



HDI INDEX DIMENSIONS IN THE CONTEXT OF HYBRID THREATS*

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Abstract. The Human Development Index (HDI index) is considered a summary index of the perception of human well-being in a selected economy. It consists of 3 sub-dimensions: the population's education, health and income. It is considered a vital indicator of the perception of the state of human development, and based on it, countries are compared in the mentioned areas. Our contribution aims to analyze the position of European countries in the context of the HDI index and, at the same time, to apply expanded indicators of education and health. Subsequently, we apply these new, supplemented dimensions in comparing the selected countries and in the context of hybrid h. Within the methodology, we use the methods of agglomerative cluster analysis and paired T-test.

Keywords: HDI index; education; income; health; Europe

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JEL Classifications: J24, O15, J10

1. Introduction

Scientific literature that discusses human capital often focuses on its definition in relation to economic growth and development. However, little attention has been paid to studies on the relationship between human capital and life expectancy, education, health, or the impact of hybrid threats on social development (Sentürk et al., 2023)

When studying Human Development, one must orient oneself to a broader concept, sustainable development. This includes environmental, economic and sociodemographic elements. A standard definition of the term is "meeting the needs of the current population in a way that does not prevent the meeting of the needs of future generations" (UN. Report of the World Commission on Environment and Development, 1987).

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According to Dao & Khuc (2023), sustainable growth, the common goal of every country, is only possible with human capital development. This represents the workforce's knowledge, skills and competencies (Mathur 1999).

The Human Development Index (HDI) is an index that measures key dimensions of human development. The access to education dimension is essential. This dimension is measured by the expected years of schooling of children of school age and the average years of schooling of the adult population. Another dimension is Long and Healthy Life, measured by average life expectancy. The last is the standard of living, measured by the gross national income per capita adjusted according to the country's price level. (Ranis et al., 2006)

The HDI index, which is the result of the work of the UN, has become an essential alternative to the traditional one-dimensional measurement of development (e.g., GDP, GNP). Many blame this "modern" indicator for the absence of an environmental dimension. (Sagar & Najam, 1998)

Several modifications were also achieved as part of the approach to the HDI index. It is primarily a general index that allows for calculating the percentage of individual dimensions on the overall success, thus identifying the attributes that are susceptible to achievement. This model also takes into account factors of the political environment of the analyzed country. (Chakravarty, 2003)

Several authors (Cahill, 2005; Sihite et al., 2021; Alijanzadeh et al., 2016) state that using the income dimension in the index is inappropriate, and the results are irrelevant due to the lack of year-to-year comparability. They also believe that the index is robust to measurement error and that the evaluation of the countryside based on other measures of the economy is significantly different. One of the first steps for evaluating the countries was to summarize the European Union's human development index data. It was then analyzed for the period 1980-2013 using general estimating equations to see if there was a trend over the years. (Aktaş & Karagöz, 2015)

Two categories of technical problems related to the 1995 HDI that affected the model's predictive power were also discussed. (Norbakhsh, 1998) While criticizing the nature of the Human Development Index, he proposes a different way of constructing the HDI to capture the net flow of human development in terms of material well-being, health and education. (Bagolin & Comim, 2008)

2. Research carried out in the conditions of Slovakia and other countries

The author's research (Michálek, 2002) confirmed the different levels of human development in the regions using the human development index based on social, demographic and economic statistical data. The results clearly show the differences between parts of the country - specifically between the regions of the northwestern and south-eastern parts of Slovakia. The HDI index's favourable values were recorded in western Slovakia's urban areas. Conversely, lower rates were observed in south-eastern Slovakia. The following study focussed on the correlation analysis of gross domestic product per capita and the human development index in the Vyšehrad Four and some Balkan countries. In most regions, the correlation was high, above 0.9. The author emphasizes the GDP performance indicator, which, according to her, is one of the best ways to compare different economies. (Hudáková, 2017)

GDP per capita is a primary measure of economic development and prosperity worldwide. However, it is a limited measure of living standards aimed at capturing changes in economic output per person and neglecting many things necessary for quality of life. For this reason, the HDI model was proposed, which, in addition to GDP, also includes the education and health of citizens. (Broček & Lalinský, 2017)

Based on world HDI research, Europe has the highest HDI with a significant advantage over the world average. On the other hand, African countries have acquired low HDI values and, therefore, should focus on increasing the

dimensions of the HDI indicator for all their citizens, which will also lead to peace and overall well-being. Asia, North America, South America and Oceania do not differ significantly in their HDI. (Kpolovie et al., 2017)

The results of the author's study (Sarabia et al., 2020) show a high correlation between the human development index and the level of corruption. This was due to the impact of the 2008 financial crisis on EU citizens. The research of the collective around the authors Cieřlik et al. (2016) presents the role of summary indicators of human development, such as the Human Development Index and its components over the standard set of variables of the international trade model. The author notes that aggregated and disaggregated human development indicators affect the volume of international trade flows.

The results of research in the area of the HDI index also serve as a proposal for health policymakers, which will be aimed at solving the increasing morbidity and mortality, especially among women over 65 years of age, in regions with poorer access to prevention and treatment services. Increased values were observed in Latvia, Bulgaria and Poland. (Mohammadian et al., 2017) As measured by the Human Development Index, the prevalence of coronary heart disease is growing in developing countries while decreasing in developed countries. For this reason, future research must pay more attention to the appropriate allocation of medical resources and the control of risk factors for coronary heart disease in world regions. (Zhu et al., 2016) In the field of health issues, the importance of HDI is very high, as confirmed by research that points to the disproportionate current and future burden of ovarian cancer in countries with lower HDI levels and calls for global action to reduce the burden and inequality of ovarian cancer in access to quality oncological care and treatment. (Cabasag et al., 2022)

Analysis and comparison of HDI information with indicators from other countries and their publication can promote positive societal changes. Many researchers suggest combining the HDI with other indicators and dimensions. For this reason, researchers have introduced a sustainable HDI based on a multidimensional synthesis of other indicators and developed new classification methods and clustering methodologies that can be used to monitor sustainable human development. (Shek & Wu, 2018; Myers et al., 2018; Berman, 2021)

The research also improved the version of the Education Index based on the data available from the PISA assessment. This new index considers the social impact of school years and the results of education systems in each country. As a result of this finding, it is necessary to change the construction of the HDI index, according to the authors. (Grisolia et al., 2022a, 2022b) We can also monitor the development of the HDI indicator with respect to environmental and energy indicators. (Lima et al., 2022; Zhang & Wu, 2022; Hwang et al., 2023, Conigliani et al., 2023)

The behavior of citizens in the country in the area of paying taxes is an essential factor in human development. The tax system is one of the main instruments by which the state exercises sovereignty through collecting, allocating and redistributing income in a given territory. The research pointed to the characteristics of tax systems and the effectiveness of government measures in relation to human development in the member states of the European Union. (Dronca, 2016)

The HDI index is also important when analyzing the behavior of citizens in the field of waste management. The authors used data from ten European countries to investigate the impact of gross domestic product, human development index, unemployment rate, and CO2 emissions on the generation rate of thirteen solid waste streams. Regression modelling was performed between the rate of waste production and each of the four indices, and significant correlations were calculated. (Namlis & Komilis, 2019)

The results of the cluster research show that European countries are grouped into four clusters according to the values of the HDI Index. Based on the results of the research analysis, European social policies should be better

designed and implemented with increased public spending to increase the population's living standards and reduce the differences between European citizens. (Androniceanu, 2022)

3. Methodology of the paper

In the research section, we will analyze selected factors that are part of the Human Development Index indicator. We will look closer at the construction of the formula and its development over the last 5 years. Subsequently, we will compare the results for the areas of education and health with other variables in relation to the GDP of selected European countries. We will also perform a clustering analysis using the data included in the

HDI index and compare them with the results of clustering our selected factors.

As part of the scientific contribution, we set three scientific questions to which we will direct our research:

1. *Are there significant differences in clusters according to the HDI index and its dimension?*
2. *Are there significant differences in the clustering of countries according to the COFOG budget classification of education and health indicators compared to the HDI index?*
3. *Is there statistical significance between the births of the HDI index and its dimensions (health, education, income) before and after the spread of the COVID-19 disease?*

We used agglomerative cluster analysis with Euclidean distance and Ward's method as part of the methodology. Subsequently, we also performed descriptive statistics and paired t-testing of variables for individual analyzed variables.

Data for the values of the HDI index and its components were analyzed for 2017 to 2021 (as the last available year is 2021) and represents 5 years. We obtained the data through the Human Development Report portal (<https://hdr.undp.org/>).

The Human Development Index (hereinafter referred to as "HDI") is a tool that compares the factors of education, health, poverty and other factors of life developed by the United Nations. It represents a means of comparing critical dimensions of human development. The resulting calculation of the indicator consists of a combination of three dimensions and looks as follows:

$$HDI = \sqrt[3]{Health\ index * Education\ index * Income\ index} \quad (1)$$

HDI indicates the standard of living and expresses the geometric mean of indices that express health, income and education. The HDI index takes on values from 0 to 1, which places countries in one of four levels of development: above 0.80 - very high human development; between 0.70 and 0.80 - high human development; between 0.55 and 0.70 - medium human development and below 0.55 - low human development. If the value of the index is low, it declares a low level of human development in the state and vice versa. The following graph shows the achieved values of the HDI index for the year 2021 together with the individual partial parameters of the formula.

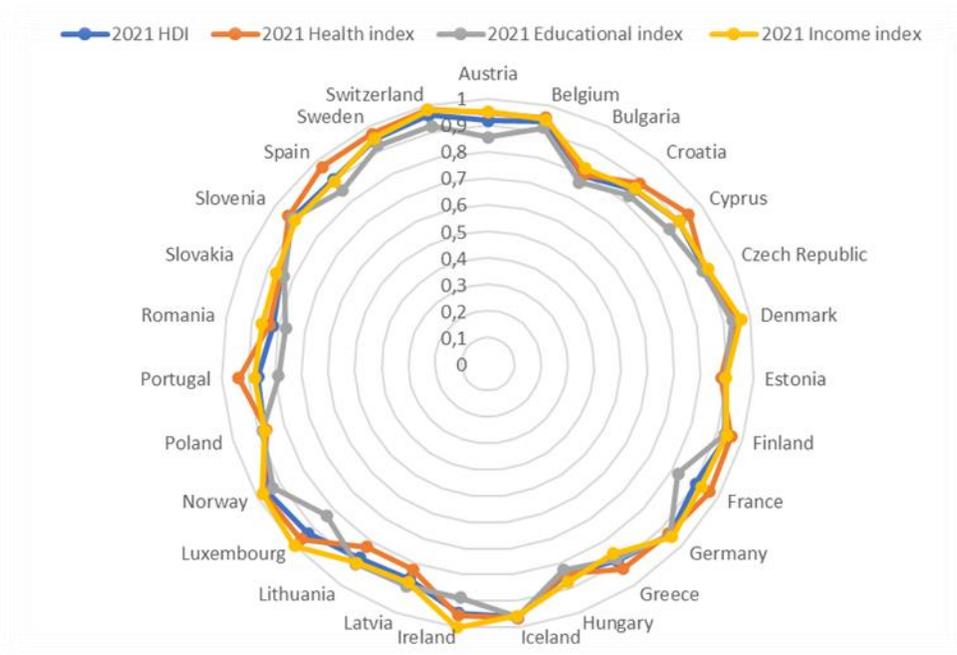


Figure 1. Development of the HDI indicator and its components in the analyzed countries
 Source: own processing

4. Results

We will monitor the HDI index for 5 years (specifically, 2017-2021), as the year 2022 is not evaluated in the statistics. We analyzed part of the results of the share of healthcare and health in the countries' GDP for the last year when data were available. As a statistical tool for processing the results, we used the R-studio and JASP programs. In our case study, we will focus on 27 European countries. In the following section, we can present the descriptive statistics of the analyzed variables.

Table 1. Descriptive statistics of the analyzed variables

	Valid	Median	Mean	Std. Deviation	Variance	Skewness	Kurtosis
% of GDP Health 2021	27	7.344	7.210	1.693	2.865	-0.366	0.120
% of expenditure Health 2021	27	15.533	15.40	2.841	8.072	-0.247	1.358
% of expenditure Education 2021	27	10.864	11.07	2.124	4.509	0.486	0.046
% of GDP Education 2021	27	5.013	5.121	0.978	0.957	0.225	1.293
2017 HDI	27	0.897	0.898	0.042	0.002	-0.327	-0.741
2018 HDI	27	0.901	0.901	0.042	0.002	-0.351	-0.624
2019 HDI	27	0.905	0.904	0.041	0.002	-0.428	-0.507
2020 HDI	27	0.898	0.900	0.042	0.002	-0.436	-0.405
2021 HDI	27	0.903	0.901	0.045	0.002	-0.493	-0.414

Source: own processing

In addition to the HDI index and its components, we also analyzed the descriptive statistics of another 4 indicators (the share of budget expenditures on health and education and the share of these categories in the country's GDP). In the next part, we will perform a statistical analysis, which we call clustering, by which we mean a set of statistical and mathematical techniques through which we can identify clusters.

A cluster represents a set of identifiable countries that are close to each other and similar, when, however, countries belonging to other clusters are different and distant in terms of characteristics - in our case, different - the basics of the HDI indicator for the years 2017-2021 and its components. We thus used 20 indicators to use this analysis.

Different groups of object similarity measures can measure the similarity between countries. The selection of individual similarity measures also depends on the observed characteristics, the values of which characterize the countries under study.

Country clustering aims to find groups of similar countries in our data. In our work, we will use a hierarchical approach, the essence of which is that the number of clusters of countries is not known at the beginning of the analysis. This approach allows analysis for smaller selections of research objects.

We correlated the input variables at a significance level of 5% ($\alpha = 0.05$), where we observed the variables' dependencies. However, a high degree of dependence between variables can be a problem, which can affect the classification results. Decomposition of the problem can be achieved through the method of principal components, in which the input indicators are transformed into new variables. These new variables, called principal components, are already mutually independent.

We only need to use 2 principal components to explain more than 82% of the variability of the original ensemble. So, we have met the rule that the number of principal components explains at least 70% of the total variance of the data.

Subsequently, we plotted the clusters in a hierarchical tree, where individual clusters are marked. We can see that 4 clusters have been created, which are heterogeneous from each other, but the companies within their cluster are homogeneous. We chose a heuristic approach to count the clusters.

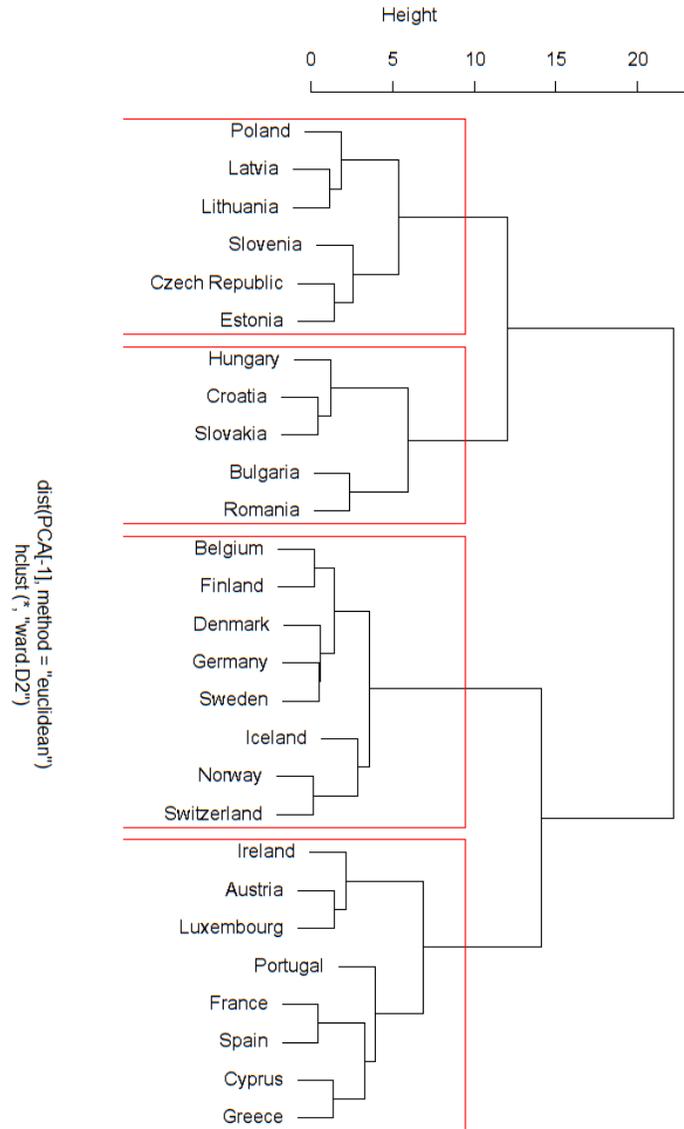


Figure 2. Clustering dendrogram
Source: own processing according to JASP

We can see that within our 4 clusters, these clusters are evenly distributed and we do not record any extreme fluctuations between countries. Slovakia is found in a group with Hungary, Croatia, Bulgaria and Romania, which shows that compared to the achieved numerical results of the HDI index, it places us in a group with a higher HDI index. Still, compared to European countries, we achieved worse results. On the contrary, the cluster that we can consider the best - because it achieves the best results - is the cluster of Belgium, Switzerland, Scandinavian countries and Germany. Here, the index HDI reaches the number 1, i.e. the best result.

In the previous part, we presented the results of the clustering of countries through the HDI index and its sub-parameters - health, education and income. Essential to our research is whether other variables can change the results of the classification of countries into clusters.

We are based on the share of individual health and education variables on the countries' GDP. For the field of education, these were the following indicators: Pre-primary and primary education, Secondary education, Tertiary education Education not definable by level, Subsidiary services to education, R&D Education, Education n.e.c.

We note that it was a share of GDP from the point of view of the COFOG budget classification within the national accounts of individual countries. For the area of health, we again used indicators that reflect their share in the country's GDP. These are the following indicators: Medical products, appliances and equipment, Outpatient services, Hospital services, Public health services, R&D Health and Health n.e.c.

In this case, we again analyzed the same countries but with different indicators. As in the scanning method, we will use Euclidean distance and Ward's method.

The method of principal components, which excludes the negative influence of the inter-correlation of the input variables, concluded that it is necessary to use 7 principal components that explain more than 80% of the variability of the original data. Based on the heuristic principle, we then determined five clusters. The following graph reflects the results.

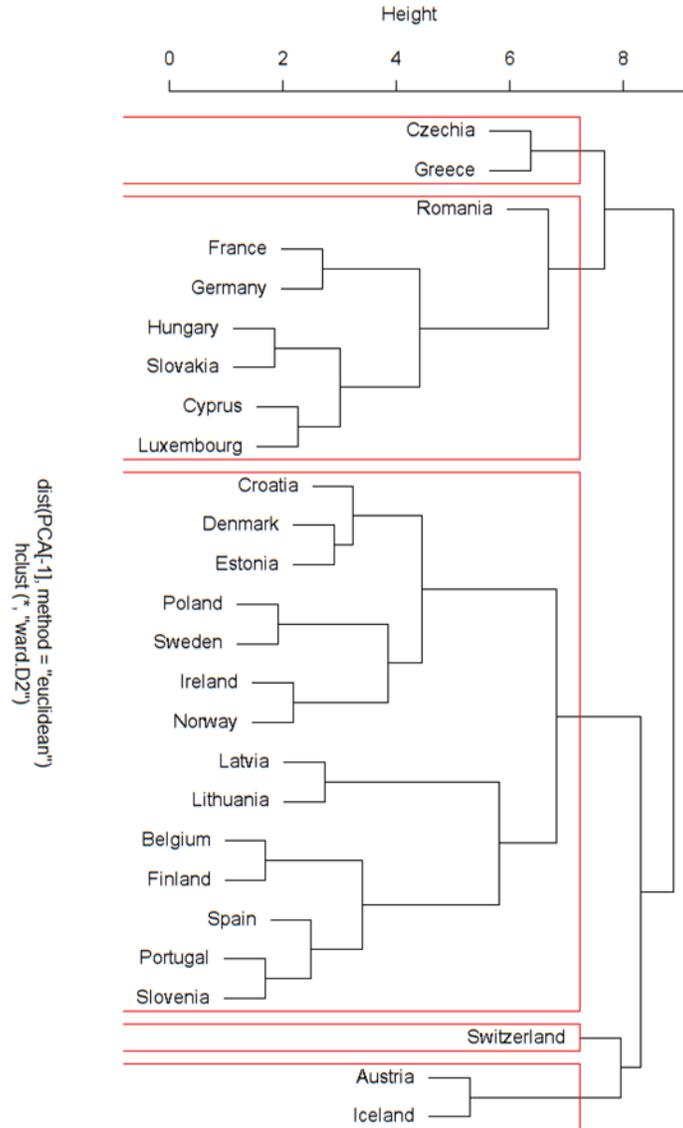


Figure 3. Clustering dendrogram
 Source: own processing according to JASP

From the dendrogram (hierarchical tree), we can conclude that the countries of Switzerland, the Czech Republic, Greece, Austria and Iceland reached values that set them apart and thus created separate clusters. The reason is, for example, in the case of Switzerland, a higher representation of the country's expenditures on selected areas of education and health than in other countries. Slovakia is among the countries with Romania, Hungary, France, Germany, Cyprus and Luxembourg. However, if we were to create an even larger number of clusters, we would find that Slovakia can be compared with neighboring Hungary in terms of its expenditure on healthcare and education.

Thus, the comparison of the HDI index and its components and selected COFOG budget classifications in the area of health and education yielded different results for the countries achieved by the clustering method.

We also tried to answer the research question regarding the change in values before and after COVID-19. Performing a t-test will give us a closer answer. A paired t-test is used to compare the values of a variable for the same country in two different experimental conditions (before and after the crisis caused by COVID-19).

Table 2. Paired Samples T-Test

Measure 1	Measure 2	Test	Statistic	z	df	p
2017 HDI	- 2021 HDI	Student	-2.584	-2.426	26	0.016
		Wilcoxon	80.000			
2017 Health index	- 2021 Health index	Student	2.619	2.030	26	0.015
		Wilcoxon	273.500			
2017 Educational index	- 2021 Educational index	Student	-3.553	-3.200	26	0.001
		Wilcoxon	38.000			
2017 Income index	- 2021 Income index	Student	-5.022	-3.915	26	< .001
		Wilcoxon	17.000			

Source: own processing

For statistical testing, we used two performed tests: students and Wilcoxon test. We performed the test at an alpha level of 0.05. The difference between the first and second assessments is statistically significant for all analyzed variables, as the p-value is lower than 0.05. The results could be predicted depending on the conditions we observed in connection with the pandemic in European countries. Expenditures on education and healthcare were increased, and citizens' incomes were adjusted and increased in connection with the problems of the economy.

During the analysis of the HDI index, characteristics suitable in the field of security, stability, resilience, technological development and the creation of national strategies implementing joint activities carried out by the government or other organizations or institutions were arrived at. These bodies aim to ensure the solution of security problems. (Valdivia-Granda, 2021) Social indicators that affect the long-term viability of hybrid systems modeling in society were analyzed by Sawle et al. (2018). From his point of view, these are important parameters that need to be considered. Several authors have taken into account the inclusion of social variables, primarily the HDI index or its partial parts.

The impact of the HDI index has been analyzed by several authors in connection with hybrid threats and hybrid wars among security communities around the world since 2000. It has increased exponentially after the conflict in Russia's Ukraine in 2014. Several research studies confirm the importance of the social impact of the HDI index, and this social context is intended to serve as a tool for changing the strategy of the attitude towards the hybrid threat. (Bingöl et al., 2017)

5. Discussions and conclusion

In the results of the study by the authors Salman Iqbal et al. (2023), it is stated that the competitiveness of each country depends on the quality of the business environment, institutions, science and research, innovations, but especially on the development of human capital.

HDI index represents a tool based on which we can measure the human development of a given region. From the point of view of several authors, it represents one of the noisy indicators we can use for international comparisons of education, income and health care. In our scientific paper, we analyzed not only the HDI index, but also other variables related to it. In our case study, we tried to solve the following questions.

Are there significant differences in clusters according to the HDI index and its dimension? The countries we analyzed in our research achieved an average HDI index of 0.90 in 2017-2021, which means that the values are at

a very good level and have a growing character. Of course, there are slight differences between the analyzed countries, which we attributed to the different values of the dimensions of education, health, and income within the framework of the country's ranking. The Slovak Republic found itself in a cluster with countries at the bottom of the analyzed countries within the HDI index, even though the value of the index increased year-on-year.

Are there significant differences in the clustering of countries according to the COFOG budget classification of education and health indicators compared to the HDI index? The clustering of selected parameters of education and health confirmed our assumptions, and we achieved statistically different results. The reason was the more detailed inclusion of health and education components and their share of GDP in the cluster analysis. The results revealed that the Slovak Republic was included in a cluster with countries that can be considered the core of Europe. Still, when looking more closely at the results of the hierarchical clustering tree, we must state that we are at a very similar level to Hungary. On the other hand, Switzerland became independent, spending rapidly more on education and health than other countries. The results of clustering using the factors of the HDI index and its dimension and clustering using the factors of the share of GDP for education and health yielded different results.

Is there statistical significance between the births of the HDI index and its dimensions (health, education, income) before and after the spread of the COVID-19 disease? In this area, we had come to interesting results where we can state that the values, especially in the income area from before and after the crown period, achieved statistically significant changes. We also recorded changes in education and health, probably the most related to the coronavirus period. In these areas, there was not only an increase in interest but, above all, an increase in the expenses of the state budgets of individual countries.

A new index has been introduced to quantify, measure and monitor progress towards the goals of the Europe 2020 strategy. It consists of relevant, accepted and reliable indicators presented by the European Commission. The new index shows that it can be a valid measure to assess the overall competitiveness of countries and that the most critical factors for the success of this strategy are good governance and social capital. It also includes the dimension of human development. (Pasimeni, 2013)

In the future, we will undoubtedly supplement the mentioned study with the effects of education (Grisolia 2022; Vergara et al., 2022), which plays an essential role in the HDI index.

We also want to focus on analyzing the relationship between the hybrid threat and the results of the HDI indicator. Above all, it will identify factors that can influence the applicability of the HDI index.

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