Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Economic vulnerability assessment of EU countries to the impact of COVID-19 pandemic with the revised CEV index

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Abstract

The COVID-19 pandemic had a wide range of detrimental consequences for the global and national economies. It is vital to identify particularly susceptible areas to adopt effective strategies to alleviate the adverse effects of a pandemic. The objective of the paper is to assess the economic vulnerability of EU countries to the COVID-19 pandemic impact using the revised CEV Index. In the study, methods of multivariate statistics were used to analyse the effects of the pandemic. The revised CEVI replaces the 20-dimensional set of features with one aggregate measure, estimated for 27 EU Member States. According to the study, the economic vulnerability of EU countries to the COVID-19 pandemic varies significantly. The most vulnerable countries are in southern Europe, where the tourism sector plays a significant role in GDP composition. Highly susceptible are also Baltic countries: Latvia and Lithuania. The pandemic's harmful impact was the least seen in Germany and Scandinavian countries. The results of this study can be used as a tool for the formulation of policies aimed at overcoming the adverse consequences of economic vulnerability. The CEVI indicates certain areas in the country's economy that make it more fragile. Thus, it can play a significant role in the decision-making process. In the event of a pandemic shock, the CEVI, in combination with other tools, can be an effective instrument for improving the economy's resilience and helping it recover faster.

Keywords: economic vulnerability, COVID-19 pandemic; multivariate statistics methods; synthetic measure

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1. Introduction

The COVID-19 pandemic has had a tremendous impact on many areas of the contemporary world. The invention of vaccines against the SARS-CoV-2 virus did not end the pandemic. The number of victims continues to rise, although this has allowed the pandemic's impact to be mitigated and spread over time. Successive waves of the pandemic followed one another. Reducing the negative consequence of the pandemic on the economy and effective protection against its destructive effects have become particularly important. The pandemic has changed the direction of various fields of study, including medical, social, and economic-related areas [1, 2], and there is a critical necessity to comprehend how different views in these fields can be evaluated. Furthermore, the global COVID-19 pandemic has had a significant impact on the research activity, including academic publications concentrating on various COVID-19 contexts and criteria evaluations [3, 4]. Therefore, the use of analytical information is important to support an effective and quick response in decision making support systems, as scientific publications on pandemics are being produced at a rapid pace [5, 6]. Research on the vulnerability of economies to the impact of pandemics is new and fast increasing.

The economic vulnerability of the COVID-19 impact is a very complex phenomenon – it includes many variables that influence the final result. Due to a large amount of data, it is challenging for an expert to conduct a comprehensive analysis of alternative solutions [7, 8]. As a result, multi-criteria decision-making methods are becoming increasingly popular [9, 10, 11].

It has become essential to identify areas in economies that are particularly vulnerable to the impact of pandemics. Understanding these provides the opportunity to take coordinated actions in helping economies to get through the subsequent waves of a pandemic. Measures of economic vulnerability showing the impact of the COVID-19 pandemic are valuable in this regard.

The paper's objective is to assess the economic vulnerability of EU countries to the COVID-19 pandemic impact using the revised CEV Index [12]. This research aims to test the hypothesis: The EU Member States are not a homogeneous group in terms of vulnerability to the impact of the COVID-19 pandemic, and differences between countries remain significant. These differences can be identified using multivariate statistics.

Based on the revised index, a ranking of EU countries, from most to least vulnerable was created. The application of the dynamic approach made it possible to measure the susceptibility of EU economies to the impact of COVID-19 over time. It ensures the comparability of scores between years.

The paper consists of five sections. The second section, following the introduction, reviews the literature. The third part presents the applied research methods. It describes the revision of the COVID-19 Economic Vulnerability Index (CEVI). In the fourth section, the study results on the basis of the revised index are provided. The paper closes the research conclusions.

2. Literature review

Researchers' interest in the COVID-19 pandemic is very high. It has resulted in rapidly growing literature on the subject. COVID-19 cures and improved vaccines are being sought, but also the mechanisms illustrating the development of the pandemic, which allow a pattern of virus spread to be established, are being analysed. Great interest in the COVID-19 pandemic has been aroused among social science researchers, who are trying to analyse the COVID-19 pandemic from various perspectives [13, 14]. Of particular interest is the issue of the vulnerability of economies to the impact of the pandemic and the factors that determine it [15]. This paper is part of this trend.

It has been observed that the pandemic does not spread equally between countries [16]. Some countries are more affected than others and suffer much more severely from its negative effects [17]. The structure of the economy plays a big role in this. Service-oriented economies, especially where the tourism sector plays an important role, are particularly negatively affected [18, 19]. The situation is similar in countries characterized by greater openness and intensive participation in foreign trade.

The issue of disruptive supply chains is of great interest to researchers. High competitive pressures have meant that global supply systems to date have been based on an efficiency fixated system. The outbreak of a pandemic triggered a shift towards a system orientated on resilience [20]. M. Aljukhadar pointed out that in the first stage of pandemic

development, a nation's culture and macroenvironmental factors such as in particular uncertainty avoidance and indulgence play a particularly important role [21].

Despite the predominant negative impact of the COVID-19 pandemic on the economy, researchers also find positive impacts in some areas, for example, stimulating the rapid development of digital currencies [22] and accelerating technological progress, or increasing the application of artificial intelligence in the economy [23].

Many indicators have been developed to assess the impact of a pandemic [24]. They illustrate the development of the pandemic, indicate the weaknesses and strengths of economies due to the impact of the pandemic on them, indicate the factors determining the impact of the pandemic, or show the resilience of economies to COVID-19. They allow the observation of the development of the pandemic and enable appropriate action to reduce the negative impact of the pandemic. Among these indicators, it is worth mentioning the COVID-19 Economic Vulnerability Index developed by the European Investment Bank [25]. According to the indicator, low-income countries are highly vulnerable to a pandemic. Another indicator is the COVID-19 vulnerability index developed by R. Acharya and A. Porwal based on population and infrastructural characteristics in India [26]. A group of researchers from India constructed a vulnerability index based on GDP dynamics and stock exchange quotations of 6 assets: S&P500, iShares 20 + Year Treasury Bond, crude oil, natural gas, gold and silver [27]. Whereas Sam Diop, Simplice Asongu and Joseph Nnanna developed another measure, which consisted of 7 variables, the COVID-19 economic vulnerability index. They also constructed the resilience index [24]. Researchers from Romania using a Group Multi-Criteria (GMC) approach developed the COPACOV - COuntry Performance Against COVID-19 indicator [9]. Researchers from the University of Ibadan created another measure – the Index for Measuring Uncertainty Due to the COVID-19 Pandemic, which is a combination of news-and macro-based trends [28]. The Oxford Coronavirus Government Response Tracker (OxCGRT) has also been created, and that index shows how government policies related to closure and containment, health and economic policy have been changing [29].

The vulnerability indicators presented here do not exhaust the rich and growing number of measures of the impact of the COVID-19 pandemic on the economies. They are considerably diverse and show different aspects of the impact of the pandemic. Below we present the author's revised index of economic vulnerability to the impact of pandemic COVID-19.

3. Data and methods. Revision of CEVI 2022 construction

The impact of the COVID-19 pandemic on the individual European economies is different. Lithuania, for example, was almost the least affected by the recession in 2020 in comparison to EU countries but is struggling with rising unemployment. Poland has one of the lowest unemployment rates in the EU, but at the same time - the highest inflation. Croatia is facing a deep recession and a marked slowdown in inflation. Most EU countries experienced a decline in GDP in 2020 compared with the previous year. The depth of the recession has been influenced by the economic importance of those sectors that have been subjected to the greatest restrictions in the era of the pandemic. First and foremost this refers to tourism, which is an important part of the economies of southern Europe. Also, sectors that are dependent on human contact and interaction, such as the cultural and creative industries and the aviation industry, have experienced substantial hits by the crisis, and they are likely to suffer for extended periods from these unprecedented shocks [30]. Limited economic activity generates lower tax revenues. In addition, this happens precisely when the government increases spending. The expansive fiscal policy pursued in many countries, including Poland, has reduced the impact of the pandemic on the economy. If it were not for the extraordinary measures taken in individual countries, the scale of the recession could have been several times greater. However, these interventions have resulted in larger fiscal deficits and public debt.

From these examples, it can be concluded that to determine the economic impact of a pandemic, it is not enough to examine a single indicator – the fall in GDP – it is a more complex and multidimensional phenomenon. For this reason, it is difficult to measure and identify. In studies that analyse multiple units described by multiple characteristics, multivariate statistical methods are used. The main idea of these analyses is to create an aggregated indicator, also called a synthetic variable, which is the basis for the hierarchy of studied objects due to the level of multidimensional phenomenon. One of the first such measures was proposed by Z. Hellwig in 1968, constructing the so-called *synthetic*

measure of development. This measure is based on multidimensional Euclidean distances from a pattern – an artificial point in the space whose coordinates are determined by the most favourable observations of diagnostic variables.

In this paper, the authors use the modified Hellwig's method. The modification mainly consists of the change of the type of variables normalisation. Instead of standardisation of variables, min-max normalisation was applied. In the case of multi-year data, the analysis may be carried out in two approaches: static and dynamic. In the static approach, data from each year are taken into account separately. In the dynamic approach, the normalization of variables takes into account data from all years, which makes it possible to assess the magnitude of changes in the level of development of objects in the analysed period. In this study, the dynamic approach was applied. The study covered all 27 countries belonging to the European Union in 2022.

The construction of a ranking list consisted of three main stages:

STAGE 1. Statistical variable selection.

STAGE 2. Construction of the synthetic indicator.

STAGE 3: Ranking of countries according to their vulnerability to the impact of the pandemic.

In the first stage of the study, a set of 32 potential diagnostic variables from the Eurostat, World Bank and UNCTAD databases was verified for their informative value. Those variables which were characterised by low discrimination capacity or duplicated information carried by other characteristics were excluded from the set. As a result of applying statistical procedures, 12 variables were eliminated from the set of potential characteristics describing the economic COVID-19 pandemic impact. The reason was too low variability (measured by the classical coefficient of variation, $V_s<0.1$) or high correlation with other characteristics (the threshold value of correlation coefficient was assumed to be 0.7). These 20 variables are presented in Table 1. The variables were grouped into 4 dimensions that form the index structure:

- Health
- People & Work
- Economy
- Business & Innovation

Compared to the ranking presented in the previous paper, the newly revised index:

- contains more variables (20 instead of 15). The additional variables were selected based on substantive and statistical criteria. It refers to variable no. 7, 8, 9, 11, 15, 17 and 19 (Table 1);
- variables calculated as dynamics indicators (quarterly change to pre-pandemic periods) were replaced by more universal measures. E.g. the GDP dynamics in Q2 2020 relative to the corresponding quarter in 2019 have been replaced by the GDP per capita variable; the same refers to export dynamics (replaced by concentration index) and number of commercial flights dynamics (replaced by intensity indicator – number of these flights on 1000 inhabitants);
- a few of the variables have been shifted to another dimension. This concerns variable no. 5, which previously belonged to the People & Work dimension, and variable no. 14 moved from the Business dimension.
- some of the variables have been left unchanged, only updated with the most recent data (variables no. 1, 2, 3, 4, 5, 6, 12, 13, 14, 16 and 20).

Table 1. List of variables used in COVID-19 Economic Vulnerability Index construction

No.	Variable	Year (for CEVI 2020 and CEVI 2021)	Source	Description/Justification
		Health		
1	COVID-19 cumulative cases per 1 mil. inhabitants	31.Dec.2021 31 Dec. 2020	The Johns Hopkins Coronavirus Resource Center [31]	The cumulative number of confirmed cases per million people. STIMULANT*
2	Practising physicians per 100 k inhabitants	2020 2019	Eurostat	Practising physicians provide services directly to patients. The higher the number, the better the country performs under pandemic conditions. DESTIMULANT*
3	Hospital beds per hundred thousand inhabitants	2019 2018	Eurostat	See description in no. 2. DESTIMULANT

4	Health care expenditure by all financing schemes as % of GDP	2020 2019	Eurostat	Underfunded and poorly functioning healthcare systems make countries vulnerable to the health impacts of the pandemic DESTIMULANT
5	Excess mortality	2021 2020	Eurostat	Cumulative deaths from all causes compared to projection based on previous years. The percentage difference between the cumulative number of deaths since 1 January 2020 and the cumulative projected deaths for the same period based on previous years. STIMULANT
			People & Work	
6	Share of population 80 years or over in total population [%]	2021 2020	Eurostat	Older populations make countries vulnerable to the health and social impacts of the pandemic. STIMULANT
7	Fixed broadband subscriptions (per 100 people)	2020 2019	World Bank Database	The greater the number of broadband connections, the more digitalised the economy and the less vulnerable to the impact of pandemics. DESTIMULANT
8	Labour market slack as % of extended labour force, 15-74	2021 2020	Eurostat	The larger share, the greater unmet demand for employment and therefore the greater the economic vulnerability STIMULANT
9	Share of employed persons in wholesale and retail trade, transport, accommodation and food service activities in total employment [%]	2020 2019	Eurostat	The higher the share, the greater the vulnerability of the economy, as employment in these services is relatively more affected by the lockdown than in other. STIMULANT
			Economy	
10	GDP per capita [mil. EUR]	2020 2019	Eurostat	The greater the value, the wealthier the country, it can allocate more resources to fight the pandemic. DESTIMULANT
11	Concentration index (exports)	2020 2019	UNCTAD	The greater the value, the lower export diversification, with ensuing economic vulnerabilities. STIMULANT
12	General government deficit as % of GDP	2021 2020	Eurostat	Above 3% GDP this variable is a stimulant. Only one country Denmark had a value below 3% GDP - so with the normalization procedure this variable received the lowest value - 0. STIMULANT
13	Government consolidated gross debt, as % of GDP	2021 2020	Eurostat	The larger the share, the more indebted country and more vulnerable to COVID-19 pandemic impact. STIMULANT
14	Gross Value Added (at basic prices) in wholesale and retail trade, transport, accommodation and food service activities, as % of total GVA	2021 2020	Eurostat	The larger the share, the greater the vulnerability to pandemic impacts, as transportation, accommodation and food service activities are the sectors most affected by the pandemic STIMULANT
15	Gross Value Added in information and communication activities, as % of total VA	2021 2020	Eurostat	The larger the share, the smaller the vulnerability to pandemic impacts, as during the covid restriction and lockdowns ICT technologies allow the economy to run DESTIMULANT
			Business	
16	Business expenditure on R&D as % of GDP	2020 2019	Eurostat	The greater the value, the more innovative the economy is and the more resilient it can be to the impact of a pandemic DESTIMULANT
17	Non innovative enterprises [%]	2018 2018	Eurostat	The greater the value, the less innovative the economy is and the less resilient it can be to the impact of a pandemic. The Community Innovation Survey is conducted at two-year interval. The next data will be available in the mid-2023.

				STIMULANT
18	Number of commercial flights per 1 k. inhabitants	2021 2020	Eurostat	Number of flights data include scheduled and non-scheduled commercial air flights. Data are expressed as measure of intensity per 1000 people. DESTIMULANT
19	Tourism intensity (nights spent by domestic and international guests at tourist accommodation establishments per inhabitant)	2019 2018	Eurostat	The greater the number, the more the economy relies on tourism, i.e., the greater the vulnerability to the impact of a pandemic. DESTIMULANT
20	International travel receipts as % of GDP	2020 2019	World Bank Database	The greater the share, the more the economy relies on tourism, i.e., the greater the vulnerability to the impact of a pandemic. DESTIMULANT

*A variable is a stimulant when its higher value allows the object to be qualified as better in terms of the studied phenomenon, in the case of destimulants, an increase in the value of a variable is associated with a decrease in the rating of an object [32, 33].

Source: authors' calculations.

In the second stage, 5 steps can be distinguished:

STEP 1. Normalisation of variables. For each year t, a normalisation of the variables is performed using the min-max scaling method from the formulas:

for the stimulant [34]

$$z_{ij} = \frac{x_{ij} - \min\limits_{i} x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}}, \tag{1}$$

$$z_{ij} = \frac{\max\limits_{i} x_{ij} - x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}},$$

for the destimulant [35]

where:
x_{ij} – *j-th* explanatory variable for *i-th* economy, $i = 1, ..., 27$, $j = 1, ..., 20$
z_{ij} – *j-th* normalised value of x_{ij},
$\min\limits_{i} x_{ij}$ - minimum value of the *j-th* explanatory variable in 2 examined years
$\max\limits_{i} x_{ij}$ - maximum value of the *j-th* explanatory variable in 2 examined years (2)

Such transformation deprives variables of their units, unifies their ranges to ⟨0,1⟩ and transforms the destimulants into stimulants.

STEP 2. Calculation of the Euclidean distance from an artificially constructed reference point

Then for every entity Euclidean distance from an artificially constructed reference point is calculated as

$$d_i^t = \sqrt{\sum_j \left(z_{ij} - z_{0j}\right)^2}, \tag{3}$$

where:
d_i^t - Euclidean distance from *i-th* economy to the reference object in year *t;*
$z_{0j} = \max\limits_{i} z_{ij}$ - value of *j-th* coordinate in the reference point,
$t = 2021, 2022$.

Distances (3) are the quantitative descriptions of the objects due to the analysed phenomenon. Because of the comparability of normalized variables, also distances from the reference point are comparable both across objects and time.

STEP 3. Calculation of dynamic measure of development.

In the next step, for t = 2021, 2022, we calculate the dynamic measures of the COVID-19 Economic Vulnerability Index (CEVI), using the formula:

$$CEVI^t = 1 - \frac{d_i^t}{\sqrt{r}}, \tag{4}$$

where:

$r = 20$ – number of variables

The denominator in the formula (4) depends only on the number of variables – it preserves the comparability of measure CEVI both across objects and time and established the values of measures in the range [0,1].

STEP 4. Aggregation of the 20 normalised indicators into four dimensions. Each of the four dimensions consists of the 4–6 indicators (see table 1). For each of these dimensions, the average values of normalised indicators in this dimension were calculated. This allows examining for each country which of the analysed dimensions has a greater impact on its position in the ranking of economic vulnerability to the impact of the COVID-19 pandemic.

STEP 5. Multiplication of obtained results by 100, for better visualization of the calculated values. Results close to 0 indicate lower vulnerability to the impact of the pandemic than those close to 100.

4. Research results. CEVI 2022 performance

In the last, third stage of the study, we create a ranking list of economies from most vulnerable to least vulnerable. The results are presented in Table 2. Note that, due to the dynamic approach, we can compare not only the position in the ranking list but also the values of the synthetic measure CEVI and values of sub-indices in each dimension.

Table 2. COVID-19 Economic Vulnerability Index (CEVI) – performance by economy

Rank 2022	Country	Dynamic Measure of Development		CEVI 2022 – CEVI 2021	Rank 2021	Difference (Rank 2022 -Rank 2021)	2022 Dimension Score (lowest vulnerability: min=0 – max=100: highest vulnerability)							
							Health		People & Work		Economy		Business & Innovation	
		CEVI 2022	CEVI 2021				2022	2022 -2021	2022	2022 -2021	2022	2022 -2021	2022	2022 -2021
1	Spain	57.4	58.9	-1.5	3	-2	52.3	4.6	70.6	-2.8	56.2	6.4	74.9	2.3
2	Latvia	56.6	59.1	-2.6	2	0	59.9	17.9	61.5	-0.4	48.9	-3.1	86.0	0.9
3	Portugal	56.3	60.4	-4.2	1	2	50.2	6.3	58.9	-5.0	60.3	2.9	70.3	1.9
4	Slovakia	55.6	56.1	-0.5	6	-2	70.2	23.5	32.4	-1.8	59.0	1.2	89.4	1.6
5	Greece	55.5	58.5	-3.0	4	1	48.5	12.1	76.3	-3.3	73.1	0.7	58.1	3.5
6	Lithuania	55.3	55.2	0.1	8	-2	55.7	14.5	56.1	-2.8	63.1	6.3	79.9	0.7
7	Slovenia	53.7	55.8	-2.1	7	0	60.2	7.7	41.8	-2.9	58.5	4.5	67.6	2.8
8	Italy	53.4	57.2	-3.8	5	3	50.4	0.7	74.7	-1.1	55.0	4.2	68.1	0.6
9	Poland	52.9	53.7	-0.8	9	0	63.0	8.3	42.0	-1.9	59.0	6.8	88.1	0.3
10	Romania	50.4	51.8	-1.3	10	0	59.3	10.2	34.1	0.1	48.5	3.6	97.8	0.4
11	Bulgaria	49.7	51.5	-1.8	12	-1	51.3	14.1	49.7	-1.6	47.9	-0.4	85.2	3.6
12	Hungary	49.2	51.7	-2.5	11	1	53.7	12.2	34.6	-1.7	50.0	0.8	81.6	1.4
13	Estonia	49.1	49.5	-0.4	13	0	58.1	15.9	50.9	-1.7	46.4	3.2	63.8	2.3
14	Croatia	49.0	46.1	3.0	21	-7	61.1	14.0	48.3	-2.1	56.9	7.1	49.2	7.5
15	Cyprus	46.4	47.6	-1.2	17	-2	57.1	15.3	36.9	-3.2	72.2	5.9	44.2	4.1
16	Netherlands	45.5	48.8	-3.2	14	2	52.1	8.5	31.4	-1.2	48.5	1.3	65.4	-0.4
17	Czechia	44.6	46.1	-1.6	20	-3	54.7	12.9	23.1	-2.2	46.5	0.3	74.3	1.1
18	Ireland	44.5	46.9	-2.5	19	-1	60.7	11.9	42.2	-2.4	33.8	4.5	72.8	1.2
19	Denmark	43.6	47.1	-3.5	18	1	41.9	6.6	47.4	0.8	53.9	5.1	60.0	0.7
20	Belgium	43.0	45.4	-2.4	22	-2	49.2	5.6	36.5	-4.0	51.2	5.4	54.6	-2.2

21	France	42.9	47.6	-4.7	16	5	38.6	4.5	38.6	-3.3	47.4	3.0	67.1	-0.6
22	Finland	42.3	48.2	-5.9	15	7	33.7	4.5	47.6	-6.8	47.4	3.7	62.6	0.0
23	Sweden	39.0	42.9	-3.9	23	0	43.4	3.0	39.4	-0.6	44.1	3.0	54.5	-0.4
24	Austria	37.7	40.2	-2.5	25	-1	23.2	5.4	53.7	0.2	48.3	3.2	46.6	1.4
25	Malta	37.0	40.7	-3.7	24	1	43.2	6.4	21.3	-6.0	47.7	3.8	49.8	5.3
26	Luxembourg	36.7	39.5	-2.8	26	0	59.4	5.8	24.9	0.9	37.4	6.5	55.3	-0.9
27	Germany	33.6	38.0	-4.5	27	0	15.6	3.7	38.4	-2.9	46.7	1.1	59.1	0.7
AVERAGE		**47.4**	**47.4**	**49.8**	**-2.4**	**x**	**50.6**	**50.6**	**9.5**	**44.9**	**-2.2**	**52.1**	**3.4**	**67.6**

Source: authors' calculations.

In 2022 (based on 2018-2021 data) the most vulnerable economies are Spain, Latvia, Portugal, Slovakia and Greece, with CEV Index scores between 55,5 and 57,4. At the other end of the scale are economies less vulnerable to the impact of the pandemic: Sweden, Austria, Malta, Luxembourg and Germany, with CEV Index scores between 33,6 and 39. The average score for the global index is 47,4 ±6,9 (out of a possible 100). In 2021 the average score for the global index was higher and equalled almost 50.

The reduction in the mean value and individual values for the global index is evidence of an improvement in the surveyed economies' vulnerability to the impact of a pandemic. Almost all countries observed a decrease in CEVI values in 2022 compared to the previous year. Only in Lithuania and Croatia was an increase in the value of the index observed. In Lithuania, the increase was insignificant, while in Croatia it increased by almost 3 points. The result was the largest among the surveyed countries negative change in the ranking position by up to 7 places. In 2021, Croatia was in the 21st position, i.e. closer to the end of the ranking, and in 2022 its position increased to 14th, which indicates the increased vulnerability of the economy to the impact of the pandemic.

Interestingly, although other countries experienced a decrease in the index value in 2022 from 0.4 points to 5.9 points, the country's position on the 2022 list did not always change for the better (lower in the ranking). Only in 9 cases, this was the case (positive value in the 7th column of the table). On the contrary, in 10 cases the position changed to worse by 1, 2 or 3 places, and in 8 cases the place in the ranking did not change at all. For Finland, for example, the index value decreased the most, and thus the country dropped from 15th to 22nd place in the ranking of the most vulnerable economies.

The second part of Table 2 contains values for sub-indicators from four dimensions of the studied phenomenon. The analysis of average values for these areas shows that the greatest vulnerability to the impact of the pandemic is characteristic of the fourth dimension (Business & Innovation). The average value for this dimension is much higher than for the other areas, which means that this dimension, on average, affects the country's ranking more strongly. The average value for the first and third dimensions is at a similar level close to 50 (out of a possible 100). And the least vulnerable dimension is on average the second one (People & Work). In the latter, there was a significant improvement in 23 countries, ranging from 0.4 points for Latvia to 6.8 points for Finland; with an average of 2.2 points. It was due to the extraordinary measures taken by national governments to protect jobs and people's incomes. In the first dimension, there was no improvement in any country, with an average deterioration of almost 10 points. In the second dimension, only two countries improved: Latvia and Bulgaria. The remaining countries experienced a deterioration, ranging from 0.3 points in the Czechia to 7.1 points in Croatia; with an average of 3.3 points. By contrast, five countries (Netherlands, Belgium, Finland, Sweden and Luxembourg) experienced a better situation in the fourth dimension. The remaining countries experienced a decline in the sub-indicator of 1.5 points on average. The worst was in Croatia. It experienced a deterioration of 7.5 points in the value of the sub-indicator. The reason for this is the large share in the Croatian economy of tourism and associated industries, which are the most vulnerable to the impact of the pandemic.

5. Conclusions

The revised CEV Index appeared to be more universal and accurate in assessing economic vulnerability. Variables based on dynamics indices seemed adequate in the first year of the pandemic, due to their strong responsiveness to

introducing restrictions in European countries. In the following years, as the economy returned to recovery, their relevance diminished. In addition, there was a problem in selecting a specific quarter for comparison. Furthermore, by discarding these variables, the revised CEV Index can be calculated for subsequent pandemic years.

The study shows that the level of vulnerability of EU economies to the impact of pandemic COVID-19 varied (the research hypothesis was confirmed). The southern EU countries and Baltic countries were the most vulnerable to the impact of COVID-19. The least susceptible were the 'old' EU countries. Germany was the leader. Active supportive government policies and measures to mitigate the negative impact of the pandemic resulted in a decrease in 2021 the CEVI score. It indicates an improvement in the situation, i.e. a slight decline in the level of vulnerability of EU countries to the impact of the pandemic. It is most evident in the change of sub-indicator scores in the CEVI second dimension (People & Work). This improvement was observed in most EU economies and was mainly the result of an expansionary fiscal policy conducted by national governments.

Our study proves that even relatively simple statistical methods provide a more complete and accurate description of the COVID-19 pandemic's economic vulnerability. Multivariate statistics deliver more objective criterion selection and the use of various types of data, which is critical for such a complex phenomenon. However, our study has some limitations, namely that all analysed economies are members of the EU with a high level of development. Therefore, this tool can be applied to countries with a similar level of development. The analysis might be extended to other geographical locations with more diverse characteristics to confirm the conclusions researched here.

Our findings may be of special relevance to economic decision-makers as a proposal for a proven tool for employing them in macro-level analyses, and to prepare and evaluate recovery measures.

In the future, it is worth considering examining the evolution of economic vulnerability to the impact of COVID-19 pandemic in European and non-European countries and their resilience, as well as the relation between the two.

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