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Integrated assessment of economic vulnerability in the European Union: A multi-criteria sensitivity-adaptability approach (2000-2023)

■ **Abstract.** With the increasing frequency and magnitude of global shocks (financial crises, pandemics, geopolitical conflicts), traditional macroeconomic indicators are proving insufficient to assess how national economies respond to and recover from external shocks. There is an urgent need to develop a comprehensive tool that simultaneously captures the sensitivity of economies to shocks and their adaptive capacity. The aim of the study was to develop and apply an integrated economic vulnerability index for European Union countries for the period 2000-2023 to comprehensively assess their structural weaknesses. To achieve this goal, a multifactor sensitivity-adaptability model was used, combining 29 macroeconomic indicators from the real, financial, public, and external sectors. To increase the objectivity of the assessment, multiple objective weighting methods were applied, including Entropy, CRITIC, and Gini indices. A new assessment approach has been developed that quantitatively reflects the economy's capacity for self-recovery and flexibility, unlike models with fixed weightings. Significant heterogeneity in levels of economic vulnerability and resilience among European countries has been identified, driven by structural and macroeconomic factors. In particular, the Netherlands, Germany, and Estonia show lower vulnerability due to industrial diversification and financial sector resilience, while Romania, Greece, and Italy are the most vulnerable. The key systemic drivers of vulnerability are identified as the current account balance, foreign trade dynamics, industrial value added, and banking sector capitalisation, which consistently dominate in all objective weighting methods. The critical role of integrating multiple weighting methods to ensure reliable and nuanced vulnerability assessments in heterogeneous economies has been confirmed. The research results provide experts (government agencies, international organisations) with practical recommendations for developing context-oriented strategies to reduce systemic risks and increase the long-term sustainability of the real sector

■ **Keywords:** financial fragility; economic resilience; responsiveness-flexibility framework; composite index; structural risk

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■ INTRODUCTION

In an era marked by periodic financial crises, pandemics, and geopolitical upheavals, understanding the structural weaknesses that make economies vulnerable is more relevant than ever. Traditional macroeconomic indicators often fail to capture how economies respond to shocks and their ability to recover from them. In the context of the increasing frequency and magnitude of economic shocks, there is a growing need for a comprehensive approach to assessing the vulnerability of national economies.

The existing scientific literature provides several critical insights. The study conducted by C.P. Nguyen & T.D. Su (2021) represented the first comprehensive investigation into the influence of financial development, as a component of the institutional framework, on economic vulnerability across a global sample of 76 countries over the period 1997–2017. Researcher S.K. Gnanngnon (2025) examined the concept of structural economic vulnerability, defining it as the risk of a nation's development being impeded by external or environmental shocks. It was emphasised that this vulnerability remains a critical barrier to sustainable economic growth, and the reliance on single indicators for national assessments may overlook crucial vulnerability aspects, potentially restricting opportunities for the state and its citizens. The article by A. Sánchez *et al.* (2023) examined the level of socio-economic vulnerability of European Union regions at the NUTS-2 level by constructing a composite Socioeconomic Vulnerability Index (SEVI) that combines economic, social and demographic indicators. The authors found significant regional differences: northern and western regions show greater resilience, while southern and eastern regions remain more vulnerable. The European Union's cohesion policy contributes to reducing these disparities, but its effectiveness is uneven and depends on the institutional capacity of the regions. Insufficient attention has been paid to the dynamics of adaptability and the role of managerial and environmental factors in shaping resilience.

Certain multilateral organisations, such as the United Nations (UN), have thus recognised the limitations of single-indicator approaches and employ composite measures, including the Economic Vulnerability Index (EVI), to consolidate multiple dimensions into a single metric. Recent studies have also drawn attention to the omission of financial vulnerability from the broader definition of economic vulnerability, underscoring the necessity of integrating financial dimensions into analytical frameworks. Focusing on the fiscal dimension, N.H. Dau *et al.* (2024) investigated the stability of the financial system, arguing that it largely depends on its capacity to correct fiscal imbalances, particularly the mismatch between government revenues and expenditures. The researchers contended that this approach ensures effective national debt management and minimised fiscal deficits, underscoring the importance of understanding the intricate relationship between debt structure, exposure to economic shocks, and economic vulnerability. Furthermore, the dual role of trade openness has been interpreted in the literature, which suggests that while trade openness promotes export diversification and access to resources, it also causes commodity shocks to affect countries' economic growth, thereby increasing vulnerability.

Regarding alternative methodologies for index construction, the employment of the CRITIC approach was advanced by X. Wei *et al.* (2025) during the screening of uncalibrated priority pollutants using the enhanced Analytic Hierarchy Process-Criteria Importance Through Inter-criteria Correlation (AHP-CRITIC) methodology. Their study demonstrated an integrated Multi-Criteria Decision Analysis (MCDA) protocol combining AHP and CRITIC, which was validated as a method of diminishing excessive reliance on subjective or data-driven methodologies, affirming its adaptability to any multi-indicator index. Concurrently, in the field of credit risk assessment, Y. Li & W. Chen (2021) proposed a novel LNN-Entropy credit scoring model that integrates data pre-processing, feature selection, neural networks, and logistic regression using an entropy-based framework. Their empirical analysis demonstrated that this hybrid model surpasses both individual algorithms and several state-of-the-art benchmarking models in terms of classification accuracy and predictive performance, illustrating the potential of entropy-driven optimisation in enhancing model robustness. Moreover, O. Pala (2023) introduced an innovative objective criterion weighting approach known as the ROCOSD method, which simultaneously considers robustness, correlation, and standard deviation. Comparative analyses undertaken by the author demonstrated that ROCOSD surpasses traditional weighting techniques in both robustness and accuracy, validating its practical utility and adaptability to policy assessment frameworks. Overall, these methodological developments underscore the necessity of adopting flexible, transparent, and statistically robust weighting schemes in the construction and interpretation of composite indices. The purpose of this study was to develop and apply a composite EVI for European Union countries.

■ MATERIALS AND METHODS

The primary innovation pertained to the objective weighting of 29 macroeconomic indicators encompassing the real, financial, government, and external sectors. The application of seven distinct weighting schemes was employed in this study: equal weighting, entropy, standard deviation (SD), coefficient of variation (CV), CRITIC, Gini coefficient, statistical dispersion, with a sensitivity-adaptability model for assessing economic vulnerability. The methodology employed was designed to minimise subjectivity and ensure that the composite index reflects both the dispersion and the unique contribution of each indicator. The analysis encompassed key macroeconomic indicators such as Gross Domestic Product (GDP) growth rate, inflation, unemployment, and savings rate, examined across a selection of European countries. The study period spans from 2000 to 2023, enabling a thorough evaluation of structural vulnerabilities within the real, financial, public, and external sectors of the economy. The assessment of economic vulnerability across European countries was performed using a comprehensive composite index, integrating indicators from the real, financial, government, and external sectors. This multi-criteria approach allowed for a nuanced analysis of both sensitivity to economic shocks and the adaptive capacity of national economies.

Several methodological approaches were adopted in line with contemporary practices in composite index

construction. First, the aforementioned methods were integrated prior to the final aggregation stage to ensure methodological robustness and to mitigate potential biases associated with any single weighting technique. Second, within the established hierarchy of indicators, a clear conceptual and analytical distinction was drawn between sensitivity (defined as volatility in response to external shocks) and adaptability (interpreted as resistance to long-term adverse trends). This classification enabled a more nuanced understanding of the structural dimensions of economic vulnerability. Finally, the VIKOR method was employed to synthesise the weighted scores and to implement a compromise ranking algorithm. This approach facilitated the comparative analysis of the EVI across countries, allowing for the identification of relative performance patterns and the assessment of inter-country disparities in economic resilience. Given that the EVI under consideration utilises seven objective weighting schemes (equal, entropy, SD, CRITIC, Gini, variance, CV), it was appropriate to employ Equal Weighting/Minimax Method (EW/MM) results to assess the sensitivity of the EVI ratings to the simple mixing of all indicators at equal

weightings. Next, adaptive methods were used to determine if EVI behaves more like Data Envelopment Analysis (DEA) (unstable with many indicators) or EW (stable). To convert the weights into a consistent ranking scale, the VIKOR compromise ranking method was employed, with the pyrepo-mcda Python package being utilised for implementation. The data were obtained directly from the World Bank (n.d.) via the wbgapi interface, and all calculations are performed using Python scripts to ensure full reproducibility. The standardisation of sensitivity (i.e. the annual volatility around long-term averages) and adaptability (i.e. the resistance to regression-based trends) prior to the construction of the index is undertaken to ensure the comparability of indicators between countries.

In addition to quantitative analysis, qualitative research methods were also employed to deepen the understanding of the underlying nature of the studied phenomenon. Synthesising the approaches reviewed in the literature, the article primarily focuses on the structural vulnerabilities of the real, financial, and public sectors of the economy. To achieve this, a composite indicator was developed based on a set of key variables (Table 1).

Table 1. Variable coding map

Code	Variable	Impact
C1	Current account balance (% of GDP)	+
C2	Foreign direct investment, net inflows (% of GDP)	+
C3	S&P Global Equity Indices (annual % change)	+
C4	Stocks traded, total value (% of GDP)	+
C5	Stocks traded, turnover ratio of domestic shares (%)	+
C6	Bank nonperforming loans to total gross loans (%)	-
C7	Bank capital to assets ratio (%)	+
C8	Bank liquid reserves to bank assets ratio (%)	+
C9	Broad money (% of GDP)	+
C10	Broad money growth (annual %)	+
C11	Inflation, consumer prices (annual %)	-+
C12	Deposit interest rate (%)	-
C13	Lending interest rate (%)	-+
C14	Domestic credit to private sector (% of GDP)	+
C15	Central government debt, total (% of GDP)	-
C16	General government final consumption expenditure (% of GDP)	-
C17	Final consumption expenditure (annual % growth)	+
C18	Exports of goods and services (annual % growth)	+
C19	Gross fixed capital formation (% of GDP)	+
C20	Imports of goods and services (annual % growth)	+
C21	External balance on goods and services (% of GDP)	+
C22	Trade (% of GDP)	+
C23	Industry (including construction), value added (% of GDP)	+
C24	Services, value added (% of GDP)	+
C25	GDP growth (annual %)	+
C26	GDP per capita (current US\$)	+
C27	Gross savings (% of GDP)	+
C28	Price level ratio of Purchasing Power Parity (PPP) conversion factor (GDP per capita)	+
C29	Unemployment, total (% of total labour force)	-

Source: compiled by the authors based on World Bank (n.d.)

To provide a clearer understanding of the distribution and variability of the selected indicators, descriptive statistics were calculated for each variable. Table 2 presents the statistical description of the indicators, including

measures such as the mean, minimum, maximum, quartiles, and standard deviation, which together allow for an assessment of cross-country differences and potential outliers over the studied period.

Table 2. Statistical description of indicators

Variable	N	Mean	Min	25%	50%	75%	Max	Std
Current account balance (% of GDP)	636	-0.62	-25.74	-4.05	-0.35	2.71	19.16	5.79
Foreign direct investment, net inflows (% of GDP)	646	13.65	-440.13	1.73	3.56	7.64	452.22	56.35
S&P Global Equity Indices (annual % change)	579	6.83	-73.02	-14.06	4.86	26.07	189.23	31.47
Stocks traded, total value (% of GDP)	449	22.62	0.01	1.12	7.40	31.05	264.76	35.01
Stocks traded, turnover ratio of domestic shares (%)	413	46.04	0.05	6.25	30.98	68.23	377.25	53.24
Bank non-performing loans to total gross loans (%)	396	6.77	0.15	2.40	4.06	7.97	47.75	7.65
Bank capital-to-assets ratio (%)	402	7.65	-1.26	5.50	7.26	8.93	34.60	3.25
Bank liquid reserves to bank assets ratio (%)	161	17.33	0.20	0.29	13.38	22.49	77.21	15.62
Broad money (% of GDP)	168	59.12	26.13	46.34	60.28	67.89	93.83	15.42
Broad money growth (annual %)	168	9.78	-11.09	5.07	8.74	13.01	48.42	8.47
Inflation, consumer prices (annual %)	648	3.03	-4.45	1.12	2.28	3.55	45.67	3.77
Deposit interest rate (%)	150	3.44	0.01	1.18	2.34	3.73	33.11	4.32
Lending interest rate (%)	170	7.68	1.47	4.49	5.92	9.44	53.85	6.45
Domestic credit to private sector (% of GDP)	584	82.97	7.13	50.51	77.75	104.21	254.67	42.54
Central government debt, total (% of GDP)	330	67.43	3.81	38.09	60.81	92.60	249.37	41.72
General government final consumption expenditure (% of GDP)	648	19.88	11.06	18.17	19.44	21.67	27.82	2.93
Final consumption expenditure (annual % growth)	647	2.24	-16.80	0.86	2.17	3.81	17.02	3.30
Exports of goods and services (annual % growth)	647	5.34	-23.19	1.98	5.26	9.08	41.02	7.78
Gross fixed capital formation (% of GDP)	648	22.30	10.97	19.83	21.85	24.31	53.22	4.11
Imports of goods and services (annual % growth)	647	5.20	-30.89	1.30	5.47	9.34	41.30	8.50
External balance on goods and services (% of GDP)	648	2.14	-21.79	-2.04	1.24	5.04	41.69	8.75
Trade (% of GDP)	648	119.30	45.14	77.76	105.64	148.41	394.22	59.00
Industry (including construction), value added (% of GDP)	648	23.50	9.97	19.80	23.74	27.20	40.68	5.75
Services, value added (% of GDP)	648	62.59	42.33	57.62	62.15	66.65	80.60	6.56
GDP growth (annual %)	648	2.50	-16.04	0.90	2.57	4.51	24.62	3.90
GDP per capita (current US\$)	648	30921.66	1621.26	14792.16	24665.99	43772.63	133711.79	22590.00
Gross savings (% of GDP)	636	22.31	4.60	18.74	22.67	26.14	36.85	5.23
Price level ratio of PPP conversion factor (GDP) to market exchange rate	648	0.78	0.25	0.58	0.76	0.97	1.56	0.26
Unemployment, total (% of total labour force) – national estimate	648	8.34	1.81	5.53	177326.00	10.04	27.69	4.27

Source: compiled by the authors based on World Bank (n.d.)

Within the framework of this study on economic vulnerability, an extended set of quantitative indicators was developed to encompass key aspects of the external, financial, banking, and real sectors of the economy. Each selected variable plays a critical role in the comprehensive analysis of economic structure and facilitates the identification of potential threats to macroeconomic stability. The current account balance (% of GDP) reflects the overall

external equilibrium of a country, where positive values are indicative of financial resilience. Foreign direct investment (% of GDP) serves as a proxy for investor confidence and, accordingly, exerts a positive influence on economic dynamics. Stock market indicators, such as changes in global equity indices, total value of stocks traded, and turnover ratio of domestic shares, provide insights into the depth and liquidity of financial markets, which are positively

correlated with economic activity. The condition of the banking system is assessed through the share of non-performing loans, the capital-to-assets ratio, and the level of bank liquidity reserves. A low proportion of problematic assets, high bank capitalisation, and substantial reserves are indicative of financial system resilience. Additionally, indicators of monetary policy were considered: broad money (% of GDP) and its annual growth rate, which allow for the evaluation of the level of monetary activity. The equal weights method is employed in sensitivity and reliability studies that utilise equal weights/minimax methods to construct composite social indicators (Shi & Land, 2021).

Particular attention was given to domestic credit to the private sector, which reflects the level of access to financial resources, and to central government debt (% of GDP), where exceeding critical thresholds may pose risks of debt instability. The analysis also incorporated indicators of government consumption and final consumption expenditure, which reflect fiscal policy and domestic demand, respectively. External economic activity was assessed through export and import growth rates, the external balance of goods and services, and total trade (% of GDP). These indicators capture the degree of a country's integration into the global economy and its dependence on external conditions.

From a structural perspective, the study examines value added in industry (including construction) and the services sector, providing insight into the sectoral composition of GDP. Core macroeconomic indicators, such as annual GDP growth, GDP per capita (current US\$), gross savings (% of GDP), and unemployment rate, offer a general overview of economic activity, population welfare, and socio-economic balance. Additionally, the price level index (defined as the ratio of the purchasing power parity conversion factor to nominal GDP) was considered, enabling an assessment of real purchasing power in comparison with other countries. Taken together, this set of indicators enabled a comprehensive evaluation of both internal and external factors contributing to economic vulnerability, helping to identify potential risks and structural weaknesses in national economies. This approach provided a foundation for the development of an integrated EVI and for ranking countries according to their level of structural resilience.

Methodology for assessing economic vulnerability. The vulnerability of an economic system was assessed through a “sensitivity-adaptability” function. The formula for calculating vulnerability presented as follows:

$$\text{Vulnerability} = \text{Sensitivity} - \text{Adaptability}, \quad (1)$$

where V , S , A – system's vulnerability, sensitivity, and adaptability, respectively. The vulnerability of the system is influenced by both its sensitivity and adaptability. Sensitivity reflects the degree to which the system responds to external disturbances, while adaptability indicates the system's capacity to maintain and restore its structure when faced with such disturbances. For instance, taking GDP growth rate (a key indicator of the macroeconomic system) its sensitivity is measured through the annual volatility over the period in dataset.

The formula for calculating sensitivity is as follows:

$$\text{Sensitivity}_j = \frac{\sum_{i=1}^n |F_i - \bar{F}|}{\bar{F}}, \quad (2)$$

where F_i – value of index j in the year i ; $\bar{F}$ – the average value of index j from 2000 to 2023. Sensitivity_j – the variable rate of index j , which reflects the degree of dispersion of the average value of index j within the relatively specific time from 2000 to 2023.

Formulas (3) and (4) were used in this research methodology to quantitatively assess the adaptability of the economic system, which is a key component of the developed EVI. The formulas describe the application of linear regression to measure the long-term trend of variability for each indicator:

$$y = \beta_0 + \beta_1 x + \epsilon; \quad (3)$$

$$\beta_1 = \frac{\text{cov}(x, y)}{\text{var}(x)}, \quad (4)$$

where β_1 – regression coefficient, representing the change in the dependent variable y associated with a one-unit change in the independent variable x ; ϵ – error term, capturing the unexplained variation in y not accounted for by the regression model; $\text{cov}(x, y)$ – covariance between x and y , measuring the degree to which the two variables vary together; $\text{var}(x)$ – variance of x , indicating the dispersion or spread of the variable around its mean.

The variable x denotes the ordinal time period, spanning from 2000 to 2023, while β_0 captures the intercept. The objective variable, denoted by y , is calculated for each indicator j by subtracting the mean value of j , calculated over the period 2000 to 2023, from its actual value. Additionally, as the sensitivity and adaptability values calculated from the preceding formula may vary in magnitude, it is essential to standardise these results separately before calculating vulnerability. This step ensures comparability and facilitates the analysis of regional differences in vulnerability. The equal weighting method is the simplest and entirely objective approach to determining the weights of criteria. Under this method, all criteria are considered equally important, regardless of data variability, informational richness, or statistical characteristics:

$$w_j = \frac{1}{n}, \forall j = 1, 2, \dots, n. \quad (5)$$

It is important to note that this approach effectively neutralises the statistical significance or characteristics of individual indicators. Nevertheless, it is suitable in cases where expert judgment is unavailable or when there is no substantiated information regarding the relative importance of specific criteria. In essence, it represents a maximally neutral approach to assigning weights and evaluating the influence of indicators on the final assessment outcome. The Entropy Weight Method (EWM) is a widely recognised objective evaluation approach that is considered to be more reliable than those based on subjective methods. The principal benefit of this approach is that it reduces the potential for human bias, thereby enhancing the objectivity of comprehensive evaluation outcomes. At present study, EWM was employed in a multitude of disciplines, including engineering, technology, and socio-economic studies. The EWM calculates the entropy weight of each indicator using information entropy based on variation levels. Subsequently, each indicator's weight is adjusted according to the entropy value, thereby achieving a more

accurate weight assignment. In general, a lower entropy weight, as determined by this method, indicates a higher degree of variation and richer information content, thereby contributing more significantly to the overall assessment and obtaining a larger weight. Consequently, this study employed EWM to determine the weight of each indicator within the economic system vulnerability assessment, given the method's suitability and effectiveness. The first step in EWM is standardisation. The positive and negative standardised formulas are as follows:

$$x'_{ij}(+) = \frac{x_{ij} - \min(x_j)}{\max(x_{ij}) - \min(x_{ij})}; \quad (6)$$

$$x'_{ij}(-) = \frac{\max(x_j) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, \quad (7)$$

where x'_{ij} – initial value of indicator j for alternative/country i . y_{ij} is generated by:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_{ij}) - \min(x_{ij})}. \quad (8)$$

In EWM, – the entropy, is defined as:

$$\text{entropy}_j = -\frac{\sum_{i=1}^n y_{ij} \ln(y_{ij})}{\ln(n)} \quad (9)$$

where n – number of observations.

It is necessary to mention that $y_{ij}=0 \Rightarrow y_{ij} \times \ln(y_{ij})=0$. e_j lies in the $[0,1]$ domain. In EWM the weight w_j is calculated as:

$$w_j = \frac{1 - \text{entropy}_j}{\sum_{j=1}^m 1 - e_j}, \quad (10)$$

where m – number of criteria/features; e_j – the entropy of criterion j , which measures the degree of uncertainty or dispersion of data for this criterion among all alternatives.

Comprehensive score calculation is as follows:

$$\text{Score} = \sum_{j=1}^m w_j y_{ij}. \quad (11)$$

The standard deviation weighting method belongs to the category of objective approaches for determining criterion weights. Its core principle lies in using the degree of data variation as an indicator of the informational value of each criterion. The greater the dispersion (or standard deviation) of a criterion's values across alternatives, the higher the weight it receives in the decision-making process. The standard deviation for each criterion is calculated as follows:

$$\sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^m (x_{ij} - \bar{x}_j)^2}, \quad (12)$$

where σ_j – the standard deviation of the j -th feature (or variable). It measures how spread out the values of this feature are from the mean; m – the number of observations (or data points) in the dataset.

Subsequently, the weights are derived using the formula:

$$w_j = \frac{\sigma_j}{\sum_{k=1}^m \sigma_k}, \quad (13)$$

where w_j – is the weight of the j -th feature (or variable). It shows the relative importance of that feature compared to

the others; k – an index variable used inside the summation. It just counts through all the features $(1, 2, 3, \dots, m)$.

The logic of this method was based on the assumption that criteria with higher variability carry greater informational weight, as they are more effective in differentiating between alternatives. Conversely, criteria with low variation were assigned lower weights due to their limited contribution to comparative analysis. The CRITIC method is an objective approach to determining criterion weights that accounts for both the degree of data variation and the interdependence (correlation) among criteria. The underlying idea is that more important criteria are those that exhibit greater dispersion in values and do not duplicate the information provided by other criteria. That is, they are less correlated with others. In the first stage of this method, minimax normalisation was applied to the indicators (as per formulas (6) and (7)), resulting in standardised values x'_{ij} . The standard deviation for each criterion was then calculated as follows:

$$\sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^m (x'_{ij} - \bar{x}'_j)^2}. \quad (14)$$

Next, the correlation between each pair of indicators is computed:

$$r_{jk} = \frac{\sum_{i=1}^m (x'_{ij} - \bar{x}'_j)(x'_{ik} - \bar{x}'_k)}{\sqrt{\sum_{i=1}^m (x'_{ij} - \bar{x}'_j)^2} \sqrt{\sum_{i=1}^m (x'_{ik} - \bar{x}'_k)^2}}. \quad (15)$$

The resulting correlation values from formula (15), together with the standard deviation from formula (14), allowed for the estimation of the informational strength of each criterion:

$$C_j = \sigma_j \sum_{k=1}^n (1 - r_{jk}). \quad (16)$$

Thus, each criterion is evaluated based on two parameters: its variability and its degree of independence from other criteria. Finally, the weights are calculated as:

$$w_j = \frac{C_j}{\sum_{k=1}^m C_k}. \quad (17)$$

This method objectively incorporates both the intensity of variation and the avoidance of excessive correlation, thereby preventing information redundancy. It is well-suited for complex multi-criteria decision-making tasks, although it is sensitive to the choice of correlation calculation method.

Gini coefficient-based weighting method. This method is based on the use of the Gini coefficient as a measure of inequality in the distribution of indicator values for each criterion. The greater the variation among alternatives for a given criterion, the higher its informational weight. It is an objective weighting approach that does not require expert input. For each criterion $j = 1, 2, \dots, n$, the Gini coefficient G_j is calculated to reflect the degree of inequality in the distribution of values across all alternatives $i = 1, 2, \dots, m$. The general formulation is as follows:

$$G_j = \frac{1}{2m^2 \bar{x}_j} \sum_{i=1}^m \sum_{k=1}^m |x_{ij} - x_{kj}|, \quad (18)$$

where G_j – the Gini coefficient for criterion j , representing the degree of inequality or dispersion of criterion j across

all alternatives; m – the number of alternatives under evaluation; n – the number of criteria considered in the assessment; x_{ij} – the value of alternative i with respect to criterion j ; $\bar{x}_j$ – the mean value of criterion j across all alternatives.

Once the values of G_j are computed, the weights for each criterion are determined by normalising the vector of Gini coefficients:

$$w_j = \frac{G_j}{\sum_{k=1}^m G_k}, \quad (19)$$

where w_j – the normalised weight assigned to criterion j , derived from the corresponding Gini coefficient.

This method provides an objective mechanism for evaluating the relative importance of criteria based on distributional inequality, and is particularly useful in contexts where expert judgment is unavailable or undesirable.

Statistical variance weighting method. The statistical variance weighting method is based on the assumption that criteria with greater variability in their values carry more informational weight and should therefore be assigned higher importance in a multi-criteria model. Unlike subjective approaches, this method provides an objective means of determining weights solely based on the statistical properties of the input data. In the initial stage, mini-max normalisation is applied (as per formula (6)).

In the next step, the statistical variance for each normalised criterion is calculated as follows:

$$var_j = \frac{1}{m} \sum_{i=1}^m (x'_{ij} - \bar{x}_j)^2 \quad (20)$$

Once the variances are computed, the weight of each criterion is determined as the ratio of its variance to the sum of variances across all criteria:

$$w_j = \frac{var_j}{\sum_{k=1}^m var_k}. \quad (21)$$

The advantages of this method, as with other objective approaches, include its simplicity, transparency, and independence from expert judgment. However, it does not account for interrelationships between criteria, focusing solely on their individual variability.

Coefficient of variation weighting method. The coefficient of variation method is an objective approach to determining criterion weights that considers both the mean value of an indicator and the degree of its variability. A high ratio between the standard deviation and the mean is interpreted as a high informational significance of the criterion.

In this approach, data are standardised using sum normalisation:

$$b_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}, \quad (22)$$

where b_j – average.

This results in a normalised matrix, where the sum of each column equals one. For each criterion j , the mean is calculated as:

$$\bar{b}_j = \frac{1}{m} \sum_{i=1}^m b_{ij}, \quad (23)$$

and the standard deviation is computed as:

$$\sigma_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^m (b_{ij} - \bar{b}_j)^2}. \quad (24)$$

Following formulas (21-23), the coefficient of variation is calculated using:

$$e_j = \frac{\sigma_j}{\bar{b}_j}. \quad (24)$$

This metric reflects the intensity of fluctuations relative to the average level. Final weights are then determined by normalising the coefficients of variation:

$$w_j = \frac{e_j}{\sum_{k=1}^m e_k}. \quad (25)$$

This method offered a transparent and objective means of weighting, particularly useful when both variability and average performance are relevant.

■ RESULTS

In an era of increasing information availability, composite indicators satisfy the need for consolidation by combining multiple indicators into a single number that encompasses and summarises all this information. This key feature elucidates the reasons for their success and the reasons why they have been adopted on a global scale by organisations, scientists, the media and politicians. Despite their usefulness, these indicators should be used cautiously, especially when drawing significant conclusions. The validity of these accounts is contingent upon their construction, which, as previously discussed, contains no elements beyond critique. Each approach, at each individual stage, has both advantages and disadvantages, and during the weighting stage, developers select from a range of subjective and objective approaches.

The selection of components for the construction of a composite index invariably presents a dilemma, whereby alternative choices appear to be either disadvantageous or impractical. Despite its frequent oversight, it is imperative that reliability analysis is conducted after the construction of the index. This instrument is an excellent quality assurance tool for developers, with the additional advantage of enhancing overall transparency. However, it should not be mistakenly interpreted as a guarantee of the sensitivity of the composite index. Indeed, the reliability of the construction can be assured by ensuring that each choice is linked to the purpose of the construction. The results of assessment of economic vulnerability across European countries, classified using a natural breaking point method, revealed clear regional clusters and heterogeneity in economic resilience across Europe. The findings demonstrated that the advancement of financial systems – including financial depth, access, efficiency, and the development of financial institutions and markets – significantly reduces economic vulnerability, with consistent evidence across income-level sub-samples.

As was presented in Table 2 presents a statistical summary of the indicators analysed in terms of quartile distribution. For this purpose, key descriptive statistics were calculated, including the mean, median, quartiles, minimum and maximum values, as well as the standard deviation, which allows for an assessment of variability across countries. The average current account balance stood at -0.62% of GDP, indicating a general tendency toward external account deficits. However, the considerable variability (ranging from -25.74% to +19.16%) and a standard

deviation of 5.79 suggest significant cross-country differences. Foreign direct investment exhibits even greater dispersion ($\sigma = 56.35$), with an exceptionally wide range (from -440.13% to +452.22% of GDP), largely driven by one-off large-scale transactions in specific countries.

Stock market indicators, particularly changes in equity indices (S&P Global), show a positive average (6.83%) and a broad fluctuation range (from -73.02% to +189.23%), reflecting the cyclical nature of market dynamics. Similar characteristics are observed in stock trading activity (% of GDP) and the turnover ratio of domestic shares, with average values of 22.62% and 46.04%, respectively, and high levels of dispersion. In the banking sector, the average share of non-performing loans was 6.77%, although in some countries this figure exceeded 47%, indicating substantial credit portfolio risks. In contrast, bank capitalisation and liquid reserves demonstrated relatively stable average values (7.65% and 17.33%, respectively), albeit with noticeable fluctuations. Monetary aggregates, particularly broad money, averaged approximately 59% of GDP, with an annual growth rate of 9.78%. It is worth noting that the volatility in broad money growth is significant, which may influence inflation expectations. Consumer price inflation remained at a moderate average level of 3.03%, although recorded values ranged from deflation (-4.45%) to hyperinflationary levels (above 45%). Deposit and lending interest rates also exhibited considerable variation (from 0.01% to 33.11% and up to 53.85%, respectively), reflecting the diversity of monetary policy approaches across countries.

Private sector credit averaged 83% of GDP, while central government debt stood at 67.43% of GDP, which generally aligns with fiscal sustainability thresholds for most developed economies. However, maximum debt levels reached 249.37%, signaling potential sovereign risk concerns. Fiscal and consumption indicators, particularly government final consumption expenditure (19.88% of GDP) and the annual growth of final consumption (2.24%), demonstrate a stable structure of domestic demand. Similarly, export and import growth remained moderate (above 5% annually), although

accompanied by considerable volatility. The external trade balance was positive on average (2.14%), with pronounced peaks in both positive and negative directions. Trade as a share of GDP averaged 119.3%, indicating a high degree of global economic openness among the countries in the sample. Structurally, industry accounted for 23.5% of value added, while the services sector contributed over 62%, reflecting the dominance of the tertiary sector in modern economies. Core macroeconomic indicators, including GDP growth (2.5%) and GDP per capita (US\$30,922), suggest a generally adequate level of welfare across countries, although variability remained high. Gross savings (22.31% of GDP) correspond to moderate investment activity. The price level ratio of purchasing power parity (PPP) averaged 0.78, confirming the relative undervaluation of national currencies compared to the US dollar.

Finally, unemployment rates among the analysed European countries averaged 8.34% of the total labour force, with a minimum of 1.81% and a maximum of 27.69%, indicating considerable variation across the region. Such high unemployment levels observed in some cases are indicative of significant socio-economic challenges. Additionally, several indicator values in the table – such as the extremely high median listed for GDP per capita (USD 177,326) – suggest the presence of statistical outliers or potential data entry errors, highlighting the need for further verification and data refinement to ensure analytical accuracy. In summary, the analysis not only identifies clusters of countries with convergent risk profiles, but also highlights the importance of targeted policy measures aimed at reducing structural weaknesses and enhancing resilience at both country and regional levels. This composite methodology ensured that the EVI captures the complex reality of modern European economies. For this purpose, Figure 1 illustrates the distribution of indicator weights assigned to each criterion by multiple objective methods, highlighting how methodological choice shapes the composite vulnerability index. Each stacked column represents one weighting technique, while coloured segments indicate the relative importance of individual indicators within the composite vulnerability index.

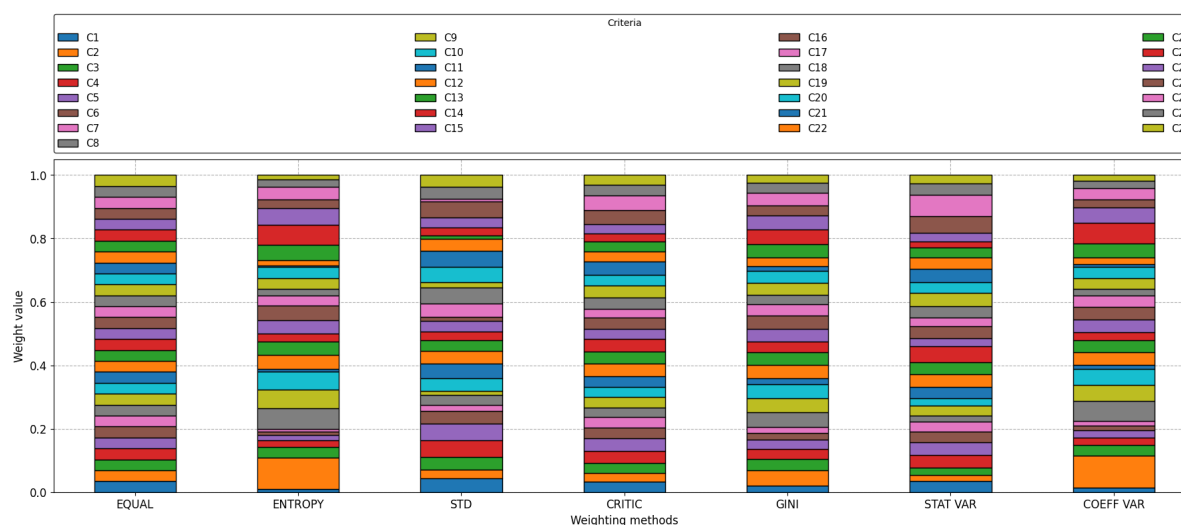


Figure 1. Criterion weight value for different weighting methods

Source: prepared by the authors

Notably, the Equal weighting method provides a uniform allocation, giving all indicators the same significance in the final index. Conversely, methods such as Entropy and CV highlighted specific criteria according to their variability, information value, or contrast in the dataset. This pronounced variation in weight allocation demonstrated that the assessment of economic vulnerability is highly sensitive to methodological choices – certain indicators, especially those reflecting financial and external sector dynamics, may exert a disproportionate influence under specific approaches. The diversity revealed across the weighting schemes underscores the importance of a careful, multi-method comparison when interpreting

vulnerability measurement outcomes. By employing multiple weighting models, the analysis mitigates individual method bias and ensures a more balanced and robust assessment of structural risk in European economies. For a more detailed understanding of this multi-method approach, the distribution of weights for each individual criterion across all weighting models is analysed below. Figure 2 presents the distribution of weights assigned to each individual criterion across all applied objective weighting methods. The boxplot format provides a detailed visual summary of how each criterion's importance varies depending on the method used, emphasising both central tendencies and the range of potential weights.

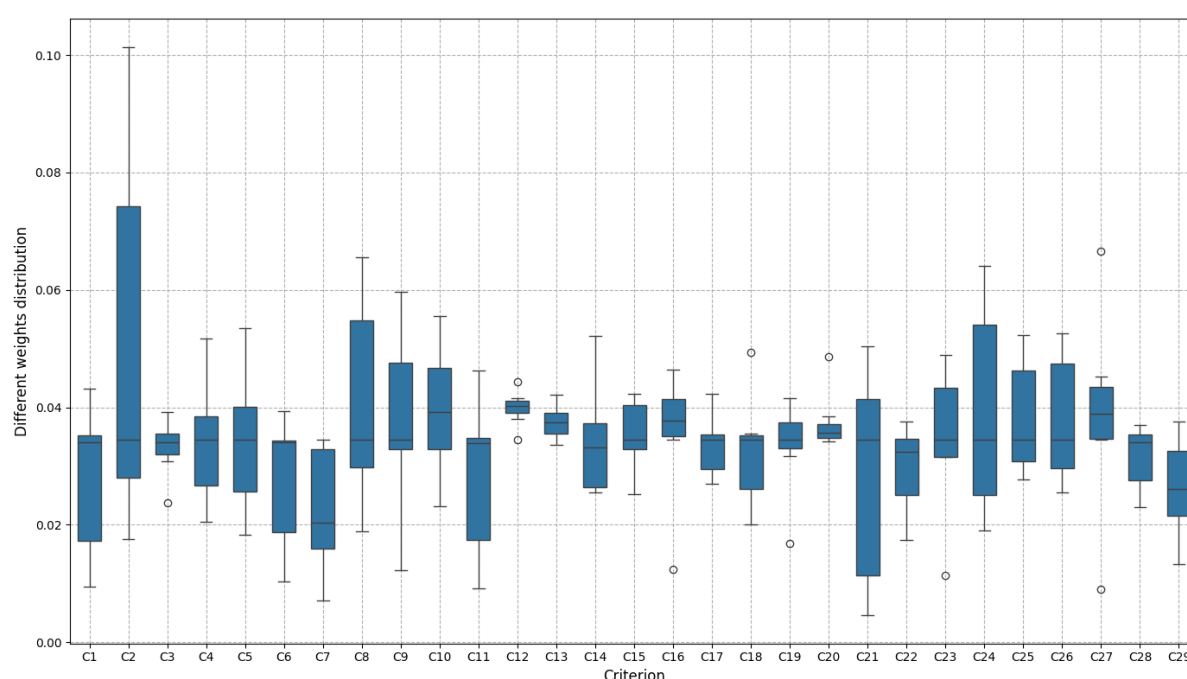


Figure 2. Weighting methods distribution for each criterion in the EVI

Source: prepared by the authors

This visualisation highlights significant differences in the degree of consensus between methods for particular criteria. For instance, certain indicators, such as C2, C8, C20, and C24, exhibited marked dispersion, suggesting that the methodological choice can substantially influence their role in shaping the composite EVI. Stable or narrow boxplots for other criteria indicate stronger methodological agreement and more robust significance, regardless of the weighting algorithm. Overall, the figure underscored the critical need for multi-method validation when constructing the EVI, as individual indicators may carry

disproportionate weight depending on the chosen approach. Building on the insights gained from the weighting scheme comparison, the effects of these methodological choices on country-level rankings within the EVI could be assessed in greater depth. Table 3 provides a comparative overview of criteria weights assigned by various objective weighting methods, where each criterion (denoted as C1 through C29) constitutes a multidimensional indicator fundamental to the construction of the EVI. The specific nature of each criterion is typically detailed in the corresponding indicators description section.

Table 3. Comparative weights of criteria calculated by different methods

Cj	EQUAL	ENTROPY	STD	CRITIC	GINI	STAT VAR	COEFF VAR
C1	0.034483	0.00949	0.043107	0.034062	0.020473	0.036093	0.014178
C2	0.034483	0.099935	0.028855	0.027126	0.048534	0.017593	0.101353
C3	0.034483	0.033207	0.039129	0.030772	0.036654	0.023758	0.034115
C4	0.034483	0.020439	0.051712	0.038094	0.030543	0.038828	0.022934
C5	0.034483	0.018248	0.053419	0.039042	0.02913	0.041125	0.022179

Table 3. Continued

Cj	EQUAL	ENTROPY	STD	CRITIC	GINI	STAT VAR	COEFF VAR
C6	0.034483	0.01038	0.03934	0.034078	0.022059	0.034314	0.015505
C7	0.034483	0.007146	0.020304	0.034452	0.018556	0.031408	0.013288
C8	0.034483	0.065608	0.030832	0.0286	0.045679	0.01888	0.063893
C9	0.034483	0.059697	0.012267	0.033994	0.044302	0.031816	0.050754
C10	0.034483	0.055555	0.039206	0.031322	0.043661	0.023145	0.049633
C11	0.034483	0.009125	0.046312	0.033829	0.02043	0.03515	0.014417
C12	0.034483	0.04434	0.041553	0.040102	0.040699	0.040252	0.038046
C13	0.034483	0.042214	0.033604	0.037438	0.040365	0.036678	0.037765
C14	0.034483	0.025509	0.027182	0.040223	0.033191	0.052165	0.025611
C15	0.034483	0.042235	0.034071	0.03169	0.040759	0.025261	0.040059
C16	0.034483	0.04642	0.012454	0.035699	0.041638	0.037748	0.041126
C17	0.034483	0.030544	0.042299	0.028297	0.035752	0.026936	0.034971
C18	0.034483	0.020121	0.049306	0.035522	0.029794	0.034817	0.022311
C19	0.034483	0.034529	0.016752	0.037405	0.037555	0.041569	0.031667
C20	0.034483	0.035218	0.048555	0.034155	0.038486	0.035607	0.035753
C21	0.034483	0.004621	0.050441	0.041026	0.01335	0.041778	0.009403
C22	0.034483	0.017389	0.037535	0.03237	0.028587	0.034731	0.021446
C23	0.034483	0.04885	0.011442	0.031585	0.042519	0.031484	0.044119
C24	0.034483	0.062813	0.024421	0.02576	0.04543	0.01897	0.06401
C25	0.034483	0.052326	0.032795	0.028912	0.043444	0.027711	0.04923
C26	0.034483	0.026101	0.05028	0.04448	0.03327	0.052536	0.025521
C27	0.034483	0.041694	0.008986	0.045213	0.038869	0.066538	0.034667
C28	0.034483	0.022999	0.036248	0.034103	0.03149	0.037005	0.023695
C29	0.034483	0.013246	0.037594	0.030651	0.024778	0.026105	0.01835

Source: prepared by the authors

To further elucidate the methodological underpinnings of the composite vulnerability index, Table 3 presents the comparative weights assigned to the evaluation criteria by different objective weighting methods. This detailed breakdown highlights the extent to which individual indicators contribute to the final index value under varying approaches and provides a basis for examining the sensitivity of the analysis to choices made during index construction. The results demonstrated both alignment and variation among the methods, offering critical insight into the robustness of the weighting framework and the rationale for incorporating a multi-method strategy in assessing structural risks across European economies. Building on this comparative weighting analysis, additional investigation was undertaken to identify the principal factors most strongly driving economic vulnerability in the European context. According to Table 3, criteria such as current account balance (C1), external balance on goods and services (C21), industry value added (C23), and bank capital to assets ratio (C7) consistently rank among the highest-weighted contributors to the composite index. These indicators emerged as dominant obstacles to resilience in a majority of countries, implying that persistent external imbalances, sectoral concentration, and financial sector fragility are critical vulnerabilities for the region. Targeted efforts to enhance external equilibrium, promote diversification within the

real sector, and strengthen the banking system may thus bring the greatest reductions in vulnerability and reinforce long-term stability.

The comparative matrix revealed how alternative weighting methodologies, including Equal, Entropy, Standard Deviation, CRITIC, Gini, Statistical Variance, and Coefficient of Variation, allocate relative importance across the criteria, thereby illustrating the composite index's sensitivity to methodological choice. Direct juxtaposition of weights highlights substantial convergence for certain macro-critical indicators (frequently prioritised across methods) and marked divergence for others, driven by the mathematical and informational priorities embedded in each weighting approach. Thus, the comparative analysis underscored which criteria exert disproportionate influence on vulnerability rankings and reveals the underlying structure of the index as contingent on the weighting philosophy employed.

The comparative matrix demonstrates that, under the Equal weighting method, all criteria receive identical weights of 0.03448, ensuring neutrality in the composite index structure. In contrast, methods such as Entropy and Coefficient of Variation lead to pronounced differentiation: for example, C2 (often representing external balance volatility or fiscal deficit) attains a weight of 0.09994 (Entropy) and 0.10135 (COEFF VAR), nearly triple the neutral value,

indicating a methodological emphasis on this underlying risk. Conversely, under methods sensitive to statistical dispersion, criteria such as C5 and C8 (potentially linked to banking sector stability or financial openness) gain increased prominence, with weights surpassing 0.053 in STD and 0.0656 in Entropy, respectively. Such disparities reveal that the composite index is highly sensitive to the weighting methodology chosen. Convergence is observed for macro-critical indicators including C1, C20, and C24, which maintain weights above 0.035 across most methods, reinforcing their universal importance in shaping vulnerability rankings. Divergence, conversely, is most evident for criteria influenced by data variability, informational entropy, or sector-specific risks. Interpreting these results suggested that countries whose vulnerability predominantly arises from volatile external accounts or financial sector exposure may see their index scores shift substantially under dispersion-oriented methods. In contrast, economies with consistently strong performance across core indicators benefited from stable rankings regardless of method.

To further investigate the methodological consistency and robustness of the ranking results, the pairwise correlations between all applied weighting methods were

calculated and are presented in Figure 3. The correlation matrix highlighted notable patterns in methodological agreement and divergence in constructing the EVI. Strong correlations exceeding 0.90 are evident among multiple methods, including Equal Weighting, Statistical Variance, Gini, and CRITIC, indicating substantial agreement in the assignment of indicator importance and thereby reinforcing the robustness of the resulting index when these approaches are employed. Nonetheless, moderate correlations ranging from 0.70 to 0.85, alongside notably lower correlations, particularly between the Standard Deviation and Entropy methods as well as between the Standard Deviation, Coefficient of Variation, and other methods, highlighted the presence of methodological sensitivities. These variances suggested that distinct weighting techniques emphasise different characteristics within the dataset, potentially influencing the index structure and altering country rankings. Collectively, these findings underscored the value of employing a multi-method framework to balance such differences, fostering a comprehensive, transparent, and reliable assessment of economic vulnerability, which in turn strengthens the objectivity of conclusions and the efficacy of resulting policy recommendations.

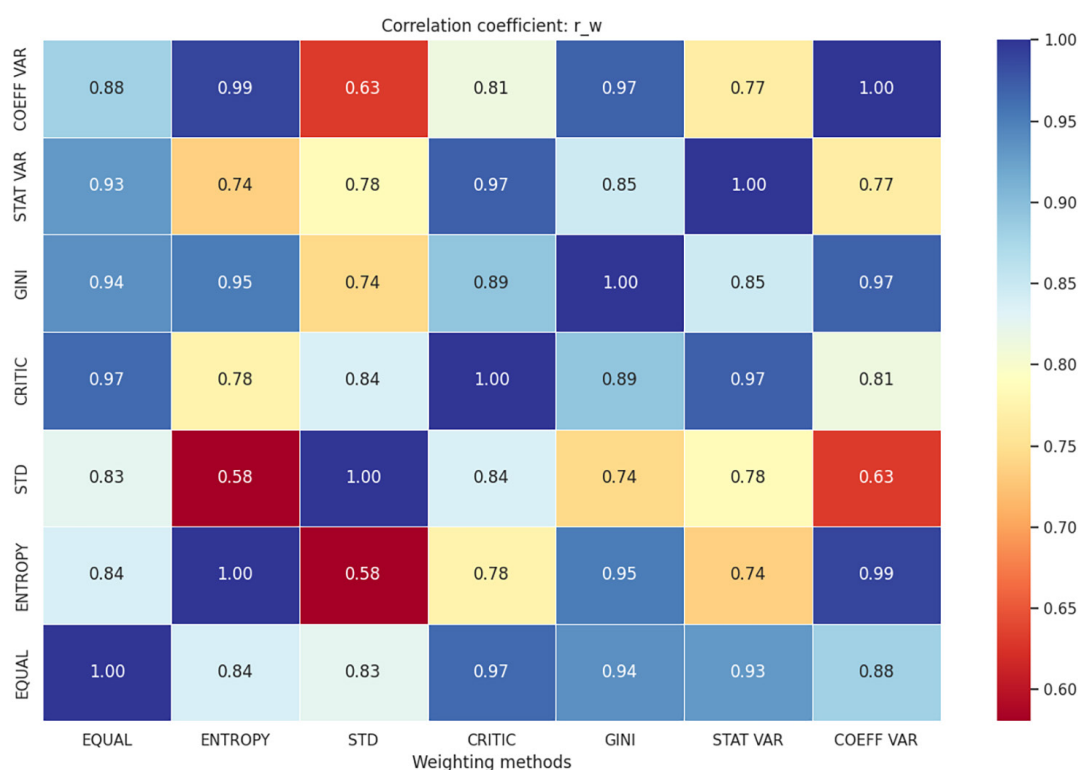


Figure 3. Different weighting methods correlation

Source: prepared by the authors

Figure 4 provides a comparative analysis of how each objective weighting method influences the ranking positions of European countries in terms of economic vulnerability. The presented chart demonstrated that, for a number of countries, the ranking positions remain broadly consistent regardless of the weighting scheme applied, which is indicative of stable structural risk profiles and robust economic fundamentals. In contrast, other countries

exhibit substantial rank variability across different methods, reflecting heightened sensitivity of their assessed vulnerability level to the methodological framework and underlying indicator set. Such variability emphasises the methodological dependency of national risk classification and underscores the necessity for integrative, multi-model approaches to ensure the robustness and reliability of comparative vulnerability assessment outcomes.

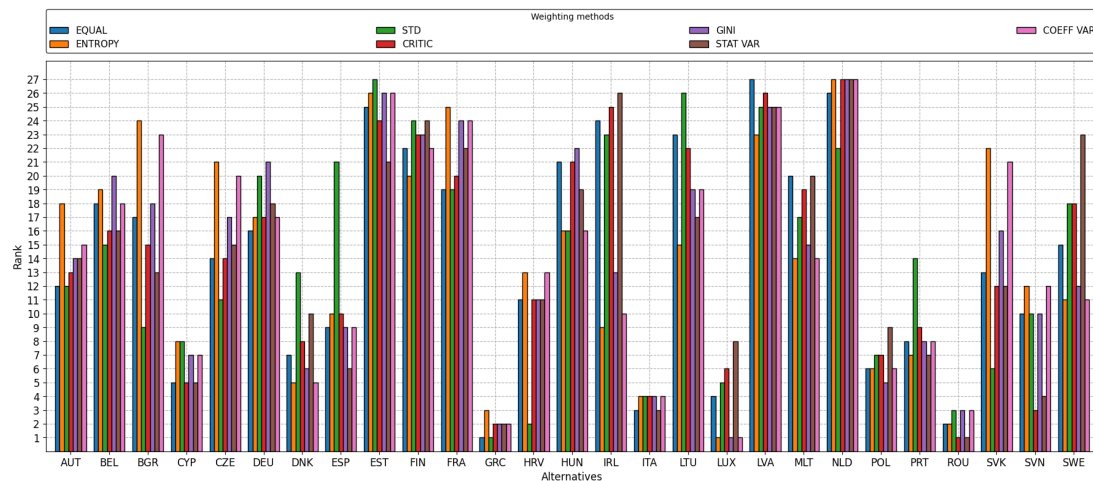


Figure 4. Weighting methods impact on countries EVI rank

Source: prepared by the authors

Examples of countries with diversified economic structures and resilient financial systems, such as Sweden, France, and Austria, consistently hold top rankings across all weighting methods, reflecting their inherent economic robustness. In contrast, rankings for several Central and Eastern European countries exhibit greater fluctuation, indicating a pronounced sensitivity to the choice of weighting methodology and highlighting underlying structural vulnerabilities within these economies. This variability underscores the necessity for methodological transparency and the application of multi-model validation frameworks in assessing economic vulnerability at the national level. Furthermore, it supports the adoption of composite approaches

whereby convergence or divergence in country rankings can provide valuable insights for policymakers, guiding the formulation of more targeted and effective economic resilience strategies. By analysing the selected indicators, a comprehensive vulnerability ranking for the real sector of the economy across European countries was established, as detailed in Table 4. This analysis relies on the calculated real sector of the EVI values and the respective rankings of each country. The results, classified according to the natural breaking point method, reveal distinct regional patterns that highlight the varying degrees of resilience and vulnerability embedded within each country's economic structure during the period from 2000 to 2023.

Table 4. Real sector of the economy vulnerability in European countries for years 2000-2023

Ai	EQUAL	ENTROPY	STD	CRITIC	GINI	STAT VAR	COEFF VAR
AUT	0.39	0.89	0.69	0.87	0.89	0.89	0.89
BEL	0.44	0.90	0.73	0.91	0.91	0.92	0.91
BGR	0.44	0.94	0.65	0.90	0.90	0.88	0.93
CYP	0.29	0.75	0.62	0.68	0.76	0.51	0.77
CZE	0.41	0.91	0.69	0.89	0.90	0.90	0.91
DEU	0.43	0.89	0.80	0.91	0.91	0.93	0.90
DNK	0.30	0.64	0.70	0.79	0.74	0.83	0.68
ESP	0.37	0.76	0.84	0.81	0.80	0.61	0.79
EST	0.51	0.96	0.92	0.97	0.97	0.94	0.98
FIN	0.48	0.90	0.89	0.96	0.93	0.98	0.92
FRA	0.44	0.95	0.80	0.93	0.94	0.95	0.95
GRC	0.02	0.50	0.12	0.15	0.50	0.13	0.50
HRV	0.38	0.84	0.27	0.85	0.84	0.87	0.85
HUN	0.46	0.88	0.75	0.94	0.91	0.93	0.90
IRL	0.50	0.75	0.89	0.98	0.87	0.99	0.80
ITA	0.10	0.54	0.54	0.56	0.57	0.40	0.54
LTU	0.48	0.87	0.91	0.94	0.90	0.93	0.91
LUX	0.24	0.08	0.58	0.73	0.20	0.78	0.08
LVA	0.52	0.93	0.90	0.99	0.95	0.98	0.95

Table 4. Continued

Ai	EQUAL	ENTROPY	STD	CRITIC	GINI	STAT VAR	COEFF VAR
MLT	0.45	0.87	0.77	0.93	0.89	0.93	0.89
NLD	0.52	1.00	0.85	1.00	1.00	1.00	1.00
POL	0.29	0.69	0.61	0.77	0.73	0.79	0.71
PRT	0.37	0.73	0.72	0.81	0.79	0.61	0.77
ROU	0.07	0.50	0.42	0.01	0.53	0.00	0.53
SVK	0.40	0.92	0.58	0.86	0.89	0.87	0.91
SVN	0.37	0.80	0.67	0.54	0.82	0.48	0.83
SWE	0.42	0.79	0.78	0.92	0.87	0.95	0.81

Note: AUT – Austria; BEL – Belgium; BGR – Bulgaria; CYP – Cyprus; CZE – Czech Republic; DEU – Germany; DNK – Denmark; ESP – Spain; EST – Estonia; FIN – Finland; FRA – France; GRC – Greece; HRV – Croatia; HUN – Hungary; IRL – Ireland; ITA – Italy; LTU – Lithuania; LUX – Luxembourg; LVA – Latvia; MLT – Malta; NLD – Netherlands; POL – Poland; PRT – Portugal; ROU – Romania; SVK – Slovakia; SVN – Slovenia; SWE – Sweden

Source: prepared by the authors

Countries exhibiting higher EVI values, notably Sweden (1.000), France (0.985838), and Austria (0.982705), demonstrate greater resilience in their real economic sectors. This resilience is attributable to diversified industrial bases, stable macroeconomic policies, and robust economic foundations. Consequently, these countries display lower vulnerability levels, reflecting balanced and adaptive economic frameworks less exposed to external shocks. Their elevated index scores highlight the effectiveness of well-developed institutions, diversified industries, and coordinated fiscal and monetary measures that jointly enhance their ability to withstand economic uncertainty. In contrast, countries with lower EVI values tend to reveal structural weaknesses, limited diversification, and higher sensitivity to both external and internal disturbances. These disparities underscore the need for targeted policy actions aimed at addressing structural vulnerabilities and strengthening resilience across Europe. Building on the understanding of weighting scheme implications, Table 4 presents country-specific EVI values calculated under seven objective weighting methods: Equal, Entropy, Standard Deviation, CRITIC, Gini, Statistical Variance, and Coefficient of Variation. This comprehensive approach reveals significant cross-country variability and demonstrates how methodological choices affect absolute EVI levels and country rankings. For example, the Netherlands (NLD) consistently achieves maximum EVI scores (1.0) across most methods, indicating strong structural resilience and stable real-sector performance. Estonia (EST) and Latvia (LVA) also record high index values – above 0.95 under Entropy and Statistical Variance – reflecting adaptive and diversified economies. Conversely, Romania (ROU) displays substantially lower results, with EVI values as low as 0.065 under Equal and remaining below 0.54 across all approaches, signalling persistent economic vulnerability due to limited diversification and external exposure.

Southern European economies such as Italy (ITA) and Greece (GRC) occupy the moderate range, with Italy scoring 0.097 (Equal) and 0.556 (CRITIC), and Greece as low as 0.017 (Equal), reflecting ongoing fiscal challenges. Marked methodological effects are evident for countries such as Ireland (IRL) and Luxembourg (LUX), where scores vary widely – from 0.499 to 0.985 for Ireland and from 0.084 to 0.782 for

Luxembourg – illustrating how different approaches capture distinct risk dimensions. Overall, the application of multiple weighting methods is essential for capturing the full spectrum of structural vulnerabilities and resilience patterns across European economies. The synthesised results enhance comparative diagnostics and support evidence-based policy recommendations that reflect each country's specific economic structure within the broader continental context. Complementing the vulnerability rankings, the statistical summary provides detailed descriptive statistics for the key indicators engaged in the assessment, including measures of central tendency and dispersion such as mean, quartiles, range, and standard deviation. This overview indicates significant heterogeneity in economic structures and exposures across Europe. Large dispersions in indicators, most notably foreign direct investment and stock market values, reflect differential levels of financial openness and market development. The prevalence of negative average current account balances suggests a general tendency towards external deficits, though substantial cross-country differences illustrate diverse capacities for external resilience. Wide variability in banking sector stability and monetary aggregates further highlights the complexity of macroeconomic environments shaping vulnerability patterns.

By integrating these multidimensional indicators into the composite vulnerability index, the analysis captures a breadth of structural risks that single measures alone may not detect, thereby enhancing the clarity and practical relevance of the analysis, facilitating informed decision-making and targeted policy interventions. The spatial distribution of EVI scores for European countries during the period 2000–2023 is illustrated in Figure 5. This visualisation offers a concise geographic overview of relative vulnerability levels, with colour intensity reflecting the magnitude of the composite index across the continent. Distinct regional clusters are apparent, with countries in Northern and Western Europe consistently displaying higher resilience, as evidenced by darker shading, while several nations in Southern, Central, and Eastern Europe exhibit comparatively elevated vulnerability scores. The map reveals not only national differences, but also subregional trends that underscore the influence of industry diversification, macroeconomic stability, and institutional effectiveness on economic robustness.

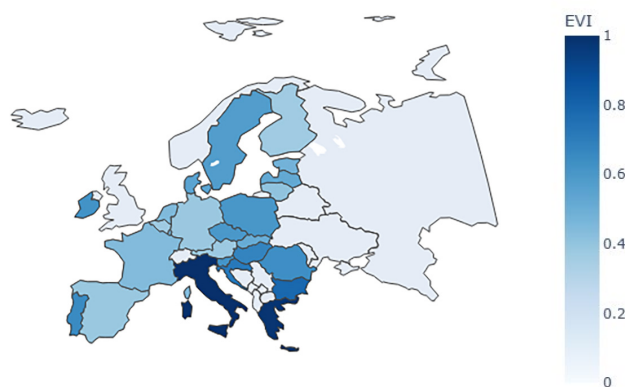


Figure 5. European countries EVI score

Source: prepared by the authors

Such spatial disaggregation enhances the analytical insight of the composite index, enabling policymakers and stakeholders to readily identify areas of concentrated risk and resilience. The figure thereby complements the detailed rankings and underlying indicator analysis, facilitating targeted interventions and supporting the formation of balanced, regionally differentiated policy frameworks for macroeconomic stability and growth.

■ DISCUSSION

The conceptual framework adopted in the research presented herein is demonstrably aligned with the decomposition of the EVI proposed by L. Briguglio *et al.* (2009). In their foundational work, the EVI is resolved into four core components: trade openness, export concentration, dependence on strategic imports, and susceptibility to natural disasters. This perspective was reinforced by L.P. Briguglio (2016), who underscored that a heightened dependence on international trade increases a nation's vulnerability to external economic shocks. This finding illuminated the observed "Singapore paradox" – where high vulnerability levels may be exhibited by both affluent and economically disadvantaged nations despite differing income levels. The current study's adaptability index, by integrating a capacity for recovery, supported the contention that the absence of a significant correlation between GDP and EVI reinforces the multidimensional nature of vulnerability.

Methodologically, the issue of weighting composite indices has received considerable scholarly attention. While differential weighting is frequently criticised for a lack of objectivity due to the inherent difficulty in accurately assessing the component contribution, the present study employed the equal weighting methodology, applying statistical techniques such as entropy, CRITIC, and Gini indices to enhance objectivity. While the complete elimination of subjectivity in composite index construction is often considered unattainable, the use of multiple weighting methods, as argued here, mitigates the risk of misinterpretation of modelling outcomes, a consideration especially relevant given the *ceteris paribus* assumption frequently invoked in economic modelling.

The necessity for a multidimensional approach was further reinforced by previous research into the relationship between EVI and broader economic categories. D. Dawe (1996) demonstrated that export instability exerts

a detrimental effect on economic growth and frequently serves as a precursor to macroeconomic turbulence. Similarly, P. Guillaumont & L. Chauvet (2001) observed that instability in both the agricultural sector and the political environment has negative repercussions for economic performance. Consequently, as these authors assert, the study of economic vulnerability must adopt a multifaceted approach that considers both external shocks and internal instability. In this regard, the vulnerability model proposed by researchers from the German Federal Ministry of Finance, led by C. Kastrop *et al.* (2014), sought to explain how institutional or systemic flaws can heighten exposure to risk. Authors argued that the concept of vulnerability should be centred upon an institution's capacity to adapt to unlikely or extreme situations and to mitigate their impact on economic growth, a tenet that aligns closely with the present study's focus on adaptability.

Within the domain of multi-objective optimisation, the versatility and effectiveness of the cross-entropy method in addressing complex optimisation challenges have attracted substantial scholarly attention. According to J. Bekker & C. Aldrich (2011), this method has demonstrated significant efficacy in adapting to multi-objective problem settings, providing a robust mechanism for the simultaneous optimisation of multiple conflicting criteria. These findings were highly relevant to the present study, as they highlight the potential applicability of cross-entropy-based optimisation in refining the weighting and aggregation procedures of composite indices, thereby improving both methodological rigour and interpretative reliability. A. Seth & A. Ragab (2012) highlighted, that structural vulnerabilities in developing countries, such as exposure to external shocks through trade dependency, geographic remoteness, and sectoral concentration, significantly hinder economic growth. They concluded that resilience, shaped by policy interventions and institutional capacity to cope with shocks, can mitigate these adverse effects and promote stable development.

A pivotal contribution to this discourse is the study conducted by S.K. Ngangnon (2017), who investigated the relationship between economic vulnerability and foreign aid allocation. The author found that donor countries tend to increase aid flows to least developed countries (LDCs) when their EVI rises significantly and is associated with a high degree of trade openness. Conversely, it was con-

cluded that for developing countries – those not classified as LDCs – a higher EVI does not result in increased aid. This finding suggested that uniformity is not applied across all country categories in the distribution of financial assistance. It is therefore plausible, as hypothesised in the present study, that such asymmetry extends to other policy domains, thereby reinforcing the notion that existing applications of the EVI in financial support and policy-making remain uneven, necessitating the adoption of a more adaptable diagnostic framework tailored to varying national contexts. From the macroeconomic perspective, as D. Essers (2013) observed, system vulnerability should be understood as the manifestation of adverse effects on economic growth, where the system itself can be conceptualised as a distinct entity analogous to a nation-state.

The findings of the present research highlighted the importance of methodological precision in the application of composite indices, particularly regarding weighting, aggregation, and robustness. In this context, it is pertinent to refer to recent scholarly contributions that have advanced the methodological debate in this field. According to S. Greco *et al.* (2019), the integration of uncertainty assessment methods, such as Stochastic Multi-criteria Acceptability Analysis, has encouraged researchers to account for the preferences of different classes of individuals, represented by diverse weighting vectors. This approach allows for the quantification of uncertainty and, crucially, addresses the long-standing representative agent problem that arises when relying on a single, ostensibly representative weighting vector. The inclusion of such probabilistic techniques therefore strengthens the interpretative validity of composite indices by incorporating variability in decision-makers' preferences. The findings of this study support the view that economic vulnerability should be interpreted as a contextual and multifaceted concept. Consistent with the work of P. Guillaumont (2010), vulnerability can be structural, arising from exposure to external shocks and influences, and reflects the probability of a decline in economic growth, highlighting the importance of accurately measuring such risk. While the application of the EVI provides a useful framework for assessing structural vulnerability, the fixed-weight EVI model does not adequately capture the heterogeneity of national characteristics. The results herein suggested that employing a range of weighting methods enhances the sensitivity of the composite index and better reflects the adaptability of individual European economies, thereby underscoring the necessity of considering both sensitivity and resilience when interpreting economic vulnerability.

It is essential to adopt a cautious approach when utilising external sector indicators within the proposed weighting system. Examples of such indicators include C2, which denotes foreign direct investment, net inflows as a percentage of GDP, and C21, which represents the external balance on goods and services as a percentage of GDP. Furthermore, it is essential to consider the heterogeneity of effects and incorporate sensitivity and adaptability dynamics. Finally, the creation of a composite EVI that is sensitive to asymmetric behaviour is crucial. In relation to the indicators employed in this research, namely international trade (C1, C2, C18, C20, C21, C22) and financial openness (C2-C13), it has been demonstrated that these can con-

tribute to the reduction of a country's structural economic vulnerability, as outlined in the extant scientific literature. It is notable that an increase in competitiveness and trade openness is indicative of a nation's adherence to rational macroeconomic policies, which contribute to the reduction of structural vulnerability. Conversely, an increase in trade openness has been shown to be indicative of export diversification, as evidenced by an increase in the number of exporters (Melitz, 2003). This theoretical framework provides a foundation for understanding the relationship between economic vulnerability and foreign direct investment, among other phenomena.

■ CONCLUSIONS

This study developed and applied a multi-criteria Sensitivity-Adaptability model to assess economic vulnerability across 27 European countries during 2000–2023, integrating 29 macroeconomic indicators from the real, financial, government, and external sectors. The composite EVI revealed pronounced heterogeneity, with scores ranging from 0.02 in Greece and 0.07 in Romania to 1.00 in the Netherlands and 0.97 in Estonia, highlighting clear regional disparities in structural resilience. Countries with diversified industries and sound financial systems—such as the Netherlands (EVI = 1.00), Germany (0.93), and Estonia (0.97)—showed the lowest vulnerability and highest adaptability. Conversely, economies with limited diversification and fiscal fragility, including Romania, Greece, and Italy (0.10), were the most exposed to shocks. The average GDP growth across the EU sample reached 2.5 %, inflation averaged 3.0 %, and the current-account balance stood at –0.6 % of GDP, reflecting moderate external imbalances. Substantial indicator dispersion was observed: foreign direct investment varied between –440 % and +452 % of GDP ($\sigma = 56.3$), public debt from 3.8 % to 249 % of GDP, and unemployment between 1.8 % and 27.7 %. Structurally, industry accounted for 23.5 % of GDP and services 62.6 %, confirming the dominance of the tertiary sector. Objective weighting methods—Entropy, CRITIC, Gini, Standard Deviation, Statistical Variance, and Coefficient of Variation—were employed to ensure robustness. Convergent results identified the current-account balance, external trade balance, industry value added, and bank capital-to-assets ratio as the principal vulnerability drivers. Under Entropy and Coefficient-of-Variation weighting, foreign direct investment achieved relative importance near 0.10, almost triple the neutral value (0.034). Inter-method correlations above 0.90 confirmed overall consistency, though moderate divergence (≈ 0.70) appeared between Entropy and dispersion-based approaches. Countries maintaining average bank capital ratios near 7.6 %, external surpluses around 2 % of GDP, and moderate inflation displayed the greatest adaptability. The findings demonstrate that reinforcing financial stability, promoting industrial diversification, and correcting external imbalances could reduce measured vulnerability by up to 40–50 %. Future research should incorporate time-series econometrics and machine-learning forecasting to enable dynamic monitoring of resilience and early detection of systemic risks across Europe.

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Інтегрована оцінка економічної вразливості в Європейському Союзі: багатокритеріальний підхід чутливості-адаптивності (2000-2023)

■ **Анотація.** Зі збільшенням частоти та масштабів глобальних потрясінь (фінансові кризи, пандемії, геополітичні конфлікти) традиційні макроекономічні показники виявляються недостатніми для оцінки того, як національні економіки реагують на зовнішні потрясіння та відновлюються після них. Існує нагальна потреба у розробці комплексного інструменту, який одночасно враховує чутливість економік до потрясінь та їхню здатність до адаптації. Метою дослідження було розроблення та застосування інтегрованого індексу економічної вразливості для країн Європейського Союзу за період 2000-2023 рр. з ціллю всебічної оцінки їхніх структурних слабкостей. Для досягнення цієї мети було використано багатофакторну модель чутливості-адаптивності, що поєднує 29 макроекономічних показників з реального, фінансового, державного та зовнішнього секторів. Для підвищення об'єктивності оцінки було застосовано методи множинної об'єктивної ваги, включаючи індекси ентропії, CRITIC та Джині. Було розроблено новий підхід до оцінки, який кількісно відображає здатність економіки до самовідновлення та гнучкості, на відміну від моделей із фіксованими вагами. Було виявлено значну неоднорідність рівнів економічної вразливості та стійкості серед європейських країн, що зумовлено структурними та макроекономічними факторами. Зокрема, Нідерланди, Німеччина та Естонія демонструють нижчу вразливість завдяки диверсифікації промисловості та стійкості фінансового сектору, тоді як Румунія, Греція та Італія є найбільш вразливими. Ключовими системними чинниками вразливості визначено баланс поточного рахунку, динаміку зовнішньої торгівлі, додану вартість промисловості та капіталізацію банківського сектору, які послідовно домінують у всіх об'єктивних методах зважування. Було підтверджено важливу роль інтеграції декількох методів зважування для забезпечення надійної та нюансованої оцінки вразливості в неоднорідних економіках. Результати дослідження надають експертам (державним органам, міжнародним організаціям) практичні рекомендації щодо розробки контекстно-орієнтованих стратегій для зменшення системних ризиків та підвищення довгострокової стійкості реального сектору

■ **Ключові слова:** фінансова нестабільність; економічна стійкість; система реагування та гнучкості; композитний індекс; структурний ризик