Evaluation of food security among European Union countries using multivariate statistical analysis

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Abstract: The purpose of this paper is to determine the level of food security in European Union member countries using selected socioeconomic indicators. The data for the research are gathered from FAOSTAT's and EUROSTAT's public databases for year 2020. We examine four socioeconomic indicators from the access pillar based on FAOSTAT, and two agricultural indicators. Following indicators are considered as stimulants, namely gross domestic product in purchasing power standard, median equivalised net income, government expenditures for agricultural R&D and agricultural factor income. On the contrary, indicators like the proportion of total household expenditures spent on food and the prevalence of moderate or severe food insecurity are considered as inhibitors. The data has been normalised using the min-max transformation. To achieve the set goal, we use a multivariate statistical method - factor analysis. We have used principal component analysis without rotation to estimate the factor analysis model. The 73,8% of total variability of original data has been explained by one common factor, that was used to catch the phenomenon of food security among analysed countries. From the above results, we conclude that the most food secure countries are Ireland, Denmark, the Netherlands and Germany, which achieve the highest values of common factor. On the contrary, Bulgaria and Romania rank among the most food insecure countries with the lowest values of common factor.

Keywords: access, agriculture, European union, factor analysis, food security, principal component analysis
JEL Classification: C38, C43

1 Introduction

The process of ensuring food security poses a significant challenge for both developing nations and economically advanced countries, such as the member states of the European Union. Furthermore, one of the main objectives of the United Nations' Agenda 2030 is ending of global hunger and malnutrition by the year 2030 (UN Gerenal Assembly, 2015). Undernutrition is a significant global public health concern with consequences for both the quality of life and the level of productivity of future generations (Trenouth et al., 2018).

The agri-food system is impacted by a number of external factors, including infrastructure development, political influences, technological advancements, weather patterns, water availability, energy resources, and climate conditions. Socioeconomic factors also include factors like population dynamics, urbanization, economic growth, and technological advancements (Béné et al., 2019; Brouwer et al., 2020; Ruben et al., 2021; van Berkum & Ruben, 2021).

In last decades the demand for measurements of food security has been growing. In order to ensure that policies are grounded in reliable evidence and that the monitoring and evaluation of food security is based on robust empirical foundations, there are still significant areas that require attention. These areas include enhancing the quality and scope of data, as well as developing improved methods, standards, and tools for assessment (Cafiero, 2013). Nowadays, there exist numerous indicators and metrics for assessing the phenomenon of food insecurity. The Food and Agriculture Organization (FAO) has developed the Food Insecurity Experience Scale (FIES) to assess individuals' experiences regarding the quantity and quality of food. When examining macro-based indicators, the FIES demonstrates a comparative advantage due to its ability to provide insights into the attributes of individuals experiencing food insecurity. Additionally, it enables the examination of food insecurity within prosperous and developed nations (Cafiero et al., 2016). Since the FIES has a high level of accuracy and internal coherence, it can be used to assess individual food insecurity (Grimaccia & Naccarato, 2020). The common determinants of food insecurity in 134 countries were analysed using FIES. The results suggested that the largest increase in the probability of experiencing food insecurity was linked with five characteristics, namely

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low educational attainment, weak social networks, low social capital, low household income and unemployment (Smith et al., 2017). Current approaches to evaluating food security, specifically the FAO approach, food consumption surveys, and anthropometric indicators require greater transparency in methods and data, as well as country-level comparisons of approaches (de Haen, 2011).

2 Methods

The main purpose of this study is determination of food security situation in European Union member countries using multivariate statistical analysis. The main goal contains of the following research questions.

- RQ_1: There is a statistically significant correlation between the selected food security variables.
- RQ_2: The selected indicators are proper for performing factor analysis model.
- RQ_3: The selected common factors, explain more than 70% of the variability of original variables.
- RQ_4: Western and northern countries of European Union are more food secure than Eastern and Southern European Union countries.

The data for the research were gathered from FAOSTAT's and EUROSTAT's public databases for year 2020. We examine four socioeconomic indicators from the access pillar based on FAO and two indicators related to agriculture monitoring Goal 2 of Agenda 2030 for EU-26 countries. Following indicators are considered as stimulants, namely gross domestic product (purchasing power standard per capita), median equivalised net income (euro), government support to agricultural R&D (euro per inhabitant) and agricultural factor income per annual work unit (euro per annual work unit, chain linked volumes 2010). On the contrary, indicators like the proportion of total household expenditures spent on food (percent of total households' expenditures) and the prevalence of moderate or severe food insecurity (percent) are considered as inhibitors. Most of the strategies that have been presented to determine the number of principal components the model should keep require non-standardised data. However, standardisation is often necessary in agricultural, biological and environmental applications (Forkman, 2019). Before performing factor analysis on selected determinants of food security, the variables have been normalised and transformed to the 0-1 scale using min-max transformation. For those indicators considered to be positive the following equation was used:

$$z_i = \frac{x_i - x_i(min)}{x_i(max) - x_i(min)} \tag{1}$$

On the contrary, negative indicators were transformed using following equation:

$$z_i = \frac{x_i(max) - x_i}{x_i(max) - x_i(min)} \tag{2}$$

where:
z_i is the normalised value of i^{th} indicator
x_i is the actual value of i^{th} indicator
$x_i(\text{min})$ is the lowest value of i^{th} indicator
$x_i(\text{max})$ is the highest value of i^{th} indicator

We have used principal component analysis to estimate the factor analysis model. Before performing factor analysis, the correlations between indicators were examined using Pearson's correlation coefficients based on following equation:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \tag{3}$$

where:

r is coefficient of correlation
$\bar{x}$ is mean of x variable
$\bar{y}$ is mean of y variable
x_i is sample of variable x
y_i is sample of variable y

Using factor analysis, the i^{th} indicator could be explained by following equation:

$$X_i = \mu_i + a_{i1}F_1 + a_{i2}F_2 + \cdots + a_{iq}F_q + \varepsilon_i \quad (4)$$

where:

μ_i for i=1,2,…,p is a mean of i^{th} indicator

F_k for k=1,2,…,q is a common factor

ε_i for i=1,2,…,p is a specific factor

a_{ik} for k=1,2,…,q is factor weight (saturation) estimating influence of q^{th} common factor on i^{th} indicator

3 Research results

In this section. The results of our research are presented. Table 1 shows Pearson correlation coefficients of individual pairs of indicators.

Table 1 Pearson's correlation coefficients of original variables in 2020

	Pearson's Correlation Coefficients, N=26 Prob > |r| under H0: Rho=0					
	Food Consumption Expenditures (% of total)	Gross Domestic Product (PPS per capita)	Prevalence of Moderate or Severe food insecurity (%)	Median equivalised net income (euro)	Government Support to Agricultural R&D (euro per capita)	Agricultural Factor Income (euro per annual work unit)
Food Consumption Expenditures (% of total)	1.000 (-)	-0.814 (***)	0.728 (***)	-0.898 (***)	-0.68216 (***)	-0.612 (***)
Gross Domestic Product (PPS per capita)	-0.814 (***)	1.000 (-)	-0.606 (***)	0.840 (***)	0.763 (***)	0.511 (***)
Prevalence of Moderate or Severe food insecurity (%)	0.728 (***)	-0.606 (***)	1.000 (-)	-0.745 (***)	-0.392 (**)	-0626 (***)
Median equivalised net income (euro)	-0.898 (***)	0.840 (***)	-0.745 (***)	1.000 (-)	0.682 (***)	0.744 (***)
Government Support to Agricultural R&D (euro per capita)	-0.682 (***)	0.763 (***)	-0.392 (**)	0.682 (***)	1.000 (-)	0.550 (***)
Agricultural Factor Income (euro per annual work unit)	-0.612 (***)	0.511 (***)	-0.626 (***)	0.744 (***)	0.550 (***)	1.000 (-)

Source: Own processing using SAS Enterprise Guide Software

A statistically significant correlation has been observed between all pairs of variables, providing confirmation for RQ1 (Table 1). There is a positive correlation between the factors that are stimulants (maximizing). The previous correlation may also be seen between variables that are considered inhibitors (minimizing). Still, there exists a negative interaction between pairs of stimulants and inhibitors. Based on the correlation matrix provided in Table 1, it may be assumed that the chosen dataset is appropriate for conducting factor analysis (RQ2). This assumption is further verified by the use of Kaiser's measure of sampling adequacy.

Table 2 Kaiser's measure of sampling adequacy

Kaiser's Measure of Sampling Adequacy: Overall MSA = 0.789					
Food Consumption Expenditures (% of total)	Gross Domestic Product (PPS per capita)	Prevalence of Moderate or Severe food insecurity (%)	Median equivalised net income (euro)	Government Support to Agricultural R&D (euro per capita)	Agricultural Factor Income (euro per annual work unit)
0.844	0.786	0.856	0.775	0.761	0.711

Source: Own processing using SAS Enterprise Guide Software

Based on the above results (Table 2), we can conclude that the overall selection of data for factor analysis is average (Overall KMO = 0.789). At the same time, the suitability of the variables food consumption expenditures and prevalence of moderate or severe food insecurity is meritorious (0.8 ≤ KMO ≤ 0.9). The selection of other indicators is average (0.7 ≤ KMO ≤ 0.8). Based on the given results, we performed factor analysis using the principal component analysis method through all the indicators.

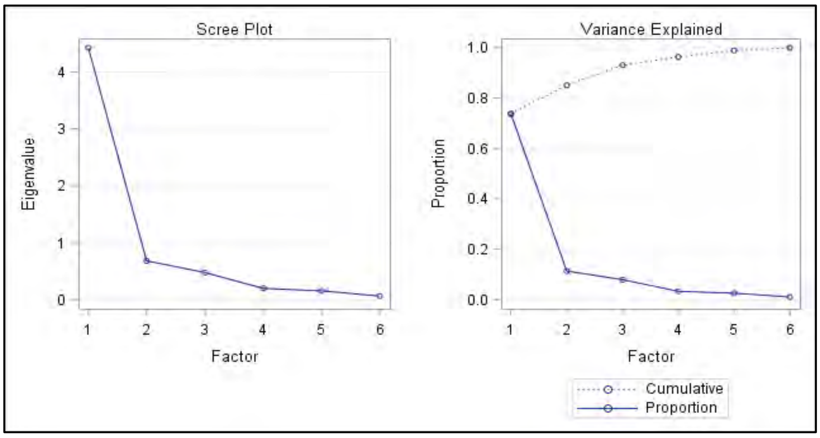
Table 3 Eigenvalues of the correlation matrix

Eigenvalue of the Correlation Matrix: Total = 6 Average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	**4.426**	3.745	0.738	**0.738**
2	0.681	0.206	0.114	0.851
3	0.476	0.278	0.078	0.931
4	0.199	0.044	0.033	0.964
5	0.155	0.091	0.026	0.990
6	0.063		0.011	1.000

Source: Own processing using SAS Enterprise Guide Software

Table 3 shows the eigenvalues of the correlation matrix. Factor 1 appears to be sufficient (Eigenvalue = 4.413), with 73.8% of the proportion of the original data variability explained (Table 3, Figure 1). This conclusion confirms RQ_3.

Figure 1 Scree plot of the eigenvalues



Source: Own processing using SAS Enterprise Guide Software

Based on the values of the factor weights (Table 4), it is clear that Factor 1 is strongly positively correlated with the normalised indicators used in the analysis. The resulting score of Factor 1, which simultaneously captures all assessed variables, is used in Figure 2 for the evaluation of the ranking of European Union member countries in terms of food security.

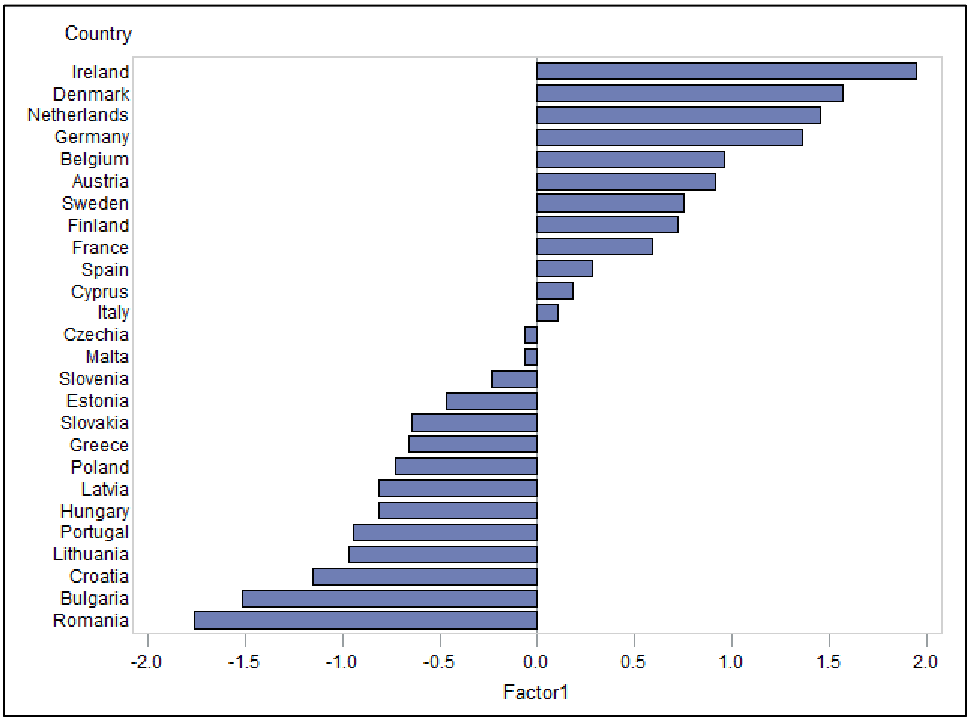
Table 4 Factor pattern

Factor Pattern					
Food Consumption Expenditures (% of total)	Gross Domestic Product (PPS per capita)	Prevalence of Moderate or Severe food insecurity (%)	Median equivalised net income (euro)	Government Support to Agricultural R&D (euro per capita)	Agricultural Factor Income (euro per annual work unit)
0.927	0.888	0.795	0.959	0.789	0.778

Source: Own processing using SAS Enterprise Guide Software

Figure 2 shows ranking of European Union countries based on common factor of food security in 2020. From the results we can conclude that western European countries – Ireland, Denmark and Netherlands are most food secure countries among Europe. On the contrary, the results suggest that eastern countries like Croatia, Bulgaria and Romania are least food secure among analysed group. The Factor 1 takes values within the interval (-2;2). Positive outcomes have been achieved by a total of twelve nations situated in the western and northern regions of Europe. On the contrary, 14 nations in Eastern and Southern Europe achieve negative outcomes, which supports RQ4. Simultaneously, the findings suggest that among the member states of the European Union, nations such Cyprus, Italy, Czechia, and Malta exhibit an average level of food security.

Figure 2 Bar chart of European countries based on common factor of food security



Source: Own processing using SAS Enterprise Guide Software

Conclusions

The task of maintaining food security is a significant challenge for both developing nations and economically advanced ones, including the member states of the European Union. The main purpose of this study is determination of food security situation in European Union member countries using multivariate statistical analysis. The analysis was performed for EU-26 countries for year 2020. To estimate the factor analysis model, we have chosen six indicators capturing access pillar of food security and agricultural indicators of Ending hunger goal of Agenda 2030. Namely, gross domestic product (purchasing power standard per capita), median equivalised net income (euro), government support to agricultural R&D (euro per inhabitant) and agricultural factor income per annual work unit (euro per annual work unit, chain linked volumes 2010). These indicators were considered to have positive effects on food security. On the contrary, indicators like the proportion of total household expenditures spent on food (percent of total households' expenditures) and the prevalence of moderate or severe food insecurity (percent) were considered to have negative effects on food security among European union countries. Correlation matrix of examined variables confirmed existence of strong linear correlation between them. To conduct the factor analysis, the original values of indicators were normalised to <0;1> scale using min-max transformation The results of factor analysis based on PCA showed that dimension of these indicators could be reduced by one common factor that explained 73,8% of variability of original dataset. After that, this Factor was used to assess food security situation among EU-26 countries in 2020. Based on the selected indicators of food security we concluded that Ireland, Denmark and Netherlands are among Europe most food secure countries. On the other side, countries like Croatia, Bulgaria and Romania seemed to be least food secure countries in European union. Overall, western and northern European countries performed better than eastern and southern countries. It should be also noted, that this study is only preliminary and in further researches more indicators could be added to compare obtained results. Moreover, it is also important to examine of households accounts to capture food security.

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