Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

Joanna Brzyska[1], Izabela Szamrej-Baran[2]

Abstract:

Purpose: The paper's objective is to identify the similarities of EU countries in terms of the entire sets of indicators. Hence, the multi-dimensional cluster analysis is applied to evaluate the economic vulnerability to the impact of the COVID-19 pandemic.
Design/Methodology/Approach: A hierarchical and non-hierarchical cluster analysis method was used in the paper. At the first step, EU countries were clustered with Ward's method, and the following k-means method was applied for grouping countries.
Findings: In the study, four clusters were identified. Southern European countries grouped in the 1st Cluster performed the highest level of vulnerability to the negative impact of the COVID-19 pandemic. Germany, the Netherlands, Ireland, and the Scandinavian countries appeared to be the least vulnerable EU economies to the impact of the COVID-19 pandemic and were grouped in the 4th Cluster. The countries of Central and Eastern Europe, most of which joined the EU in the 21st century, were characterized by moderate vulnerability and belonged to the 2nd and 3rd Cluster.
Practical Implications: The results obtained can be used by policymakers to make better decisions to mitigate the negative impact of the pandemic on economies.
Originality/Value: Most clustering of countries according to the impact of a COVID-19 pandemic examines how the virus spreads from a medical point of view. There is little literature on the economic impact of a coronavirus pandemic. This study will fulfill this gap.

Keywords: Cluster analysis, COVID-19 pandemic, vulnerability, Ward'Method, K-means clustering.

JEL classification: C38, I10, I14, I15, I18, I39.

Paper Type: Research study.

---

[1]Institute of Economics and Finance, University of Szczecin, Poland, e-mail: *joanna.brzyska@usz.edu.pl;*
[2]Institute of Economics and Finance, University of Szczecin, Poland, e-mail: *izabela.szamrej-baran@usz.edu.pl;*

*Classification of the EU Countries According to the Vulnerability of their Economies
to the Impact of COVID-19 Pandemic*

968

1. Introduction

The end of the second decade of the 21st century was an extraordinary period for the global economy. The outbreak of the COVID-19 pandemic and the rapid spread of the virus worldwide triggered strong reactions from many countries in the form of the introduction of lockdowns, which had never been seen before on such a scale. The highly advanced process of globalization has been disrupted, and the complex system of solid linkages between countries has been breached. This could not remain without an impact on the economies of the countries. In a short time, there was a significant decline in international trade and a fall in GDP. The first forecasts were pessimistic. The WTO predicted a fall in world trade of 32% in 2020 (WTO, 2020). According to UNCTAD, the decline in global trade was more significant than during the financial crisis in 2008 (UNCTAD, 2020). However, reality turned out to be more optimistic. Declines were significantly smaller than initially forecast - at 7.5% (WTO, 2021).

The COVID-19 pandemic and its impact did not affect all countries to the same extent. While some of them showed very high vulnerability and the negative impact of the pandemic caused significant damage (many companies bankrupted, unemployment increased significantly, and there was a substantial decline in GDP), other countries were affected to a significantly lesser extent. Engaging in this situation arises the question of which countries were characterized by higher and lower sensitivity to the impact of the COVID-19 pandemic and what factors determined the differentiation of this impact. Is it possible to distinguish groups of countries similar to each other in this respect? The paper's objective is to identify the similarities of EU countries in terms of the entire sets of indicators. Hence, the multi-dimensional cluster analysis is applied to evaluate the economic vulnerability to the impact of the COVID-19 pandemic. This will allow the grouping of countries with similar levels of vulnerability to the impact of the coronavirus. It will also provide an opportunity to make comparisons between countries with similar vulnerability levels and learn from countries that have been successful in dealing with the adverse effects of the pandemic.

2. Literature Review

There is a worldwide effort of the research community to explore the medical and economic impact of the COVID-19 pandemic. Many different disciplines try to find solutions and drive strategies to a wide variety of different problems. The literature on clustering countries in terms of vulnerability to the impact of the COVID-19 pandemic is dominated by an approach that focuses primarily on health aspects. This takes into account the number of new cases of COVID-19, the number of deaths caused by the virus, the number of people vaccinated against coronavirus, or the state of health services as measured by the number of doctors, available ventilators, and free hospital beds or other metrics (Zarikas *et al.,* 2020). This approach examines the spread of the virus in the community (Liu *et al*., 2020; Zubair *et al.,* 2021). The knowledge gained helps to understand its mechanism of action and prepare for the

pandemic attack. On the other hand, relatively few, although their number is growing, are studies considering the economic aspect, which classify countries due to the impact of the COVID-19 pandemic on their economies.

Researchers in Brazil, in a study of the ability of countries to respond to the impact of the COVID-19 pandemic, distinguished countries on each continent that were least and most vulnerable to the impact of the pandemic (Cartaxo *et al.,* 2021). Countries' response capacities were determined based on socioeconomic, political and health infrastructure conditions. Vulnerabilities were identified based on the indicator sensitivity. The highest-risk group consisted of the USA, Brazil, and India, whereas the lowest-risk group included China, New Zealand, and Germany. The greatest vulnerability of the highest-risk group was related first to economic factors such as merchandise trade, followed by public health (immunization), highlighting global dependence on Chinese trade, like protective materials, equipment, and diagnostic tests.

Rizvi, Umair, and Cheema analyzed 79 countries for their vulnerability to the impact of the COVID-19 pandemic. Based on socioeconomic, disease prevalence, and health system indicators considering COVID-19 confirmed cases and COVID-19 death cases as evaluation parameters, they divided countries into 4 clusters (Rizvi *et al.,* 2021).

In turn, Kamenidou, Stavrianea, and Liava analyzed Greek citizens regarding whether they take the necessary precautions to prevent the development of COVID-19 disease (Kamenidou *et al.,* 2020). They divided Greeks according to homogeneous behavior into five groups: the Meticulous Proactive Citizens, the Self-isolated Citizens, the Cautious Citizens, the Occasionally Cautious Citizens, and the Unconcerned Citizens.

There have also been various studies measuring the impact of the pandemic on specific areas of the economic sphere. These include studies of the impact of a coronavirus pandemic on the airline market (Wasowska *et al.,* 2020), tourism (Abbas *et al.,* 2021; Lee and Chen, 2020; Sigala, 2021), and economic security (Kozicki *et al.,* 2020; Grima *et al.,* 2020; Khan *et al.,* 2020).

In an attempt to describe the impact of the pandemic on the economy, many researchers created original indicators. Using these measures, they then classified countries with similar features. Diop, Asongu, and Nnanna created two indices, the COVID-19 economic vulnerability index, and the resilience index (Diop *et al.,* 2020). They surveyed 150 countries worldwide and constructed four scenarios relating to vulnerability and resilience characteristics, namely: low vulnerability - low resilience, high vulnerability - low resilience, high vulnerability - high resilience, and low vulnerability - high resilience. In turn, Raga, and te Velde (2021) proposed a resistance index, calculated as the difference between the economic exposure on the impact of the COVID-19 pandemic and resilience to the shock (the ability to act on the shock). Also, the EIB constructed the COVID-19 Economic Vulnerability Index, which showed that the low-income group of countries has a higher vulnerability to the

Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

970

negative economic impact of a pandemic than high-income countries (Zwart *et al.,* 2020). Indicators allow ranking and identify countries with similar levels of vulnerability to pandemic impacts.

3. Research Methodology

Cluster analysis - a term introduced in Tryon (1939) or clustering is one of the most well-known data mining methods. It is a tool for exploratory data analysis, the purpose of which is to arrange objects into groups (called clusters) in such a way that objects in the same group are more similar (in some sense) to each other than to those in other groups. In other words, it is a method of searching for and extracting clusters, i.e., groups of similar objects from data. It is an unsupervised method, which means that all relations and regularities are found only based on input features.

There are two main types of data clustering algorithms, hierarchical and non-hierarchical (Gore, 2000). Hierarchical agglomeration methods lead to creating the so-called tree hierarchy of the elements of the analyzed set (dendrogram). Hierarchical clustering methods do not require the number of clusters to be specified initially (on dendrograms, the choice of the number of clusters can be made at the end of the analysis by intersecting the dendrogram at the appropriate height), but they do require high computational power. The hierarchical cluster also works with variables instead of cases; it can cluster variables together in a manner somewhat similar to factor analysis. This procedure was also used in this paper to reduce the set of explanatory variables.

Non-hierarchical methods are fast but require specifying in advance the number of clusters into which the data can be classified. The choice of the number of clusters has a significant influence on the quality of segmentation. If the number of clusters is too large, it may cause the clusters to be internally homogeneous, making it difficult to interpret the results and apply them in practice. On the other hand, the smaller the number of clusters, the less homogenous they are.

Selecting the number of clusters in k-means clustering can be done in several ways. One method is to arbitrarily determine the number of clusters and then later change the number of clusters to obtain better results. The second method proposed by Guidici (Guidici and Figini, 2009) is to perform an initial analysis using a hierarchical method, estimating the number of clusters. For such a chosen number of clusters performing an analysis using a non-hierarchical method, for example, the k-means method.

While using the Generalized EM and K-means Cluster Analysis module of STATISTICA, we can use the v-fold cross-validation algorithm for automatically determining the correct number of clusters in the data. This algorithm divides the input set sequentially into an increasing number of segments and then checks the precision of the division for each segment. This seems to be the best method for selecting the number of clusters.

In this paper, the latter two approaches will be used. We will present and apply both algorithms from each group of methods - the hierarchical algorithm and then one of the algorithms from the non-hierarchical methods group, the k-means procedure. In the next part of the paper, we will briefly describe both algorithms and then apply their implementation in STATISTICA to segment countries by the vulnerability of their economies to the impact of the COVID-19 pandemic.

The last consideration is a normalization of data. If the variables have different scales and means, we might want to normalize them. K-means algorithm uses Euclidean distance that is highly prone to irregularities in the size of various features. K-means algorithm can generate better results after the modification (normalization) of the databases. In this paper, we first normalize each variable with two formulas; the first is for the stimulant (Walesiak, 2014).

$$z_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}},$$

(1)

and the second for the destimulant (Kukuła and Bogocz, 2014) to transform it into stimulants:

$$z_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}},$$

(2)

where:
x_{ij} - *j-th* explanatory variable for *i-th* economy, i = 1, ..., 27, j = 1, ..., 15
z_{ij} - *j-th* normalized value of x_{ij}.

Such formulas transform variables into normalized ones - deprives explanatory variables of their units and unifies their ranges to $\langle 0,1 \rangle$. The normalized value of stimulant is set to 0 for the minimum value of the explanatory variable and 1 for the maximum value of the explanatory variable or transform the de stimulants to the same pattern - 0 is for the maximum and 1 for a minimum value of the explanatory variable.

The study covered all 27 EU countries. An initial list of 23 variables potentially describing the economic impact of the COVID-19 pandemic was further statistically Examined and, based on the correlation matrix and the coefficient of variation value, reduced to 17 variables. Then we use Ward's method of hierarchical clustering to divide these variables into separate clusters and choose the variables representing these groups. After using this approach, the list of variables was reduced to 15, which is shown in Table 1. These variables belong to different areas of the economy, related to health, labor market, demographics, business, and innovation.

3. Results and Discussion

In the first step, the classification of EU countries according to the degree of vulnerability of their economies to the impact of the COVID-19 pandemic was carried

Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

972

out. Ward's method - one of the most commonly used agglomerative hierarchical cluster analysis methods - was applied in this part of the study. It is based on the core idea of objects being more related to nearby objects than to objects farther away. At the beginning of the procedure, each object is assumed to be a separate cluster; then, the most similar subgroups are stepwise combined into subsets until a single cluster containing all observations is obtained. In other words, it generates a series of models with cluster solutions from 1 (all cases in one cluster) to n (each case is an individual cluster). All calculations were performed in the STATISTICA 10 program. The clustering results in the form of a dendrogram are presented in Figure 1.

**Table 1.** *List of variables used in cluster analysis*

No.	Variable	Description	Type of variable: S: Stimulant D: Destimulant	Source	Year
X1	COVID-19 cumulative cases per 1 million inhabitants	The cumulative number of confirmed cases per million people.	S	The Johns Hopkins Coronavirus Resource Center	1 May 2021
X2	Practising physicians per hundred thousand inhabitants	Practising physicians provide services directly to patients. The higher the number, the better the country performs under pandemic conditions.	D	Eurostat	2018
X3	Hospital beds per hundred thousand inhabitants	See description in X2	D	Eurostat	2018
X4	Health care expenditure as % of GDP	Underfunded and poorly functioning healthcare systems make countries vulnerable to the health impacts of the pandemic	D	Eurostat	2018
X5	Excess mortality	The excess mortality indicator is computed as the relative difference (expressed in percentage) of the number of deaths in 2020 from its average over the period 2015–2019. Annual data for 2020 are estimated from weekly deaths data. The higher the value, the more additional deaths have occurred compared to the baseline.	S	Eurostat	2020
X6	Total unemployment rate as % of active population	A low level of unemployment can withstand the impact of the pandemic without excessive welfare costs.	S	Eurostat	2020
X7	Share of population 75 years or over in total population [%]	Older populations make countries vulnerable to the health and social impacts of the pandemic.	S	Eurostat	2020
X8	Decrease in GDP at market prices [%]	The absolute value from the percentage difference between 1 and the dynamic index value for Q2.2020 compared to Q2.2019. The greater the value, the greater the decline in GDP; that is, the vulnerability of the economy increases.	S	Eurostat	Q2.2020 / Q2.2019
X9	Exports of goods, percentage change compared to same period in previous year	The greater the value, the greater the decline in exports; that is, the vulnerability of the economy increases.	S	Eurostat	Q2.2020 / Q2.2019
X10	General Government deficit as % of GDP	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.	S	Eurostat	2020
X11	Gross Value Added (at basic prices) in wholesale and retail trade, transport, accommodation and food service activities, as % of total GVA	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	S	Eurostat	2018
X12	Business expenditure on R&D as % of GDP	The greater the value, the more innovative the economy is and the more resilient it can be to the impact of a pandemic	D	Eurostat	2019
X13	Share of enterprises introduced business process innovation (%, innovative core activities)	See description X12.	D	Eurostat	2018
X14	Number of commercial flights percentage change to previous year (%)	Number of flights data include scheduled and non-scheduled commercial air flights. Data are expressed as the percentage change of the number of flights in 2020 compared with the previous year. Index of dynamic (2019=100) – calculated as index of dynamic.	D	Eurostat	2020
X15	Travel receipts in balance of payments as % of GDP	The greater the value, the more the economy relies on tourism, i.e., the greater the vulnerability to the impact of a pandemic.	S	Eurostat	2019

Source: *Authors' calculations*.

Based on the evaluation of the dendrogram structure, it was determined that the most appropriate agglomeration distance of the cut-off level would be 1.5. This creates four clusters of countries. Looking from the top of the dendrogram, the first one includes eight countries (Belgium, Germany, Greece, Spain, France, Italy, Austria, Portugal). The second contains three countries, Denmark, Finland, Sweden. The third covers eight countries, Bulgaria, Estonia, Ireland, Cyprus, Latvia, Lithuania, Luxembourg,

Netherlands. The fourth group also contains eight countries, Czechia, Croatia, Hungary, Malta, Poland, Romania, Slovenia, Slovakia.

Figure 1. *Dendrogram of clustering EU countries using Ward's method*
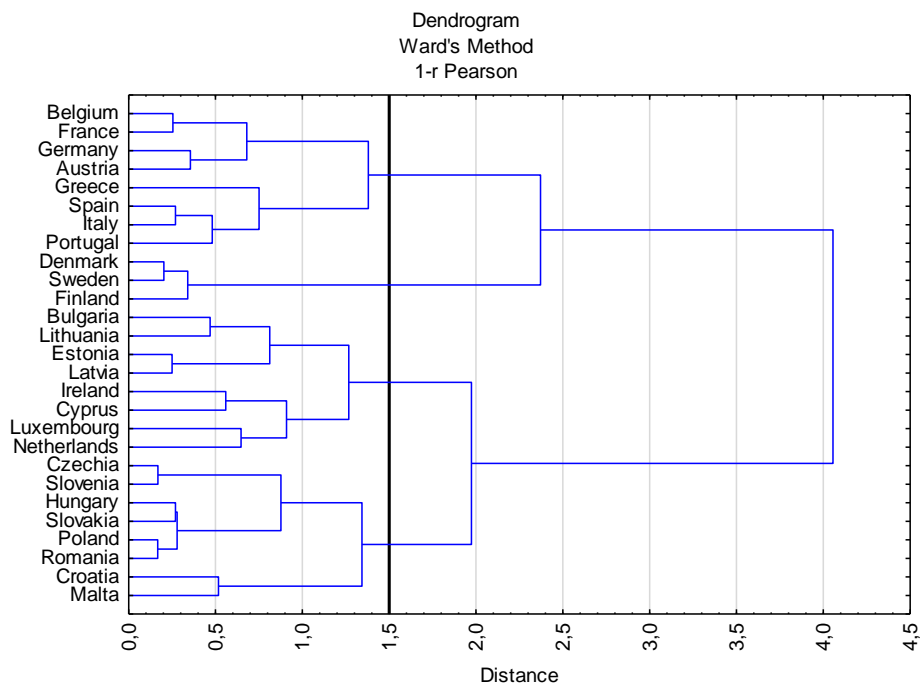
Source: *Authors' calculations.*

The 1st Cluster is characterized by high values of variables from the health area - practicing physicians and hospital beds per 100 000 inhabitants. At the same time, the average unemployment rate and the average share of population 75+ in countries belonging to this Cluster are the highest. Additionally, these countries have the highest general government deficit (% of GDP).

Countries belonging to the 2nd Cluster have the highest average health care expenditure (% of GDP), the highest BERD (% of GDP). At the same time, they have the smallest average number of COVID cumulative cases per 1 million population, the most miniature average hospital beds per 100 000 inhabitants, and the lowest general government deficit (% of GDP).

Countries in the 3rd Cluster are characterized by the most significant decrease in the average number of commercial flights as percentage change to the previous year and have the largest share of gross value added at basic prices in wholesale and retail trade, transport, accommodation, and food service activities. They also have the lowest decrease in exports of goods in second quarter 2020 compared to the same period in

Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

974

the previous year. They are also featured by the lowest value of health care expenditure (% of GDP) and the lowest BERD (% of GDP).

The 4th Cluster consists of countries with the highest average number of COVID cumulative cases (per 1 million population), highest excess mortality, and the highest share of travel receipts in the balance of payments (% of GDP). The lowest are, practicing physicians (per 100 000 inhabitants), total unemployment rate, and population 75+.

The next step is to classify EU countries by the vulnerability of their economies to the COVID-19 pandemic using non-hierarchical object clustering methods such as K-means clustering. In K-means, each Cluster is associated with a centroid. The main objective of the K-means algorithm is to minimize the sum of distances between the points and their respective cluster centroid. This algorithm involves moving objects from Cluster to cluster to minimize intra-cluster variability and maximize inter-cluster variability.

Figure 2. *Graph of cost sequence (scree Plot of K-means)/V-Fold Cross Validation Algorithm Analysis of economic impact of COVID-19 pandemic.*
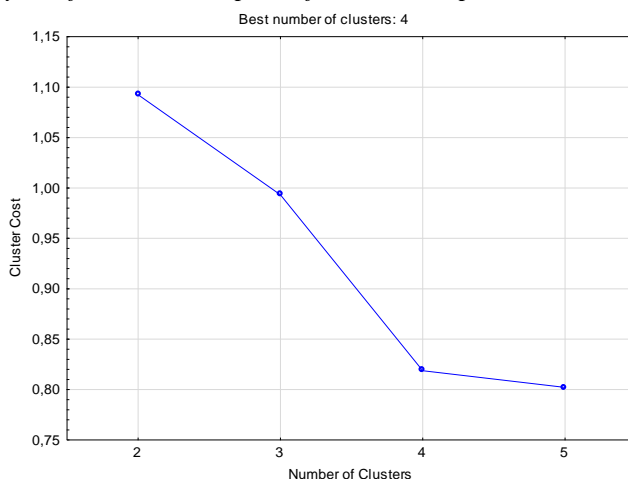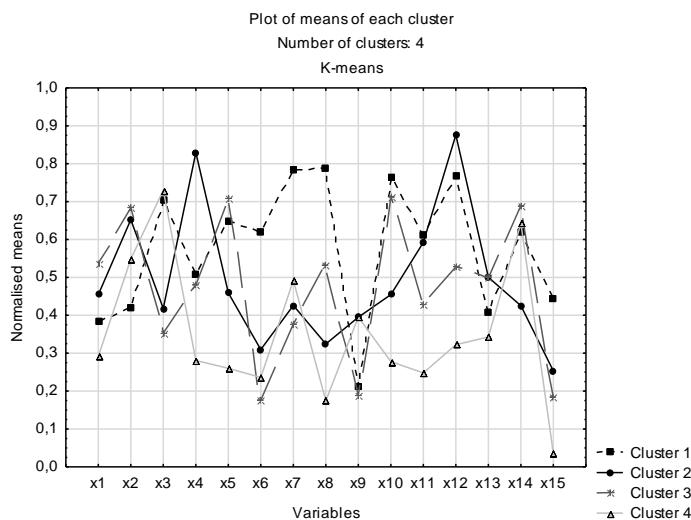

Source: Authors' calculations.

At the beginning of this method, the number of clusters must be specified. To determine the correct number of clusters, we used the previous analysis based on Ward's method and the analysis of the graph of cost sequence derived from the V-fold Cross-Validation Algorithm, which is presented in Figure 2. Both methods show that the optimal number of clusters is 4.

Using the K-means method, an attempt was made to divide the community into four classes. In the first one, there were five countries, Greece, Spain, Croatia, Italy, Portugal. In the second 7 countries, Bulgaria, Estonia, Cyprus, Latvia, Lithuania, Luxembourg, and Romania. The next group is the most numerous because it contains

as many as nine countries: Belgium, Czechia, France, Hungary, Malta, Austria, Poland, Slovenia, and Slovakia. The fourth group contains six countries, Denmark, Germany, Ireland, Netherlands, Finland, and Sweden.

Figure 3 presents K-means clustering results - graph illustrating mean values of each variable that discriminates the four clusters. All variables were normalized using the formula 1 and 2.

Figure 3. *Graph of mean values for each cluster after k-means clustering.*

Plot of means of each cluster
Number of clusters: 4
K-means

Source: Authors' calculations.

The diagram shows that countries from the 1st Cluster have the worst situation for as many as six variables and the best for only one variable - practicing physicians per 100 000 inhabitants. These six variables with the worst values (respectively the lowest or the highest, depending on the type of variable) are the total unemployment rate, the share of population 75+, the percentage decrease in GDP at market prices, general government deficit (% of GDP), gross value added at basic prices in wholesale and retail trade, transport, accommodation, and food service activities, travel receipts in the balance of payments (% of GDP). These demonstrate the greatest vulnerability of countries' economies to the impact of the COVID-19 pandemic.

The 2nd Cluster consists of countries for which four variables have the worst performance, practicing physicians (per 100 000 inhabitants), health care expenditure (% of GDP), BERD (% of GDP), business process innovation (% of enterprises).

In the 3rd Cluster, for three variables, the weakest performances were observed. These are COVID cumulative cases (per 1 million population), excess mortality, and the number of commercial flights (% change to the previous year). At the same time, there are four variables in this Cluster with the best averages: hospital beds (per 100 000

Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

976

inhabitants), total unemployment rate, share of population 75+, a decline of exports of goods in 2nd quarter 2020.

In the last, 4th Cluster, as many as nine variables have the best average performances: COVID cumulative cases, health care expenditure (% of GDP), excess mortality, the percentage decrease in GDP at market prices, general government deficit (% of GDP), GVA in wholesale and retail trade, transport, accommodation, and food service activities, (as % of total VA), BERD (% of GDP), business process innovation (% of enterprises) and travel receipts in the balance of payments (% of GDP). In contrast, only 2 of them are the worst in terms of the purpose of the study. These are hospital beds (per 100 000 inhabitants) and decline in exports of goods in 2nd quarter 2020. This Cluster seems to be the least sensitive to the impact of the COVID-19 pandemic on the economies of its constituent countries.

5. Conclusions

In the study, the 27 EU countries were divided into groups using Ward's and K-means methods. Four clusters were identified. The division into clusters according to both methods is similar but not identical. The sizes of these groups differ slightly, but the within-group characteristics are very similar. The K-means method enabled the identification of groups of countries according to their level of vulnerability to the impact of the COVID-19 pandemic.

The highest vulnerability is found in the 1st Cluster, including Southern European countries (Italy, Greece, Spain, Portugal, and Croatia). They are characterized by a low level of the health care system, are strongly affected by the population aging process, and are heavily indebted. At the opposite extreme is the 4th Cluster, consisting of Germany, the Netherlands, Ireland, and the Scandinavian countries. The impact of the pandemic on the economies of these countries is more minor. This is due to several reasons - a better health care system, higher innovation, and lower debt levels. The countries in the other two clusters have an intermediate level of vulnerability. In the 2nd Cluster, there are seven countries, of which 6 are New Members in the EU. They are characterized mainly by underfunded health care and R&D sectors. The 3rd Cluster is the most numerous and groups mainly countries from Central and Eastern Europe. Countries' strengths in the 3rd Cluster were a relatively small decline in exports in 2020, a relatively young population as for developed countries, and low unemployment. However, there was a dynamic spread of SARS-CoV-2 disease and high excess mortality.

Those countries that have successfully fought against the pandemic can be a model for other countries to follow. Since they share similar determinants, countries in the same Cluster should benefit from each other's experiences in dealing with pandemics. Thus, policymakers can make better decisions to mitigate the negative impact of the pandemic on economies.

References:

Abbas, J., Mubeen, R., Iorember, P.T., Raza, S., Mamirkulova, G. 2021. Exploring the Impact of COVID-19 on Tourism: Transformational Potential and Implications for a Sustainable Recovery of the Travel and Leisure Industry. Current Research in Behavioral Sciences, 2. DOI: 10.1016/j.crbeha.2021.100033.

Cartaxo, A.N.S., Barbosa, F.I.C., de Souza Bermejo, P.H., Moreira, M.F., Prata, D.N. 2021. The Exposure Risk to COVID-19 in Most Affected Countries: A Vulnerability Assessment Model. PLOS ONE, 16(3). DOI: 10.1371/journal.pone.0248075.

Diop, S., Asongu, S.A., Nnanna, J. 2020. Covid-19 Economic Vulnerability and Resilience Indexes: Global Evidence. Research Africa Network Working Papers 20/070. DOI: 10.2139/ssrn.3705253.

Gore, P.A. 2000. Cluster Analysis. In: Tinsley, H.E.A., Brown, S.D. (Eds) Handbook of Applied Multivariate Statistics and Mathematical Modeling. Academic Press, 297-321. DOI: 10.1016/B978-012691360-6/50012-4.

Grima, S., Dalli Gonzi, R., Thalassinos, I.E. 2020. The Impact of COVID-19 on Malta and its Economy and Sustainable Strategies. Available at SSRN: https://ssrn.com/abstract=3644833.

Guidici, P., Figini, S. 2009. Model Specification. In: Applied Data Mining - Statistical Methods for Business and Industry. John Wiley & Sons, Inc, 41-146. DOI:10.1002/9780470745830.

Kamenidou, I., Stavrianea, A., Liava, C. 2020. Achieving a Covid-19 Free Country: Citizens Preventive Measures and Communication Pathways. International Journal of Environmental Research and Public Health, 17(13), 4633. DOI: 10.3390/ijerph17134633.

Khan, S., Rabbani, R.M., Thalassinos, I.E., Atif, M. 2020. Corona Virus Pandemic Paving Ways to Next Generation of Learning and Teaching: Futuristic Cloud Based Educational Model. Available at SSRN: https://ssrn.com/abstract=3669832.

Kozicki, B., Gornikiewicz, M., Walkowiak, M. 2020. The Impact of COVID-19 Pandemic on the Economic Security of Russia and European Countries. European Research Studies Journal, 23(3), 324-338. DOI: 10.35808/ersj/1886.

Kukuła, K., Bogocz, D. 2014. Zero Unitarization Method and its Application in Ranking Research in Agriculture. ECREG STUDIES Economic and Regional Studies, 7(3), 6. DOI: 10.22004/ag.econ.265035.

Lee, C., Chen, M.P. 2020. The Impact of COVID-19 on the Travel and Leisure Industry Returns: Some International Evidence. Tourism Economics. DOI: 10.1177/1354816620971981.

Liu, T., Gong, D., Xiao, J., Hu, J., Ganhao, H.G., Rong, Z., Ma, W. 2020. Cluster infections play important roles in the rapid evolution of COVID-19 transmission: A systematic Review. International Journal of Infectious Diseases, 99(374-380). DOI: 10.1016/j.ijid.2020.07.073.

Patel, V.R., Mehta, R.G. 2011. Performance Analysis of MK-means Clustering Algorithm with Normalization Approach. World Congress on Information and Communication Technologies, 974-979.

Raga, S., te Velde, D.W. 2020. Economic Vulnerabilities to Health Pandemics: which Countries are Most Vulnerable to the Impact of Coronavirus. Report. Supporting Economic Transformation, 6-11.

Classification of the EU Countries According to the Vulnerability of their Economies to the Impact of COVID-19 Pandemic

978

Rizvi, S.A., Umair, M., Cheema, M.A. 2021. Clustering of Countries for COVID-19 Cases based on Disease Prevalence. Health Systems and Environmental Indicators. MedRxiv. DOI: 10.1101/2021.02.15.21251762.

Sigala, M. 2020. Tourism and COVID-19: Impacts and Implications for Advancing and Resetting Industry and Research. Journal of Business Research, 117, 312-321. DOI: 10.1016/j.jbusres.2020.06.015.

Tryon, R.C. 1939. Cluster analysis. New York: McGraw-Hill.

UNCTAD. 2020. Global Trade Update. Retrieved from: https://unctad.org/en/PublicationsLibrary/ditcmisc2020d2_en.pdf.

Virmani, D., Taneja, S., Malhotra, G. 2015. Normalization based K means Clustering Algorithm. International Journal of Advanced Engineering Research and Science, 2(2), 36-40.

Walesiak, M. 2014. Przegląd formuł normalizacji wartości zmiennych oraz ich własności w statystycznej analizie wielowymiarowej. Przegląd Statystyczny, 61(2), 363-372.

Wasowska, K., Wincewicz-Bosy, M., Dymyt, M. 2021. The Impact of Covid-19 on Air Transport Operation in Poland. European Research Studies Journal, 24(2), 523-535. DOI: 10.35808/ersj/2140.

WTO. 2020. Trade Falls Steeply in First Half of 2020. Retrieved from: https://www.wto.org/english/news_e/pres20_e/pr858_e.htm.

WTO. 2021. Statistical database. Retrieved from: https://data.wto.org/.

Zarikas, V., Gareiou, Z., Poulopoulos, S.G., Zervas, E. 2020. Clustering Analysis of Countries Using the COVID-19 Cases Dataset. Elsevier, Data Brief No 105787. DOI: 10.1016/j.dib.2020.105787.

Zubair, M., Asif Iqbal, M., Shil, A., Haque, E., Moshiul Hoque, M., Sarker, I.H. 2021. An Efficient K-Means Clustering Algorithm for Analysing COVID-19. In: Abraham, A., Hanne, T., Castillo, O., Gandhi, N., Nogueira Rios, T., Hong, T.P. (Eds). Hybrid Intelligent Systems. Advances in Intelligent Systems and Computing, 1375. DOI: 10.1007/978-3-030-73050-5_43.

Zwart, S., Davradakis, E., Marchitto, B., Santos, R. 2020. The EIB COVID-19 Economic Vulnerability Index - An Analysis of Countries Outside the European Union. European Investment Bank. DOI: 10.2867/812925.