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Vadym PAKHOLCHUK
Ph.D., senior lecture department of financial support of troops
Military institute Taras Shevchenko National University of Kyiv,
Kyiv, Ukraine
ORCID ID: 0000-0002-9657-6148
Scopus Author ID: 58677885400
e-mail: vadym_pakholchuk@knu.ua

ASSESSMENT OF VULNERABILITIES IN THE REAL SECTOR OF EUROPEAN ECONOMIES

Анотація. *Оцінка економічної вразливості є ключовим інструментом для аналізу стабільності та стійкості реального сектору економіки держав, особливо в умовах глобальних економічних трансформацій та зовнішніх шоків. У статті розглянуто підхід до оцінювання економічної вразливості реального сектору економіки європейських країн із урахуванням таких чинників, як промисловий розвиток, макроекономічні показники та рівень зайнятості населення. Запропоновано комплексну методологію, що поєднує метод ентропійної ваги (EWM) для визначення значущості індикаторів із системою чутливості та адаптивності для вимірювання економічної вразливості. У дослідженні проаналізовано основні макроекономічні індикатори, зокрема темпи зростання ВВП, рівень інфляції, безробіття та заощаджень. Для оцінювання структурної вразливості реального сектору використано статистичні дані за період 2000–2023 років, а також розроблено Індекс вразливості реального сектору економіки на основі даних Світового банку. Результати дослідження свідчать про значні регіональні відмінності: країни Північної та Західної Європи характеризуються нижчим рівнем вразливості завдяки збалансованій промисловій структурі та ефективній економічній політиці, тоді як країни Східної та Південної Європи демонструють вищу чутливість до економічних шоків, що зумовлено наявністю структурних диспропорцій. Методологія дослідження базується на інструментах економетричного моделювання з використанням програмного середовища Python, що дозволило здійснити аналіз динамічних взаємозв'язків між макроекономічними показниками. Отримані результати засвідчують, що країни з диверсифікованою економічною базою мають вищу стійкість, тоді як економіки з обмеженою промисловою диверсифікацією залишаються більш уразливими до зовнішніх ризиків. Запропонований підхід поглиблює методологічні засади оцінювання економічної вразливості та формує основу для обґрунтування політичних рішень, спрямованих на зміцнення стійкості реального сектору в умовах економічної нестабільності. Представлені висновки мають важливе значення для розроблення стратегій сталого економічного розвитку в регіонах Європи.*

Ключові слова: *вразливість економіки, європейські країни, реальний сектор, метод ентропійного зважування.*

JEL Classification: O40; O 47; O 11, C10

Absztrakt. *A gazdasági sebezhetőség értékelése kulcsfontosságú eszköz az államok reálszektorának stabilitásának és ellenállóképességének elemzésére, különösen a globális gazdasági*

átalakulások és külső sokkok idején. A tanulmány olyan megközelítést mutat be, amely az európai országok reálszektorának gazdasági sebezhetőségét értékeli az ipari fejlettség, a makrogazdasági mutatók és a foglalkoztatási szint figyelembevételével. Egy átfogó módszertan került kidolgozásra, amely ötvözi az entrópiasúlyozási módszert (EWM) a mutatók jelentőségének meghatározására, valamint az érzékenységi és alkalmazkodási rendszerrel a gazdasági sebezhetőség mérésére. A kutatás során a főbb makrogazdasági indikátorokat – például a GDP-növekedést, inflációt, munkanélküliséget és megtakarításokat – elemezték. A reálszektor strukturális sebezhetőségének értékeléséhez a 2000–2023 közötti időszak statisztikai adatai, valamint a Világbank adataira épülő Reálszektor Sebezhetőségi Index került alkalmazásra. Az eredmények jelentős regionális eltéréseket mutatnak: Észak- és Nyugat-Európa országai alacsonyabb sebezhetőséget mutatnak a kiegyensúlyozott ipari struktúrának és hatékony gazdaságpolitikának köszönhetően, míg Kelet- és Dél-Európa országai nagyobb érzékenységet mutatnak a gazdasági sokkokkal szemben, ami a szerkezeti aránytalanságokra vezethető vissza. A kutatás módszertana ökonometriai modellezési eszközökre épül Python programkörnyezet alkalmazásával, amely lehetővé tette a makrogazdasági változók közötti dinamikus kapcsolatok elemzését. Az eredmények azt mutatják, hogy a diverzifikált gazdasági bázissal rendelkező országok nagyobb ellenállóképességgel bírnak, míg a korlátozott ipari diverzifikációval rendelkező gazdaságok továbbra is sebezhetőbbek maradnak a külső kockázatokkal szemben. Az ismertetett megközelítés elmélyíti a gazdasági sebezhetőség értékelésének módszertani alapjait, és alapot teremt olyan politikai döntések megalapozásához, amelyek a reálszektor ellenállóképességének növelését célozzák gazdasági instabilitás esetén. A levont következtetések különösen fontosak az európai régiók fenntartható gazdasági fejlődési stratégiáinak kidolgozása szempontjából.

Kulcsszavak: *gazdasági sebezhetőség, európai országok, reálszektor, entrópiasúlyozás módszere.*

Abstract. *The assessment of economic vulnerability is a key tool for analyzing the stability and resilience of the real sector of national economies, particularly in the context of global economic transformations and external shocks. This article proposes an approach to evaluating the economic vulnerability of the real sector in European countries, taking into account factors such as industrial development, macroeconomic indicators, and employment levels. A comprehensive methodology is introduced, combining the Entropy Weight Method (EWM) to determine indicator significance with a sensitivity and adaptability framework for measuring economic vulnerability. The study analyzes major macroeconomic indicators, including GDP growth rates, inflation, unemployment, and savings levels. Structural vulnerability of the real sector is assessed using statistical data from 2000 to 2023, and a Real Sector Vulnerability Index is developed based on data from the World Bank's economic development indicators. The findings reveal significant regional disparities: countries in Northern and Western Europe exhibit lower levels of vulnerability due to balanced industrial structures and effective economic policies, while countries in Eastern and Southern Europe display greater sensitivity to economic shocks, reflecting structural imbalances. The methodology is based on econometric modeling tools and utilizes Python-based data analysis packages to explore dynamic relationships between macroeconomic variables over time. The results indicate that countries with diversified economic bases tend to demonstrate higher resilience, whereas economies with limited industrial diversification remain more susceptible to external risks. The proposed approach enhances the methodological foundation for evaluating economic vulnerability and provides a basis for informed policy decisions aimed at strengthening the resilience of the real sector under conditions of economic instability. The insights gained are of critical importance for policymakers in identifying and mitigating risk factors, thereby contributing to sustainable economic development across European regions.*

Keywords: *economic vulnerability, European countries, real sector, entropy weighted method.*

Problem statement. The real economy is of critical importance in ensuring the economic stability and resilience of European countries, serving as the foundation of industrial production, agriculture, infrastructure, and services. This sector exerts a direct influence on employment rates, income levels, and overall economic growth, making it essential for long-term sustainability. However, the contemporary economic environment presents numerous challenges that threaten the stability of the real economy. Economic globalisation has increased competition and interconnectedness, rendering European industries more vulnerable to external shocks. Volatile international markets, fluctuating commodity prices, and disruptions in global supply chains further exacerbate these risks. Additionally, unforeseen crises such as the COVD-19 pandemic and ongoing military conflicts have exposed significant weaknesses in production, trade, and financial systems. Another pressing concern is energy security, as heavy reliance on energy imports creates economic vulnerabilities, leading to price instability and supply shortages. These factors contribute to instability in the real sector, triggering serious macroeconomic consequences such as inflation, rising unemployment, and declining living standards. Conducting thorough research into the vulnerabilities of the real economy has therefore become increasingly relevant. The identification of these weaknesses and the understanding of their impact is a crucial step in the development of effective economic policies that enhance resilience, ensure sustainable development, and promote long-term economic stability in Europe.

Analysis of recent research and publications. Economic vulnerability is defined as an economy's exposure to exogenous shocks arising from economic openness, while economic resilience refers to the policy-induced ability to withstand or recover from such shocks (Briguglio et al. [1]; Cordina et al. [2]). The Economic Vulnerability Index (EVI) has been used since 2000 as a criterion for identifying least developed countries, alongside GDP per capita and human capital measures (Cariolle et al. [3]). Research has focused on developing frameworks for measuring economic resilience, proposing an index that gauges policy adequacy in areas such as macroeconomic stability, microeconomic market efficiency, good governance, and social development (Briguglio et al. [1]; Cordina et al. [2]). Interestingly, some vulnerable economies exhibit high per capita output levels, which can be explained by a neo-classical growth model incorporating vulnerability. This model suggests that more vulnerable economies tend to have higher per capita capital stock and output but lower per capita consumption, as resources are allocated to counteract vulnerability (Cordina et al. [2]). We also could not deny the importance of the lack of economic progress as driving factor to potential stagnation (Guillaumont [4]). A lot of attention to this question was after crises or recessions in different countries (Béné [5]; Whelan & Maître [6]). There are different approaches to measure the economic vulnerability: starting from econometric modeling and ending with complex integral indicators (Wang [7]; Cariolle et. al. [3]; Altimari [8]). But some of the most recent researchers primary focus on regional or even economic structure differences and peculiarities influence on economy vulnerability (Blancard et al. [9]; Meinen et al. [10]; Akter & Grafton [11]; Ünlü et al. [12]; Liu [13]; Gnangnon

[14]). This work highlights new dimensions of the classical composite indicator approach enhanced with innovative self-optimized method for subset of European countries.

This study highlights previously unresolved parts of the problem for example, despite significant progress in researching the vulnerabilities of the real sector of the economy, the issues of integrating the results of these studies for a comprehensive assessment of economic resilience remain insufficiently studied. New risk factors and market conditions affecting the real sector need to be taken into account and require additional research to determine effective management mechanisms.

Research aim and objectives. This article aims to analyse the existing and potential vulnerabilities of the real sector of the economy of European countries in order to develop recommendations to reduce their impact on economic stability, increase the resilience of the real sector industries to external shocks and ensure effective management in the face of current risks.

Methods and methodology. The research employs a comprehensive methodology, integrating the entropy weight method (EWM) for indicator weighting with a sensitivity-adaptability framework for measuring economic vulnerability. The analysis includes key economic indicators such as GDP growth rate, inflation, unemployment, and savings rates, which are examined across a range of European countries. The study employs statistical data from 2000 to 2023 to evaluate the structural vulnerabilities of the real sector of the economy. This is achieved through the Real Sector of the Economy Vulnerability Index, which is calculated using data from sources such as the World Bank.

All computations were conducted with python programming language. Specifically, “pyrepo-mcda” package was used in this research development. The VIKOR compromise ranking method from “pyrepo-mcda” was used in order to rank all countries according to the computed metrics It gives an opportunity to natively apply different multi-criteria methods for decision process. The data was obtained with “wbgapi” package, which is basically a convenient python interface for World Bank Database. Application of qualitative methods, ensuring a comprehensive understanding of the research problem.

Results and discussions. The problems of economic vulnerability and resilience have always been of concern to scientists and practitioners. However, despite a number of published articles, it is necessary to take into account the changing dynamics of the global economy and the emergence of new, previously unknown threats and assess their impact on the economic vulnerability of states.

Bussière and Mulder [15] examine and assess the role of political instability in heightening economic vulnerability, focusing particularly on the crises of 1994 and 1997. They conclude that political instability significantly exacerbates economic vulnerability, especially in nations with weak economic structures and minimal reserves. Incorporating political factors into economic models enhances their capacity to explain and predict economic crises. Economies are shown to be more susceptible to economic instability during election cycles and in the aftermath, particularly when election outcomes are uncertain.

Briguglio et. al. [16] investigates the relationship between conventional theories of economic growth and economic vulnerability. The author demonstrates that vulnerability, defined as inherent susceptibility to external shocks, has notable effects on both per capita income levels and overall economic growth. The model presented assumes a balance of adverse and beneficial shocks; however, because production and utility functions adhere to diminishing marginal returns, as per traditional economic theory, negative shocks tend to have a more substantial impact than positive ones. Cordina [2] suggests that while economic vulnerability may lead to increase per capita output, it also results in lower levels of consumption, as economies allocate resources toward building resilience to counteract the adverse effects of external shocks. These findings, the author argues, may provide insights into resolving the "Singapore paradox".

Economic vulnerability refers to the probability that a country's economic progress will be disrupted by unexpected external events, often termed exogenous shocks (Guillaumont [4]). Interest in the economic vulnerability of developing countries has surged since the 1990s, as the global economic crises of that era underscored their susceptibility to shifts in international markets. In 2000, the economic vulnerability index (EVI) was introduced as an additional criterion alongside GDP per capita and human capital (measured by the Human Asset Index) for identifying least developed countries (LDCs). Since then, the EVI has undergone revisions, particularly in 2006 and 2009, as recommended by the United Nations Committee for Development Policy (UNCDP) for LDC classification.

Béné [5] develops an index for economic vulnerability and applies it, along with a poverty measure, to examine vulnerability and chronic poverty in remote rural communities engaged in fishing and farming in Congo. His findings indicate that full-time fishers are particularly vulnerable economically, that mobility heightens this vulnerability, and that households may remain highly vulnerable even when their incomes exceed the local average.

It is important to mention work of Wang [7], when he critically evaluated the construction of the Economic Vulnerability Index (EVI) employed by the United Nations, explored its link to economic volatility, and recommended adjustments to both the aggregation weights and the variables incorporated in the index.

But idea of EVI evolved, and Cariolle et. al. [3] assessed the impact of methodological updates to the Economic Vulnerability Index (EVI), which the United Nations uses to identify Least Developed Countries (LDCs). He explored how these revisions have affected evaluations of structural economic vulnerability over time and created retrospective EVI series based on standardized definitions to more accurately capture real changes in vulnerability.

Whelan and Maître [6] analyzed how the Great Recession in Ireland influenced economic vulnerability across social classes. They found that, while economic vulnerability doubled following the recession, the polarization between vulnerable and non-vulnerable groups lessened. Notably, middle-class groups experienced heightened vulnerability, often referred to as a "middle-class squeeze", as their relative risk increased.

Their analysis revealed a doubling of economic vulnerability post-recession, alongside a marked reduction in polarization between vulnerable and non-vulnerable classes. Economic vulnerability was heavily segmented by social class; however, certain groups, including the higher salariat, non-agricultural self-employed, semi-unskilled manual workers, and those who had never been employed, showed relative improvements, underscoring the "middle-class squeeze". The effect of household work intensity on economic vulnerability decreased significantly, while it began to play a larger role in influencing outcomes for non-agricultural middle-class groups.

Briguglio [1] revises and expands the indices for economic vulnerability and resilience, presenting an updated framework to evaluate a country's risk of harm from external economic shocks. Findings suggest that highly vulnerable countries, including some successful small island states, often exhibit high resilience scores, indicating the implementation of policies aimed at mitigating external shocks. Conversely, some larger, poorer developing countries demonstrate low economic resilience, despite limited exposure to external shocks due to restricted trade activities. The study emphasizes that highly vulnerable economies can still achieve economic stability and growth if they adopt resilience-focused policies in governance across economic, political, social, and environmental areas.

Enhancement to the Economic Vulnerability Index (EVI) was proposed by Altimari et al. [8]. He suggested integrating resilience-related variables, reflecting a country's capacity to recover from external shocks. Using a Structural Equation Modeling (SEM) approach, this study offers an alternative to the EVI's traditional weighted-average method, which relies on set weights. The research evaluates the effectiveness of both the weighted-average EVI and the SEM-based model in explaining real GDP per capita growth over 19 years across 98 countries.

Some interesting insights was revealed by Blancard et al. [9] examining the economic vulnerabilities faced by small island regions, which are compounded by various structural disadvantages. Traditional literature has highlighted the critical role of agriculture in creating structural vulnerability, suggesting that economies with a high dependence on agriculture are more vulnerable. However, recent food crises suggest that vulnerability stems not solely from agricultural dependence but also from the efficiency of the sector and the orientation toward diversified and self-sufficient domestic production. This paper proposes a new indicator of structural economic vulnerability, based on the premise that promoting local agriculture could drive development. The authors incorporate the agriculture sector's share of GDP, represented by dependence on imported food, into the standard economic vulnerability index. For robustness, the indicator uses an endogenous weighting system derived from data envelopment analysis. Simulations across 131 developing economies indicate that considering food dependency significantly reduces the structural vulnerability of small island economies.

The COVID-19 pandemic has also highlighted the fragility of economic systems and the individuals within them, bringing to the fore new dimensions of vulnerability linked to health crises. Small firms have shown heightened vulnerability during the pandemic due to financial constraints and disproportionate impacts compared to larger

enterprises. Meinen et al. [10] argue that the sectoral structure of economies played a key role in determining both exposure and resilience during this period, thereby setting the groundwork for understanding economic vulnerability in the context of global health emergencies.

In synthesizing these discussions, it becomes apparent that both economic vulnerability and resilience are grounded in a variety of interconnected social, political, and economic factors. Effective policy must navigate these complexities, fostering environments that both anticipate potential shocks and strengthen capacities for recovery. As highlighted by Akter and Grafton [11], understanding socio-economic characteristics and their influence on hazard exposure can inform more equitable disaster risk reduction policies.

A notable dimension of economic vulnerability lies in its relationship to socioeconomic status, particularly among marginalized groups. For instance, studies have revealed that older adults, specifically those aged 75 years and older, are particularly susceptible to economic abuse, which compounds their vulnerability in times of economic downturn (Ünlü et al. [12]).

In terms of resilience, the capacity for recovery from economic shocks varies significantly across regions, often influenced by underlying societal structures. Liu discusses urban resilience in the context of Chinese cities, highlighting essential determinants such as economic diversity, governance quality, and social cohesion as vital for recovery post-crisis (Liu [13]).

One of the recent researches in this topic Gnangnon [14] investigates the impact of export product concentration on poverty volatility in 120 developing countries from 1980 to 2014. Using a feasible generalized least squares estimator, the study finds that export product concentration increases poverty volatility in low-income countries but reduces it in relatively more advanced developing nations. This effect is attributed to improved manufacturing export performance, which helps mitigate poverty fluctuations. Furthermore, the results suggest that greater export product diversification (or economic complexity) enhances poverty volatility reduction.

Summarizing many of the approaches discussed in the review of existing studies, this article will focus on the structural vulnerabilities of the real economy. For this purpose, a composite indicator will be used, which will include several indicators (Table 1). To assess the state of the real economy from 2000 to 2023, the following indicators were chosen: annual inflation, consumer spending as a percentage of the previous year, capital expenditures as a percentage of GDP, industrial production value added as a percentage of GDP, services as a percentage of GDP, GDP growth rate, GDP per capita, savings in the economy, and unemployment. The choice of indicators in this case is not random, but reflects compliance with the principles of scientific justification and the possibilities for using such a system of indicators. The statistical data for the calculations were taken from the World Bank's World Development Indicators database.

Table 1 presents a comprehensive overview of several economic indicators, used in this ressearch. The annual inflation rate averages 2.9%, with moderate variability, ranging from -4.4% to 45.7% (std = 3.7). Final consumption expenditure shows an average annual growth rate of 2.2%, spanning from -14.3% to 15.6% with a standard

deviation of 3.3. Gross fixed capital formation represents 22.3% of GDP on average, ranging between 10.7% and 54.3%, also with moderate variability (std = 4.2). Industry value added, including construction, accounts for 23.7% of GDP on average, fluctuating between 10.0% and 41.5% and showing a wider dispersion (std = 5.7). Services contribute the largest share to GDP, averaging 62.4%, with values from 42.3% to 80.4% and a standard deviation of 6.5. GDP growth rates show an average of 2.5% annually, with considerable variability ranging from -14.8% to 24.5% (std = 3.9). GDP per capita exhibits significant variability, with a mean of $30,317.1, ranging widely from $1,621.3 to $133,711.8 (std = 22,203.5). Gross savings make up 22.4% of GDP on average, with a range from 4.7% to 37.2% and a standard deviation of 5.4. Finally, the unemployment rate averages 8.5%, spanning from 1.8% to 27.7%, with moderate variability (std = 4.3). Overall, the data reflect a blend of stability in certain areas, such as gross fixed capital formation, alongside higher volatility in indicators like GDP per capita and GDP growth.

Table 1.

Statistical description of indicators

index	count	mean	min	25%	50%	75%	max	std
Inflation, consumer prices (annual %)	621	2,9	-4,4	1,1	2,2	3,4	45,7	3,7
Final consumption expenditure (annual % growth)	621	2,2	-14,3	0,9	2,2	3,8	15,6	3,3
Gross fixed capital formation (% of GDP)	621	22,3	10,7	19,9	21,9	24,3	54,3	4,2
Industry (including construction), value added (% of GDP)	621	23,7	10,0	20,0	23,9	27,4	41,5	5,7
Services, value added (% of GDP)	621	62,4	42,3	57,3	62,1	66,4	80,4	6,5
GDP growth (annual %)	621	2,5	-14,8	1,0	2,7	4,5	24,5	3,9
GDP per capita (current US$)	621	30317,1	1621,3	14422,9	24345,9	43068,5	133711,8	22203,5
Gross savings (% of GDP)	621	22,4	4,7	18,5	22,7	26,4	37,2	5,4
Unemployment, total (% of total labor force) (national estimate)	621	8,5	1,8	5,6	7,4	10,2	27,7	4,3

Source *own editing based on [17]*

The vulnerability of an economic system is assessed through a "sensitivity-adaptability" function. The formula for calculating vulnerability is presented as follows:

$$Vulnerability = Sensitivity - Adaptability \quad (1)$$

In this context, V, S, A represent the 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:

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

where F_i is the value of index j in the year i; $\bar{F}$ is the average value of index j from 2000 to 2023. $Sensitivity_j$ is 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.

This article will synthesise the findings of the review of existing studies, focusing on the structural vulnerabilities of the real economy. In order to achieve this, a composite indicator will be employed, comprising a number of individual indicators (see Table 1). In order to assess the state of the real economy, a number of indicators were selected for analysis. These include annual inflation, consumer spending as a percentage of the previous year, capital expenditures as a percentage of GDP, industrial production value added as a percentage of GDP, services as a percentage of GDP, GDP growth rate, GDP per capita, savings in the economy, and unemployment. The selection of indicators is not arbitrary; rather, it is based on the principles of scientific justification and the feasibility of employing such a system of indicators. The statistical data for the calculations were obtained from the World Bank's World Development Indicators database.

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

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

The variable Aj represents the trend in the variability of the dependent variable j, specifically reflecting its adaptability. The variable x denotes the ordinal time period, spanning from 2000 to 2023, while B captures the intercept. The objective variable, denoted by yj, 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 standardize these results separately before calculating vulnerability. This step ensures comparability and facilitates the analysis of regional differences in vulnerability.

The Entropy Weight Method (EWM) is a widely recognized 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, EWM is 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 employs 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 standardization. The positive and negative standardized formulas are as follows:

$$x'_{ij}(+) = \frac{x_{ij} - \min(x_j)}{\max(x_{ij}) - \min(x_{ij})} \quad (5)$$

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

y_{ij} is generated by:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_{ij}) - \min(x_{ij})} \quad (7)$$

In EWM, e_j - the entropy, is defined as

$$e_j = -\frac{\sum_{i=1}^{n} y_{ij} \ln(y_{ij})}{\ln(n)} \quad (8)$$

Necessary to mention that $y_{ij} = 0 => y_{ij} \times \ln(y_{ij}) = 0$

E_j lies in the $[0,1]$ domain. In EWM the weight w_j is calculated as

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m} 1 - e_j} \quad (9)$$

Comprehensive score calculation is as follows:

$$Score = \sum_{j=1}^{m} w_j y_{ij} \quad (10)$$

By analyzing the indicators, we obtained a detailed vulnerability ranking for the real sector of the economy across various European countries (Table 2). This analysis is based on the calculated Real Sector of the Economy Vulnerability Index values (referred to as “Vulnerability Index”) and the respective rankings of each country. The results, classified according to a natural breaking point method, reveal distinct regional patterns, shedding light on the resilience and vulnerabilities inherent in each country’s economic structure.

The countries with higher Vulnerability Index values, such as Sweden (1.000), France (0.985838), and Austria (0.982705), demonstrate a more resilient real sector, which likely benefits from diversified industrial bases, stable macroeconomic policies, and robust economic foundations. Consequently, these countries rank lower in terms of vulnerability, indicating a more balanced and adaptive economic structure that is less susceptible to external shocks. These nations' high scores reflect well-developed frameworks for maintaining economic stability and adaptability through diversified industry and well-coordinated fiscal policies, enhancing their capacity to weather economic uncertainties.

Table 2.

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

ISO	Pref	Rank	ISO	Pref	Rank
SWE	1.000000	27	**MLT**	0.857509	13
FRA	0.985838	26	**LTU**	0.852588	12
AUT	0.982705	25	**LUX**	0.835249	11
BEL	0.980605	24	**SVK**	0.825233	10
NLD	0.973644	23	**PRT**	0.801506	9
DNK	0.962334	22	**POL**	0.792463	8
DEU	0.959167	21	**BGR**	0.777313	7
HRV	0.954824	20	**LVA**	0.732487	6
EST	0.952415	19	**CYP**	0.729129	5
SVN	0.941910	18	**ITA**	0.592025	4
ESP	0.939443	17	**GRC**	0.448178	3
HUN	0.881681	16	**ROU**	0.158685	2
CZE	0.874101	15	**IRL**	0.151592	1
FIN	0.865327	14			

Source *own editing based on [12]*

Conversely, countries with lower Vulnerability Index values, such as Ireland (0.151592) and Romania (0.158685), rank highest in terms of vulnerability, reflecting significant challenges within their real sectors. These low scores suggest heightened exposure to economic disruptions due to factors such as structural imbalances, over-reliance on limited sectors, and weaker industrial bases. For example, Romania and Ireland's vulnerabilities may be partially rooted in their narrower industrial diversification and increased dependence on foreign investment, making them more susceptible to market volatility and external pressures. These nations' high vulnerability rankings underscore the need for structural reforms aimed at reducing dependence on particular sectors and enhancing the resilience of their real economies.

The analysis also highlights several regional trends. For instance, Northern and Western European nations, including the Netherlands (0.973644), Germany (0.959167), and Denmark (0.962334), generally fall within the moderate to low vulnerability range. This categorization reflects the advantages of balanced industrial structures, effective

macroeconomic performance, and generally resilient economic systems, all of which support sustainable growth and adaptation to economic changes. These economies benefit from strong industrial sectors that contribute to economic resilience, allowing them to withstand external disturbances with relative stability.

In contrast, Eastern European countries such as Romania (0.158685) and Bulgaria (0.777313) exhibit higher levels of economic vulnerability. These elevated vulnerability levels could be due to a combination of structural economic challenges, lower degrees of industrial diversification, and a greater reliance on external markets and financial systems. The economic structures in these countries may face limitations in adapting to global shocks or economic shifts, highlighting potential areas for policy intervention aimed at fostering industrial growth, diversifying economic activities, and stabilizing macroeconomic conditions.

Southern Europe shows a similar variation in economic vulnerability levels. Countries like Italy (0.592025) and Greece (0.448178) have moderate to high vulnerability rankings, which can be attributed to factors such as ongoing economic instability, fiscal constraints, and limited industrial diversity. The structural issues within these economies increase their exposure to economic disruptions, potentially affecting their ability to maintain consistent growth and stability in the face of global economic changes. Addressing these vulnerabilities may require structural reforms to strengthen industrial resilience and reduce dependence on external economic inputs.

Figure 1 shows visually geographical distribution of the real sector vulnerability of the European economies according to ranking from 1 to 27 scale.

It is important to note that the statistical results reflect, in particular, the more stable economies of Central Europe. In contrast, Eastern European countries and the Balkans appear to be more vulnerable, according to the rating.

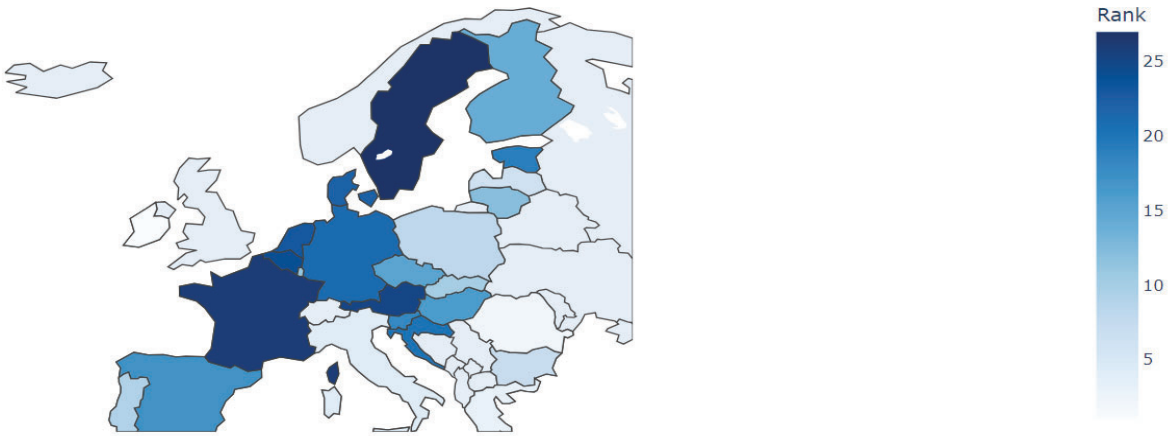

Figure 1. Real sector of the economy vulnerability in European countris
Source: *own calculations*

Conclusion. This assessment of the Real Sector of the Economy Vulnerability Index across European nations provides a comprehensive understanding of the varying

levels of economic resilience and susceptibility. Countries with well-developed, diversified industrial bases and stable economic policies exhibit lower vulnerability and greater resilience, while those with structural imbalances and limited industrial diversity face higher levels of vulnerability. These insights emphasize the importance of policy measures aimed at economic diversification, industrial strengthening, and macroeconomic stability as key strategies for reducing vulnerability and promoting sustainable economic resilience across Europe. It is recommended that future research endeavours extend the application of the methodological approach to the study of the financial sector. Furthermore, it would be beneficial to ascertain the list of factors that characterise the industrial and real estate markets.

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