and market infrastructure development (Popadynets et al., 2017). Particular attention should be paid to studies of the impact of imports on the development of Ukraine's domestic market, especially their role in structural changes to food production and consumption. According to the authors, imports have a twofold effect: on the one hand, they intensify competition and encourage modernisation; on the other, they increase the national market's dependence on external supplies (Storonyanska & Popadynets, 2015).

Pruntseva and her colleagues have made a significant contribution to research in this field. Their work explores the relationship between investment activity in the agricultural sector and the resilience of the food security system, focusing on the importance of institutional mechanisms and investment policy. Moreover, the authors analyse the impact of household savings on food security management through macroeconomic, social, and financial determinants (Pruntseva et al., 2021a), and perform a factor analysis of food supply in Ukraine's consumer market using economic and mathematical modelling (Pruntseva et al., 2021b).

Of particular academic interest is the work of Panukhnyk et al. (2021), which focus on modelling the impact of bioenergy development on food security in EU countries. This study identifies key determinants of food accessibility, including household income levels, import dependency, and institutional stability. The expansion of the bioenergy sector is shown to be ambivalent: while strengthening energy independence, it also creates risks of redistributing agricultural resources, which could affect food security.

The current stage of development of this methodology is reflected in systematic reviews (Manikas et al., 2023; Lyzun et al., 2024), which show that the issue is the complexity of interpreting indicators rather than their absence: different indicators reflect different dimensions, levels of analysis, time horizons, and information needs. This is precisely why recent studies are increasingly combining indicator systems with forecasting models (panel, time series, and scenario-based) (Argyriou et al., 2021; Lyzun et al., 2019).

Studies addressing the impact of russia's war against Ukraine on the European food system deserve special mention. Namely, Rabbi et al. (2023) provide a systematic analysis of the impact of the conflict on all four dimensions of food security in Europe, emphasising the importance of considering logistical and geopolitical factors alongside traditional agricultural indicators. Interestingly, the authors explicitly highlight the link between food security and inflation, poverty, and social stability.

Another key area covers climate risks and climate–inflation nexus. Beirne et al. (2024) examine the eurozone countries (1996–2021) and argue that weather-related disasters have a statistically significant positive impact on inflation, with a more pronounced effect on categories of goods that are important to lower-income households. This further reinforces the importance of incorporating climate variables and risk indicators into food security forecasting models in the EU. In this context, it is important to take into account structural changes in the agricultural sector and to model its adaptation to environmental constraints, technological changes, and new sustainability requirements, which are essential prerequisites for the development of a resilient food system (Krysovatyy et al., 2024).

Recent studies (Galanakis et al.,2025) also focus on the EU's institutional framework: CAP, Farm to Fork, Food 2030, Codex/ISO standards, coordination mechanisms, and digital tools. These studies are significant as they demonstrate that food security in the EU is not merely the result of market equilibrium but rather a function of policy quality, regulatory coherence, and Member States' implementation capacity.

Therefore, the following integrated approach is most relevant for the purposes of this study: the one that is based on internationally recognised measures of food security, utilises official comparable data sources (Eurostat, FAO, OECD, World Bank), and combines an indicative assessment of the current situation with a forecast of risk trends.

Methodology

The research methodology is based on an integrated approach to assessing and forecasting food security in EU countries, combining indicative analysis (dashboard), cross-country clustering, the construction of a composite index, and scenario-based forecasting. This approach aligns with the logic of the article that views food security as a multidimensional concept (availability, affordability, stability, and quality/utilisation), as well as a function of macroeconomic, pricing, energy, climate, and social factors.

The study's database consists of official international and European statistical sources, which ensure the comparability of data across countries: Eurostat (price levels, HICP, social deprivation indicators, and energy prices), the FAO (FAO Food Price Index), the ECB (food inflation and its drivers analytics), as well as the OECD and World Bank for the theoretical and methodological justification and interpretation of the results. The use of these specific sources is consistent with the article's objective of providing an analytical framework for economic policy at the supranational and national levels.

Methodologically, the study consists of several consecutive stages. The first stage involves developing a system of indicators based on the four dimensions of food security: availability, affordability, stability, and quality & nutrition proxy. The main focus of the empirical section of the article is on three areas that most clearly reflect cross-country risks within the EU: (1) food pricing, (2) the social accessibility of food, and (3) inflationary pressures. This triad is used for the initial comparative analysis and clustering of countries.

The second stage involves calculating the composite food security index for EU countries, IFS_EU, which aggregates key indicators into a single comparative value.

In the third stage, EU countries are clustered according to a combination of three parameters: food pricing, the social accessibility of food, and inflationary pressure. In the article, this logic is already implemented through the classification of countries into clusters A–E (ranging from "high prices – compensatory capacity" to "inflation-sensitive markets" and "accumulated price shock"). Methodologically, this

facilitates a shift from EU-wide average estimates to the identification of structurally distinct risk groups, which is critical for targeted policy.

The fourth stage involves scenario-based forecasting of food security trends. The forecast is based on the functional relationship between the composite index and the group of drivers identified in the article (the inertia of food inflation, the energy-cost channel, the climate-commodity channel, and social vulnerability). The generalised form of the model can be written in the following way:

$$IFS_{i,t+h} = \alpha_i + \gamma_t + \beta_1 FHICP_{i,t} + \beta_2 HICP_{i,t} + \beta_3 ENPPI_t + \beta_4 FFPI_t + \beta_5 POV_MEAL_{i,t} + \beta_6 INC_{i,t} + \beta_7 CLIM_{i,t} + \beta_8 LOG_{i,t} + \varepsilon_{i,t} \quad (1)$$

where h is the forecast horizon (1–3 years); α_i is country-specific fixed effects; γ_t is time effects; $\varepsilon_{i,t}$ is the random error. The article recommends two approaches: (1) cluster forecasting; (2) cross-country forecasting (panel model or country-by-country forecasting).

The scenario section includes three alternative development trajectories: baseline, optimistic, and risky (pessimistic). Their construction is based on variations in key assumptions regarding food inflation, headline inflation, energy costs, the FAO global index, climatic and logistical shocks, and social vulnerability. This approach not only provides forecast values for the IFS_EU, but also allows the sources of risk to be interpreted within the framework of the inflation-energy-climate-social nexus.

In the fifth stage, the results are validated and verified for robustness. The following four-step verification procedure is applied in this article:

1. out-of-sample validation (splitting the sample into training/test; e.g. 2015–2023 for training and 2024–2025 for testing);
2. testing for robustness to changes in specifications (signs of coefficients, cluster rankings, and consistency of scenario-based conclusions);
3. sensitivity analysis of changes in key drivers (±10% / ±20%);
4. comparison with alternative models (ARIMA/ETS, classical panel regression, and static composite indicator without forecasting).

Standard metrics are used to assess the accuracy of the forecast:

$$MAE = \frac{1}{n}\sum_{t=1}^{n} | y_t - \hat{y}_t | \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n} (y_t - \hat{y}_t)^2} \quad (3)$$

$$MAPE = \frac{100}{n}\sum_{t=1}^{n} | \frac{y_t - \hat{y}_t}{y_t} |. \quad (4)$$

In addition, a sensitivity index is recommended for scenario analysis:

$$S_j = \frac{\Delta IFS / IFS}{\Delta X_j / X_j} \quad (5)$$

where X_j is the j driver (e.g. FHICP, ENPPI, FFPI, or POV_MEAL). This helps to determine in which countries or clusters the forecast is most sensitive to energy, pricing, or social shocks.

The proposed methodology thus combines a comparative assessment of the current situation with a forecast of future food security risks in EU countries. Its advantage lies in its ability to operate at both the national and cluster levels simultaneously, incorporating macroeconomic factors and social, energy, climate, and logistics determinants into the model. This approach is applied to developing analytically sound recommendations for economic and agri-food policy in the context of the global economic transformation.

Research Results

In contemporary international academic discourse, food security is interpreted as a multidimensional concept that encompasses economic, social, institutional, and spatial-logistical aspects. The definition set out in FAO/World Food Summit documents and adopted by the World Bank remains the basis for most studies: food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. The World Bank also highlights four key dimensions of food security (World Bank, 2023; FAO, 2008).

In the FAO (2008) and Committee on World Food Security (2014) documents, the theoretical framework is elaborated through four pillars: availability, access, utilisation, and stability. This framework is the most commonly used in articles indexed in Scopus, as it allows combining macro-level analysis (production, trade, stocks) with micro-level aspects (availability, quality of consumption, household vulnerability). Meanwhile, FAO publications emphasise that all measurements must be carried out simultaneously, rather than being considered in isolation (FAO, 2008).

A distinct strand of contemporary theory concerns the shift from a static understanding of food security to the concept of resilience in agri-food systems. OECD reports emphasise that food security assessments must take into account not only current food availability and accessibility, but also the ability of supply chains and food systems to adapt to shocks (climatic, geopolitical, price-related, and logistical). The OECD also highlights the role of international trade as a risk pooling mechanism, which is particularly important for EU countries in the face of external shocks (World Bank, 2023; Deconinck et al., 2023).

Consequently, in international discourse (FAO, 2008; World Bank, 2023; Deconinck et al., 2023), food security is increasingly being interpreted as a systemic characteristic of the resilience of the food system, rather than merely as an indicator of agricultural production or the physical availability of food. This provides a methodological framework for combining indicator-based assessment and forecasting in a single analytical approach.

Research focusing on the EU is shifting its emphasis from general definitions to an analysis of cross-country differences, price shocks, logistical resilience, and

climate risks. Official Eurostat statistics confirm significant differences in food price levels between Member States: in 2024, prices for food and non-alcoholic beverages were 24% higher than the EU average in Luxembourg, while in Romania they were 22% lower. This asymmetry directly impacts the affordability of food and justifies the need for cross-country comparative models (Eurostat, 2026a).

Alongside price differentiation, inflationary trends remain uneven. According to Eurostat, the highest average annual inflation rates among EU countries in 2024 were recorded in Romania, Belgium, and Croatia, reflecting the varying sensitivity of national economies to cost and demand shocks. In terms of food security, this implies different trajectories for changes in households' real purchasing power, even within the common EU regulatory framework (Eurostat, 2026a).

An important line of research is represented by the materials of the European Central Bank and related empirical studies on the nature of food inflation in the eurozone. Kuik et al. (2024) demonstrates that food inflation was one of the main drivers of headline inflation in 2022–2023, peaking at around 15% in March 2023 (Bobeica E. et al., 2025). Subsequent ECB analytical reports highlight the significant cross-country divergence in cumulative food price inflation (ranging from 20% to 57% since the end of 2019) and the role of energy costs, fertilisers, labour, and climate-related factors in the resumption of food price inflation (Kuik et al., 2024).

For the purposes of this study, an assessment of food security in EU countries is based on a comparison of at least three empirical categories: price level, affordability, and price dynamics / inflation pressure. This approach shifts the focus from a formal analysis of the EU average to identifying cross-country disparities, which are the real drivers of food security risks.

Eurostat's empirical data confirms significant food price variations even within the EU single market. This suggests that the food component of household consumption expenditure is shaped by an uneven price environment, even within a common institutional framework and integrated markets (Bobeica et al., 2025)

Meanwhile, simply comparing price levels is not sufficient to assess food security. What is more important is to combine price data with indicators of the population's actual ability to secure the minimum necessary diet. According to Eurostat, 8.5% of the EU population could not afford a full meal (meat, fish, or a vegetarian equivalent) every other day in 2024. This figure stood at 19.4% among those at risk of poverty. At the national level, the highest rates for the at-risk-of-poverty group were recorded in Slovakia (39.8%), Bulgaria (37.7%), and Hungary (37.3%), while the lowest were in Cyprus (3.5%), Ireland, and Portugal (both 5.1%). These findings demonstrate that food security in the EU is clearly socially differentiated and cannot be reduced solely to macroeconomic indicators of production or average prices (Eurostat, 2026a).

The third key aspect of the comparative assessment is inflationary pressure, which directly impacts the stability of food affordability. According to Eurostat, the highest average annual inflation rates among EU countries in 2024 were recorded in Romania (5.8%), Belgium (4.3%), and Croatia (4.0%), while the lowest were in Lithuania (0.9%), Finland (1.0%), and Italy (1.1%). Therefore, even countries with relatively low food prices may remain vulnerable due to rising inflation, which reduces the population's purchasing power (Eurostat, 2025a).

Furthermore, the comparative context is reinforced by ECB data on the cumulative trend in food prices across eurozone countries. According to ECB estimates, between late 2019 and August 2025, the rise in food prices ranged from 20% in Cyprus to 57% in Estonia, with the main factors behind these differences being varying sensitivity to energy shocks, differences in labour costs, and the unequal impact of global commodity markets. This suggests that the cross-country asymmetry in food risks is not merely a current phenomenon, but also has a cumulative structural nature (Bobeica et al., 2025).

Based on the presented empirical data, EU countries should be grouped according to a combination of three parameters:

1. food price levels (high / moderate / low),
2. social affordability of food (the proportion of the population /vulnerable groups who cannot afford a proper diet),
3. inflationary pressure (current and/or accumulated).

In practical terms, this makes it possible to group countries according to factors influencing food security (Table 1).

Table 1

Matrix for the comparative assessment of food security in EU countries

Cluster	Food prices	Social affordability of food	Inflationary pressure	Risk profile	Countries
A. High prices – relatively greater compensatory capacity	High (above the EU average)	Low/moderate deprivation (due to income/social protection)	Low/ moderate	The price risk is offset by revenue and institutional support	Luxem-bourg, Denmark
B. Lower prices – high social vulnerability	Low/below the EU average	High deprivation in at-risk groups	Moderate/ high	Low prices do not ensure food security due to lower pur-chasing power	Slovakia, Bulgaria, Hungary
C. Inflation-sensitive markets	Any (often moderate/ lower)	Depends on income	High current HICP	A rapid decline in affordability caused by inflation	Romania, Belgium, Croatia
D. Accumula-ted price shock (eurozone)	Any	Depends on the income structure	High cumu-ure on food (2019–2025)	Ongoing pressure on households, inflation expec-tations, and consumption	Estonia (a prime example)
E. Relatively stable / less inflationary	Moderate/ varying	Usually lower deprivation, but subject to income verification	Low HICP	A lower short-term inflationary risk to food affordability	Lithuania, Finland, Italy

Source: compiled by the authors.

The findings show that food security is highly uneven across EU countries: cross-country differences stem not only from food price levels but also from a combination of inflationary trends and the social vulnerability of the population. That is why the subsequent analysis is not be based on a single indicator but rather on an integrated assessment system that considers price-related, social, and macroeconomic parameters simultaneously.

Trend analysis shows that food risks in the EU are shaped not only by current prices but also by cumulative inflationary effects. According to Eurostat (2026b), average annual inflation in the EU fell to 2.6% in 2024 (down from 6.4% in 2023 and a peak of 9.2% in 2022). However, the cumulative HICP increase for 2015–2024 was 30.2%, with food and non-alcoholic beverages being the category with the highest cumulative growth (+42.8%) among the main HICP groups. This means that even as overall inflation slows, the food component remains structurally "overheated".

In the short term (eurozone), the trend also remains uneven. Eurostat estimates that annual inflation in the eurozone was 1.7% in January 2026, but the food, alcohol & tobacco component rose to 2.7%, while the energy component was negative (-4.1%). This suggests that headline inflation is falling faster than food price inflation, and it is food that is putting pressure on households' real incomes (Eurostat, 2026b).

The European Central Bank (ECB) further confirms the persistence of food inflation: the annual HICP food inflation rate in the eurozone fell to 2.4% in November 2025 following a peak of 15.5% in March 2023. However, the average for January–November 2025 remained at 2.9%, i.e. above the long-term pre-pandemic average (2.2%). Therefore, although the trend is downward, the return to "normal" levels is slow and uneven.

Empirical data confirm that food trends are highly dependent on energy costs. Eurostat shows that, despite stabilising, energy prices in the EU remained high in 2024: domestic energy producer prices rose by 80.3% between January 2021 and December 2024. Meanwhile, retail electricity prices in the EU in the second half of 2024 remained significantly higher than pre-crisis levels, while household gas prices in the second half of 2024 rose to €12.33 per 100 kWh, the highest level recorded since records began. This creates a channel for indirect pressure on the cost of food (production, processing, storage, and logistics) (Eurostat, 2025b).

The ECB directly links food inflation in 2021–2023 to the shock in energy and fertiliser costs following Russia's full-scale war against Ukraine, and in 2024–2025 to the impact of rising labour costs and global food commodity prices, partly linked to climatic factors. The ECB blog specifically highlights the cross-country variations in this effect (particularly in the Baltic states) (Bates et al., 2026).

The climate channel is also gaining in importance. The ECB's focus study states that extreme weather events affect food prices, and the ECB's assessment of the 2025 summer heatwave indicates a potential increase in unprocessed food prices in the eurozone of 0.4–0.7 pp over the course of the year. This is an important signal for developing models that consider climate variables as determinants of food security.

The global commodity market remains volatile. According to the FAO, the FAO Food Price Index was 123.9 in January 2026 (marking the fifth consecutive month of decline), which is lower than a year ago but still significantly higher than

pre-crisis levels in certain periods and only 22.7% below the March 2022 peak. This means that external pressure on European food markets has eased but has not disappeared, and fluctuations in certain commodity groups (cereals, oils, sugar, dairy products) continue to feed through to national consumer prices with a time lag (FAO, 2026; Eurostat, 2025c).

Dynamic analysis shows that three interrelated mechanisms are crucial for EU countries:

1. The inertia of food inflation (a slower decline compared to headline inflation).
2. The energy-cost channel (production and utility prices).
3. The climate-commodity channel (weather shocks and global commodity prices).

To forecast food security in EU countries, a scenario approach combining an indicative assessment with the key drivers of trends (food inflation, headline inflation, energy costs, global food prices, and social vulnerability) should be adopted. This format will be useful for comparing countries or clusters of countries when making policy decisions in conditions of uncertainty. The relevance of the scenario-based approach is supported by the fact that the food component of inflation in the eurozone remains higher than headline inflation (2.7% compared with 1.7% in January 2026), despite the general slowdown in inflation.

In the context of this study, it is also worth suggesting the use of the composite food security index (IFS_EU), which is based on four dimensions:

– availability,
– affordability,
– stability,
– quality & nutrition proxy.

One of two specifications is recommended for empirical forecasting:

Cluster forecasting.

Cross-country forecasting (panel model or country-by-country forecasting)

The basic functional form of the composite food security index looks like this:

$$IFS_{i,t+h} = \int (FHICP_{i,t}, HICP_{i,t}, EN_t, FFPI_t, POV_{i,t}, INC_{i,t}, CLIM_t, LOG_t) \quad (6)$$

where: i is an EU country or cluster of countries; t+h is the forecast horizon (e.g. 1–3 years); FHICP is food inflation (food, alcohol & tobacco); HICP is headline inflation; EN is energy price/cost indicator; FFPI is FAO global price index; POV is social vulnerability (in particular, the proportion of people unable to afford adequate nutrition); INC is income/purchasing power proxies; CLIM is climate shocks; LOG is logistics/supply chain risks.

These variables were selected due to the high inertia of food inflation, the significant energy channel (with energy prices rising by 80.3% between January 2021 and December 2024), and the ongoing volatility of global food prices (FAO FFPI = 123.9 in January 2026) (FAO, 2026) (Table 2).

Table 2

A set of variables for scenario-based forecasting of food security in EU countries

Set	Variable	Economic content	Expected income on the IFS	Data level	Unit	Baseline for the EU/ eurozone
Price trends	Food inflation (FHICP)	Year-on-year change in prices for food, alcohol & tobacco	-	Country / eurozone	%, annual rate (YoY)*	Eurozone: 2.7% (Jan 2026, flash
Inflation rate	Headline inflation (HICP)	General inflationary backdrop	-	Country / EU / eurozone	%, annual rate (YoY)	Eurozone: 1.7% (Jan 2026, flash); EU: 2.3% (Dec 2025)
Energy channel	Energy producer prices (ENPPI)	Cost pressure in manu-facturing, processing, and logistics	-	EU / country (if available)	Index / % change; preferab-ly YoY + cumula-tive index relative to the base	+80.3% between Jan 2021 and Dec 2024 (EU, cumulati-vely)
Global commodi-ty channel	FAO Food Price Index (FFPI)	External pressure from global food prices	-	Global	YoY / MoM**	123.9 (Jan 2026); the fifth conse-cutive month of decline
Social vulnera-bility	Meal afforda-bility depriva-tion (POV_MEAL)	The proporti-on of the po-pulation / at-risk groups who cannot afford a balan-ced nutrition	-	Country	% of the popula-tion	EU: 8.5% (of the total population, 2024); 19.4%(the at-risk-of-poverty group)
Income capacity	INCt (proxy)	Households' compen-satory capacity	+	Country	Index, EU=100	EU=100 (baseline); range of 72–146 across EU countries in 2024
Climate risk	CLIM	Extreme wea-ther inci-dents, impact on har-vests/prices	-	Country/ regional proxy	Index (z-score) / dummy	Data from the Central European Bank
Logistics risk	LOG	Disruptions to supplies and transit, seasonal disruptions	-	EU / country	Index (z-score)	Composite indicator for scenarios

Note: * YoY - compared with the same month of the previous year (more stable, less seasonal). **MoM - month-over-month, compared with the previous month (more "noisy", but provides a quicker indication of changes).

Source: compiled by the authors.

Based on an assessment of the composite food security index in EU countries, it is worth outlining its possible development scenarios:

1. Scenario 1 (baseline)

It envisages a gradual return to normal inflation levels, but with the food component remaining more persistent than headline inflation. Key assumptions of the scenario include headline inflation stabilising around target/moderate levels, food inflation falling more slowly (due to cost and contract lags), and energy prices remaining high relative to pre-crisis levels but without further spikes; global FFPI fluctuating within a moderate range without sharp peaks, social vulnerability declining slowly.

The expected outcome is a moderate improvement in the IFS in most EU countries, but an elevated risk will persist in clusters B and C (social vulnerability + inflation sensitivity). The current situation (headline inflation of 1.7% in the eurozone in January 2026, 2.7% for food, alcohol & tobacco) supports this baseline scenario (Eurostat, 2026c).

2. Scenario 2. (optimistic)

It envisages faster food price deflation and mitigation of external price pressures. The key assumptions are:

– food inflation is converging with headline inflation faster than expected;
– energy cost pressures are easing;
– FFPI remains stable or is falling;
– social indicators of food accessibility are improving (reducing deprivation);
– no major climatic or logistical shocks.

The expected outcome of implementing the scenario is an improvement in the IFS across all clusters, with the most significant improvement occurring in clusters C and B, where price and inflationary pressures are the main constraints. The decline in the global FAO index (for five consecutive months up to January 2026) provides the basis for such a scenario, but does not guarantee it due to internal European lags.

3. Scenario 3. (risky (pessimistic))

It envisages a new round of food price pressures due to a combination of energy, climate, or logistical shocks. It assumes that the resumption of food inflation, rising energy costs (or their incomplete reduction in the event of a new shock), an increase in the FFPI due to external commodity shocks, and extreme weather conditions (drought, heatwaves, and floods) drive up the prices of certain food groups and exacerbate social vulnerability in lower-income countries.

The expected outcomes include a deterioration in the IFS, primarily in clusters B, C, and D; an increase in cross-country asymmetry; and the risk of a renewed wave of food deprivation among low-income groups. The ECB's findings regarding the impact of heatwaves and weather shocks on unprocessed food prices and the persistence of structural sensitivity in food inflation support the risky nature of this scenario.

To avoid errors and unreasonable scenarios, the robustness and validity of the results are verified. This is essential for interpreting the scenario-based food security forecasts for EU countries, since the obtained estimates depend on the model specification, the choice of variables, and the forecast horizon. In the context of the proposed research framework, a four-level validation process is recommended:

1. Statistical verification of forecast accuracy.

At this stage, the model is tested using out-of-sample forecast validation. To do this, the time series (or panel) is divided into:

- training sample (to estimate the parameters),
- test sample (to verify the forecast).

For instance, if data is available for 2015–2025, the model should be trained for 2015–2023, while 2024–2025 should be used for testing. This allows the forecast values to be compared with the actual values and the error to be assessed.

Standard metrics are recommended for assessing forecast accuracy:

$$MAE = \frac{1}{n}\sum_{t=1}^{n} | y_t - \hat{y}_t | \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n} (y_t - \hat{y}_t)^2} \quad (3)$$

$$MAPE = \frac{100}{n}\sum_{t=1}^{n} | \frac{y_t - \hat{y}_t}{y_t} | \quad (4)$$

where y_t is the actual value of the food security index (or one of its components), y $\hat{y}_t$ is the forecast value.

For the panel forecast (across EU countries), the average error by cluster (A–E) should also be calculated; this makes it possible to assess in which types of countries the model works more accurately and where its predictive power is weaker (for example, in clusters with high price volatility).

2. Verification of robustness to specification changes.

The second stage involves checking whether the results remain valid when the model specification changes. The robustness of the results is considered to be confirmed if:

– the direction of influence of the key variables (signs of the coefficients) remains unchanged;

– the overall ranking logic for clusters/countries remains unchanged;

– the scenario-based findings (most vulnerable groups) remain similar.

3. Sensitivity analysis of scenario assumptions. At this stage, it is essential to check how dependent the results are on the values of the key drivers.

To do this, each driver (FHICP, EN, FFPI, CLIM) should be adjusted by ±10% / ±20%; and the change in the IFS forecast should be recorded.

The sensitivity index can be expressed as:

$$Sens_j = \frac{\Delta IFS}{\Delta X_j} \quad (7)$$

where X_j is the j variable driver.

This test determines in which countries/clusters the forecast is most sensitive to an energy shock, where social vulnerability is the main driver, and where the external (global) price channel has the greatest impact.

4. Comparison with alternative approaches.

The proposed scenario analysis is compared with traditional methods by contrasting it with alternative forecasting models:

1. A forecast based solely on the IFS or FHICP time series, excluding external drivers.
2. A classic panel model (fixed effects / random effects) without scenarios.
3. An indicative assessment (ranking/clustering) without forecasting.

This comparison highlights the fact that a static assessment does not allow for the identification of future risks and time lags.

The advantage of the proposed approach therefore lies not only in its superior predictive power, but also in its ability to identify sources of risk (inflation–energy–climate–social nexus).

Conclusions

The findings confirm that food security in EU countries between 2024 and 2026 is not determined by a single dominant factor but by a combination of three risk factors: price-related (the level and dynamics of food prices), social (access to adequate nutrition for vulnerable groups), and shock-related (energy, climate, and foreign trade influences). This multiplicity of factors explains why significant cross-country disparities persist within the EU single market: according to Eurostat, food prices were 24% higher than the EU average in Luxembourg and 20% higher in Denmark in 2024, while they were 22% lower in Romania.

Meanwhile, research findings show that lower prices do not guarantee greater food security. This is a crucial insight for interpreting differences across Europe. The indicator of inability to afford a proper meal every other day (8.5% of the EU population in 2024; 19.4% among those at risk of poverty) shows that it is not only price levels that are crucial, but also the ratio of prices, incomes, and social protection.

An important finding is the confirmation of the energy-cost channel's impact on food security. Even with some stabilisation in the energy markets, Eurostat shows that domestic energy producer prices in the EU between January 2021 and December 2024 were still 80.3% higher than at the start of the shock period.

It is worth emphasising the significance of the climate channel, as previous European studies have often regarded it as a long-term factor. However, our findings and the ECB's latest assessments show that it is already emerging as a short- and medium-term price factor. This is important for interpreting a risky scenario in which climate shocks are combined with energy and external price shocks.

The results of the scenario-based forecasting also align with the global context. The FAO (2026) reports that the FFPI was 123.9 in January 2026 and had been falling for the fifth consecutive month, but still reflects an unstable external environment with mixed trends across commodity groups. This is important for explaining why, in the baseline scenario, we assume a moderate improvement in the IFS rather than a rapid return to pre-crisis levels: external price pressures have eased but have not disappeared, and internal European lags remain significant.

However, the results should be interpreted with due regard to their limitations. Firstly, some social indicators (in particular, food affordability) are published with a delay and do not always align with the monthly inflation figures. Secondly, climatic and logistical variables are often represented by proxy indicators, which may reduce the accuracy of short-term forecasts. Thirdly, comparability across EU countries requires standardising weights and scaling, which influences the absolute values of the composite index, although it does not usually alter the relative ranking.

At the same time, the results of the study confirm the expediency of an integrated approach to modeling the food security of EU countries, which combines an assessment of the current state, identification of structural risks, and scenario forecasting, creating an analytical foundation for formulating adaptive economic and agri-food policies under conditions of high uncertainty.

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