GLOBAL HEALTH SECURITY (GHS) INDEX MODEL EXTENSION AND ASSESSMENT OF THE WESTERN BALKAN COUNTRIES POSITION

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ABSTRACT: The paper discusses the assessment of global health security based on the extension of the Global Health Security (GHS) index basic model (prevention, detection and reporting, rapid response, health system, compliance with international standards, and environmental risk) with parameters: Gross Domestic Product (GDP) per capita, Democracy Index (DI) and Corruption Perceptions Index (CPI), using multiple linear regression analysis (MLRA) and artificial neural networks (ANNs). Based on the size of the coefficient of determination (R2), the validity of the extension of the basic GHS model was evaluated based on the results achieved on a sample of 42 countries. In the second part of the study, the results of individual segments of the international safety assessment of health systems for the countries of the Western Balkan (WB) countries are discussed, by comparing them with countries of similar size in the EU. The results showed that health security systems in WB countries are at a much lower level compared to countries of similar size in the EU, which was also reflected in the COVID 19 pandemic during 2020 and 2021. In WB countries, in the post-pandemic period, the consequences in different areas (human health, economy, culture, education, etc.) will be much more visible in relation to EU countries with a significantly higher degree of development of health systems defined by the GHS model.

KEYWORDS: *GHS model, GHS model extension, EU, Western Balkan countries*

INTRODUCTION

The Ebola epidemic in 2014 initiated the World Health Organization (WHO) to start the process of building health prediction systems for local health systems to predict and prevent a pandemic. In 2015, the International Health Regulation (IHR) formed an international team organized by the Nuclear Threat Initiative (NTI) and the Johns Hopkins Center for Health Security (JHCHS) in collaboration with the Economist Intelligence Unit (EIU), which publishes a report on Global Health Security (GHS) index each year, which scans the state of the health system in each country and its ability to adequately respond to a pandemic (Dalglish, 2020). The COVID-19 pandemic, which occurred at the end of 2019 (Lincoln, 2020), which affected the whole world and lasted for more than a year and a half without clear indications of its end, confirms the justification of creating GHS and its analysis (Shahbazi and Khazaei, 2020).

The basic structure of the GHS index model consists of answering 140 questions that are classified within 85 sub-indicators, and those in 34 indicators that are classified into 6 categories: Prevention, Detection and Reporting, Rapid Response, Health System, Compliance with international standards and Risk Environment. To calculate the GHS index for 2019, the results for 195 countries in the world were processed, which included all European countries for the processing of which 21 experts from 13 countries were hired (GHS, 2020). Modeling of sub-indicators, indicators, and categories within the GHS model gives a result in the range of 0–100 for each country, where the value of 100 indicates the most favorable position, i.e. perfect health security conditions, and 0 the worst position with the worst health security capacity, measured using the criteria defined in the GHS (GHS, 2020).

Today, the GHS index is considered an objective tool for a realistic assessment of the readiness of individual countries to provide adequate responses to the prevention and fight against the emerging pandemic (Abbey et al., 2020), which reflects the threat to human health and the country's economic system as a whole.

The basic GHS index, in this study, was extended by the influence of the economic parameter (Gross Domestic Product (GDP) per capita) and the parameters of social relations through the Democracy Index (DI) and the Corruption Perceptions Index (CPI) (Bhattacharyya and Hodler, 2009). The research in this paper was conducted based on the results for 42 European countries (Živković and Panić, 2021).

RESEARCH METHODOLOGY AND RESULTS DISCUSSION

To predict the dependence of the size of the GHS index (dependent variable Y that defines the level of security of a country's health system) on influencing factors (input variables X_1–X_6), and then expanded with GDP per capita, DI, and CPI (X_7–X_9), statistical methods Multiple Linear Regression Analysis (MLRA) (Ho, 2006) and Artificial Neural Networks (ANNs) (Arsić et al., 2020) were applied, using the SSPS software package (Landau and Everitt, 2004).

In this model, the following predictors were used: X_1 – Prevention, X_2 – Detection and reporting, X_3 – Rapid response, X_4 – Health system, X_5 – Compliance with international standards, X_6 – Risk environment (https://www.ghs-index.org/); X_7 – GDP per capita (https://en.wikipedia.org/wiki/List_of_Countries_by_GDP_(nominal)_per_capita); X_8 – Democracy Index – DI (https://en.wikipedia.org/wiki/Democracy_Index); X_9 – Corruption Perceptions Index – CPI (https://en.wikipedia.org/wiki/

Table 1.

Descriptive statistical analysis of the input and output values of parameters of the model

Variable	Range	Minimum	Maximum	Mean	Std. Deviation	N
X_1	61.7	19.4	77.9	51.96	13.339	42
X_2	68	29	81.1	60.89	18.603	42
X_3	70.2	21.7	97	48.67	15.475	42
X_4	48.3	21.9	91.9	44.50	12.399	42
X_5	55.4	25.8	70.2	56.84	10.447	42
X_6	43.8	43.3	81.2	69.84	11.623	42
X_7	106.2	3.4	87.1	30.26	24.439	42
X_8	7.39	2.48	109.6	7.34	1.671	42
X_9	59	28	9.87	58.90	18.036	42
Y	42.6	35.3	77.9	54.83	11.1151	42

Corruption_Perceptions_Index). As an outcome, i.e. output of the model (Y), the GHS index is defined (https://www.ghs-index.org/).

MLRA is one of the most commonly used methods for modeling the dependence between two or more independent variables (predictors) and one dependent target variable, by adjusting the coefficients in the linear equation for each variable $i = 1,..., n_i$ (Živković et al., 2009). MLRA refers to examining the relationship between two or more variables, using the same set of paired variables taken from the same set, with a focus on prediction. As for a prediction, if two variables are in perfect correlation, then knowing the value of one variable allows predicting the results of another variable, i.e. the result of one variable can be used to predict the result of another variable (Ho, 2006).

The effect of MLRA application for defining the linear dependence $y = f(xi) + a$ is measured by the value of the coefficient of determination (R^2), which in many cases does not give good results, so in that case, nonlinear models are used (Živković et al., 2009; Arsić et al., 2020). As a result of the MLRA over the available data set, a prediction equation was obtained:

$$Y=a+b\_1 X\_1+b\_2 X\_2+...+b\_n X\_n$$

where *Y* represents the dependent variable that is predicted, *a* is a constant, *b* is a non-standardized regression coefficient, and *X* is the value of the predictor.

Table 1 shows the values of descriptive statistical analysis for all nine input parameters (X_1–X_9), as well as for output parameter Y, for 42 European countries.

Table 2.

Correlation matrix for inputs and output of the model

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Y	1									
X_1	0.886**	1								
X_2	0.811**	0.689**	1							
X_3	0.819**	0.637**	0.485**	1						
X_4	0.812**	0.669**	0.455**	0.782**	1					
X_5	0.723**	0.655**	0.541**	0.505**	0.432**	1				
X_6	0.668**	0.576**	0.441**	0.401**	0.583**	0.440**	1			
X_7	0.445**	0.352*	0.247	0.280	0.420**	0.243	0.801**	1		
X_8	0.631**	0.568**	0.513**	0.324*	0.444**	0.484**	0.861**	0.752**	1	
X_9	0.723**	0.591**	0.509**	0.504**	0.637**	0.452**	0.927**	0.848**	0.853**	1

Note: ** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

In order to define the correlation dependence of the output parameter of the model (Y) as a function of the input parameters (X_1–X_9), bivariate correlation analysis was performed, and thus Pearson correlation coefficients with the appropriate degree of statistical significance were calculated (Table 2).

The obtained values of Person's correlation coefficients indicate a high degree of correlation between Y and X_1–X_9 higher than 0.6** (**statistical significance of 0.01), except between Y and X_7 (GDP per capita), where the value of this coefficient is 0.445**, which indicates that the problems in the level of health security are more dependent on organizational resources than material ones. Correlations between individual predictors in the model are significant, with a high level of statistical significance, except for the correlation of X_7 with X_2, X_3 and X_4 (0.247, 0.280, 0.243, respectively) without statistical significance, which indicates that their significant improvement does not require material conditions, but goodwill and interest of state bodies, as evidenced by significant correlations of X_8 and X_9 with X_2, X_3, and X_4.

EXPANSION OF THE BASIC GHS INDEX

The expansion of the basic GHS index was done gradually, by defining the dependence of GHS (Y) on GDP (X7), DI (X8), and CPI (X9), as well as the simultaneous dependence on X7–X9 using data for 42 European countries. Using the MLRA, the dependences Y = f (X7); Y = f (X8); and Y = f (X9) were defined, as well as Y = f (X7, X8, X9), shown by following equations, with the values of the coefficient of determination (R2), respectively.

$$Y=48.697+(0.203\cdot X_7) \qquad R^2=0.198$$

$$Y=24.020+(4.199\cdot X_8) \qquad R^2=0.399$$

$$Y=28.568+(0.446\cdot X_9) \qquad R^2=0.523$$

$$Y=16.044-(0.279\cdot X_7)+(0.776\cdot X_8)+(0.705\cdot X_9) \qquad R_2=0.628$$

Based on the defined dependencies shown by equations (2)–(5), Figures 1 to 4 show the relationship between the calculated values of the GHS index and the measured values of the basic GHS model with the coefficient of determination R^2: 0.076, 0.343, 0.479, and 0.477, respectively.

Figure 1

Dependence between Regression adjusted (press) predicted and GHS (Overall Score) values, by extending the basic GHS model with GDP per capita values

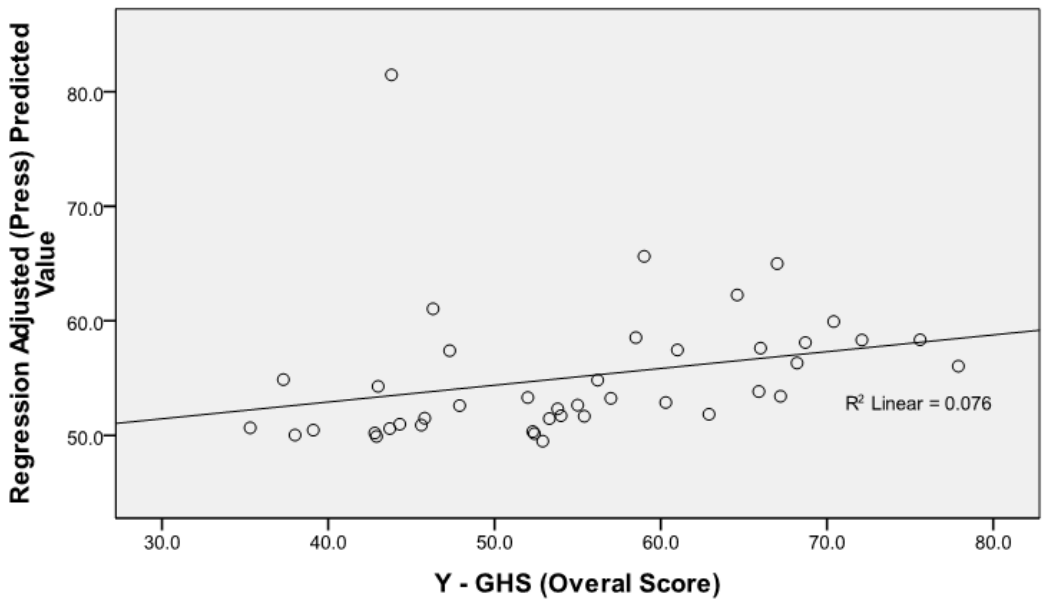


Figure 2

Dependence between Regression adjusted (press) predicted and GHS (Overall Score) values, by extending the basic GHS model with DI values

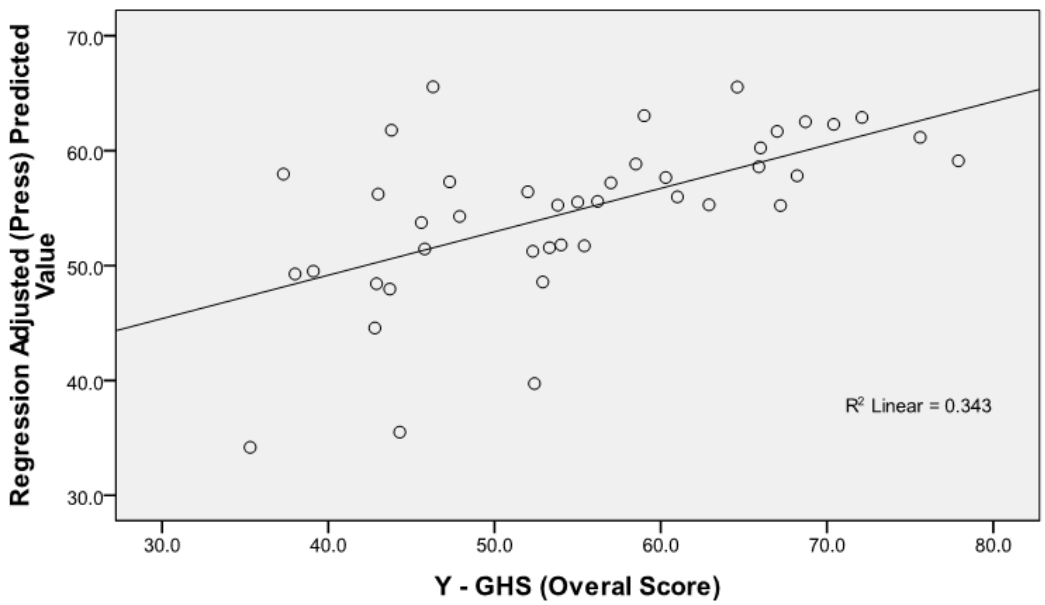


Figure 3

Dependence between Regression adjusted (press) predicted and GHS (Overall Score) values, by extending the basic GHS model with CPI values

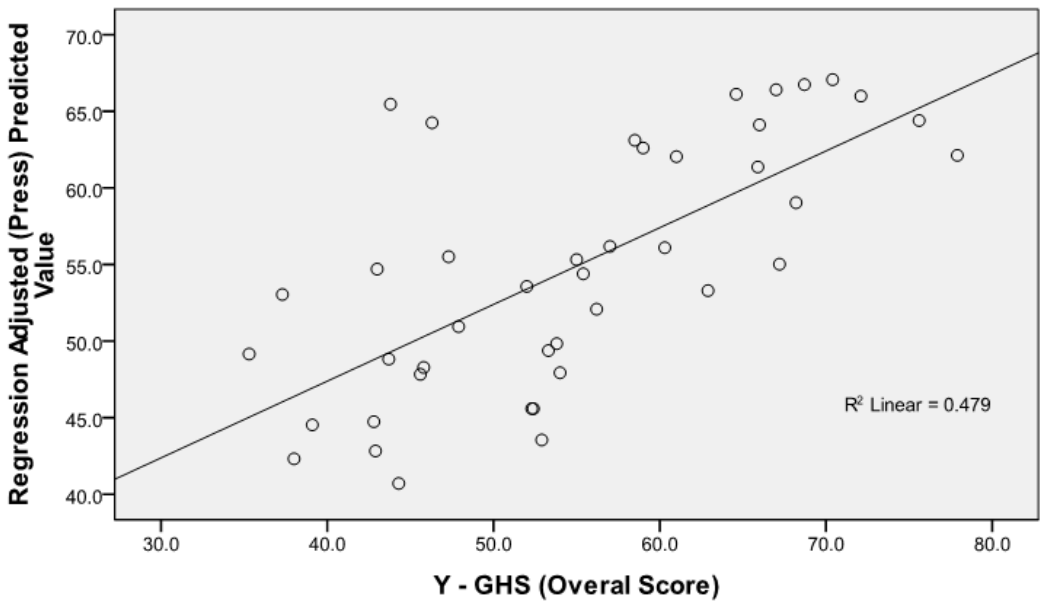


Figure 4

Dependence between Regression adjusted (press) predicted and GHS (Overall Score) values, by extending the basic GHS model with GDP per capita, DI, and CPI values

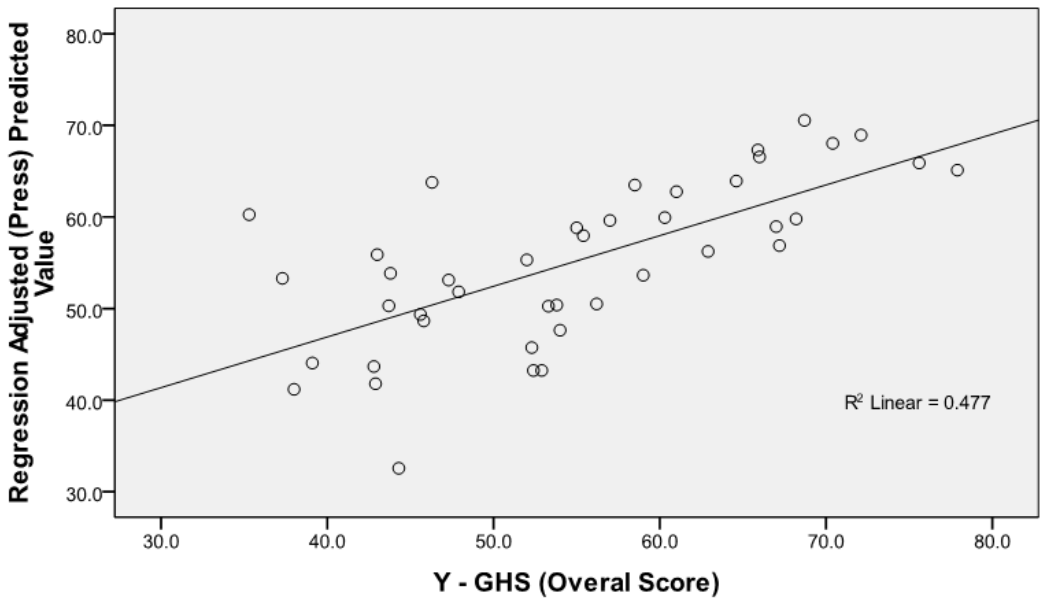
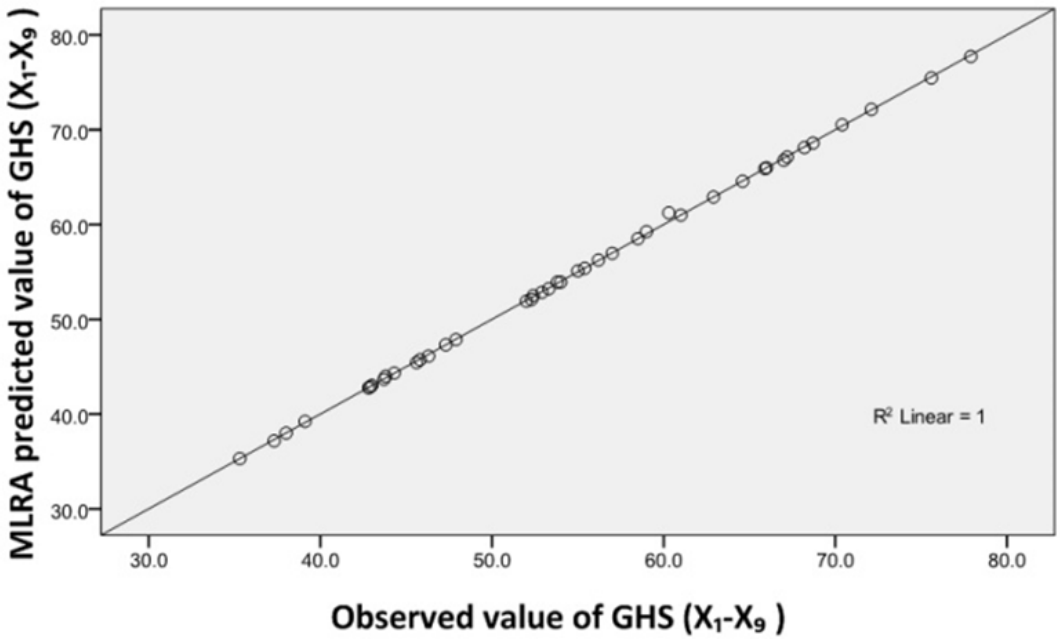


Figure 5

Dependence between MLRA predicted and GHS (Overall Score) values (X1–X9)



Since the obtained results indicate a significant correlation of GHS index values with expanding predictors (GDP per capita, DI, and CPI), the GHS index value was calculated based on both basic and expanding $Y = f(X_1 – X_9)$, and the dependence of the calculated values of Y according to the extended model with the measured values is shown in Figure 5.

The obtained results shown by the above mentioned equation, as well as in the diagram in Figure 5 with the coefficient of determination $R^2 = 1.00$, indicate the justification of expanding the basic model of the GHS index with the economic parameter of the country (GDP per capita), as a predominant factor for the health system of a country, as well as the significant influence of social relations factors (DI and CPI).

The validation of the GHS index extension using the MLRA model was performed using the nonlinear ANNs model. The ANNs architecture used in this study is shown in Figure 6, where a relative error value of 0.4% was achieved in the training phase, while in the testing phase it was 0.6%, with a coefficient of determination $R^2 = 0.996$.

Figure 6

ANNs structure for Y = f (X1–X9)

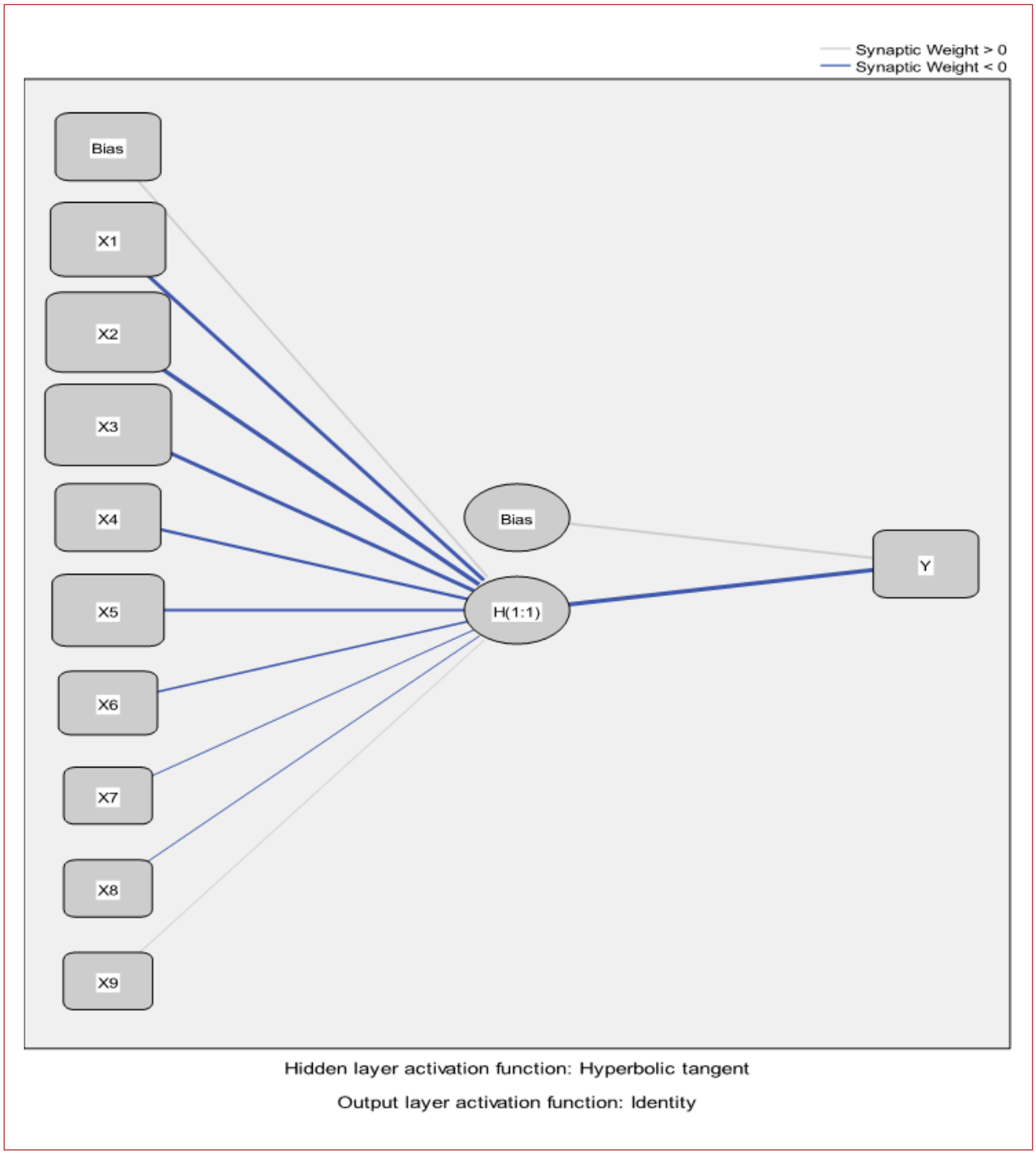
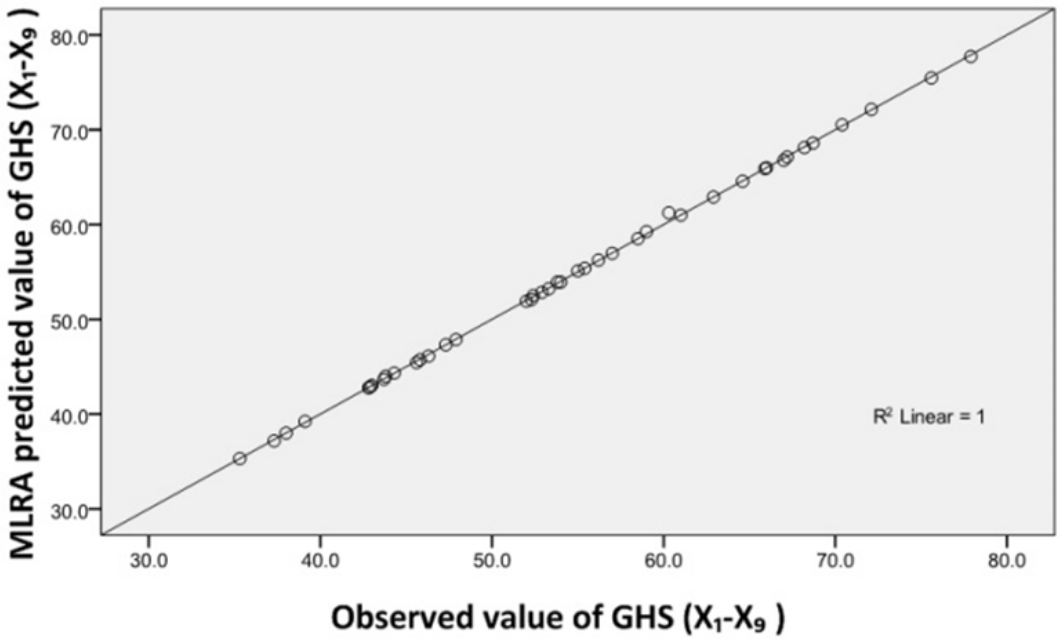


Figure 7 shows the relationship between the calculated values of the GHS index extended with the predictors GDP per capita, Di, and CPI (X_1–X_7) using the ANNs and the recorded values of the GHS index, with the coefficient of determination R^2 = 0.988. The obtained results confirm the justification of the expansion of the basic GHS index by the influence of the predictors GDP per capita, DI, and CPI.

Figure 7

Dependence between ANNs predicted and observed values of GHS (X1–X9)



THE LEVEL OF HEALTH SYSTEMS SECURITY IN WB COUNTRIES

The Western Balkans (WB) countries – Albania, Montenegro, Northern Macedonia, Serbia, and Bosnia and Herzegovina are relatively low ranked in the world according to the GHS index, at 39–90 out of 195 ranked countries in the world and 26–40 out of 42 ranked European countries, which indicates a relatively low level of security of health systems in these countries compared to EU countries of similar size (Table 3).

The size of GDP per capita in WB countries is in the range of 4.8–8.5 103$, and in countries of similar size in the EU it is in the range 17.2–58.5 103$. At the same time, social relations measured through DI, in WB countries range from 4.86–6.49 and in comparable EU countries 7.49–9.01, and CPI in WB countries is in the range: 36–45, and in comparable EU countries in the range 60–87, which show the results of providing adequate responses of health systems to threats in the conditions of the COVID-19 pandemic in these countries.

Table 3 shows the results of the assessment of the security of health systems in WB countries in relation to countries of similar size in the EU, comparing ranked positions in the world and in Europe based on the size of the basic GHS index, as well as the ratio of additional predictors (GDP per capita, DI and CPI).

Table 3.

Assessment of the level of the health system (GHS index) and the size of GDP per capita, DI and CPI in: a) WB countries and b) Comparable countries of similar size in the EU

Country	GHS index (0–100)	Rank in the world (195 countries)	Rank in Europe (42 countries)	GDP per capita (10^3 $)	DI (0–10)	CPI (0–100)
a) WB countries:						
Serbia	52.3	41	26	8.5	6.49	39
N. Macedonia	39.1	90	40	6.0	5.97	35
Albania	52.9	39	24	4.8	5.89	35
B&H	42.8	79	39	5.7	4.86	36
Montenegro	43.7	68	35	7.9	5.65	45
b) Comparable EU countries:						
Sweden	72.1	7	3	50.2	9.01	82
Austria	58.5	26	17	48.6	8.29	77
Slovenia	67.2	12	7	25	7.50	60
Denmark	70.4	8	4	58.4	9.22	87
Latvia	62.9	17	12	17.2	7.49	56

Table 4.

Assessment of health system safety levels through GHS model categories for: a) WB countries and b) Comparable countries of similar size in the EU

Country	Prevention	Detection and reporting	Rapid response	Health system	Compliance with international norms	Risk environment
a) WB countries:						
Serbia	43.8	74.3	52	35.9	53.0	55.7
N. Macedonia	36.7	41.7	51.8	38.3	37.8	50.8
Albania	37.0	41.7	33.1	25.4	44.8	57.7
B&H	36.5	55.4	32.1	29.5	53.5	58.8
Montenegro	48.8	46.2	55.1	56.6	49.7	59.2
b) Comparable EU countries:						
Slovenia	67.0	73.7	63.3	54.9	72.1	73.7
Austria	57.4	73.2	42.3	46.6	52.8	84.6
Denmark	72.9	86.0	58.4	63.8	62.6	80.3
Latvia	56.0	97.3	54.7	47.3	51.1	67.2
Sweden	81.1	86.0	62.8	49.3	71.3	89.5

Source: www.ghsindex.org

Table 4 shows comparative results for WB countries and comparable EU countries of similar size, by all categories of the basic GHS index, as a reliable indicator of the level of individual health systems security to provide adequate responses to pandemic threats, according to which WHO attitudes and actions are determined (WHO, 2006).

The obtained results indicate that in all categories of the GHS model, the achieved score for WB countries is in most cases in the range of 25–74 points out of 100 possible, while the result in comparable EU

countries is in the range of 50–97 points. These results indicate that the security of health systems in WB countries is much lower than in countries of similar size in the EU, which indicates that the readiness of health systems for adequate responses to the epidemic threat in WB countries is significantly lower.

CONCLUSION

The obtained results of GHS index values and analysis conducted on data for 42 European countries showed that the extension of the original GHS model with non-medical parameters (GDP per capita, Democracy index, and Corruption perceptions index) gives a more adequate answer in its structure with high-value R2 approximately one in both cases, indicating their significant impact on the GHS.

Given that WB countries have much lower values of GDP per capita, lower index of democracy, and higher index of perception of corruption compared to developed EU countries, both in the basic and extended model, they have a much lower level of health security compared to developed EU countries, which gives much less readiness to give an adequate response to the pandemic. In the conditions of the COVID-19 pandemic, the results achieved in the WB countries during 2020 and 2021 indicate that the consequences of the COVID-19 pandemic in the WB countries will be greater in relation to countries of similar size in the EU. Improving the security of health systems in WB countries should be expected in the process of their EU integration, by harmonizing internal relations with EU standards, which should lead to an increase in population standards (GDP per capita), increased democracy, and reduced corruption.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Concept of the manuscript was made by, X.X. and Y.Y.; the methodology was designed by, X.X.; collection of data was done by X.X; statistical analyses of data was performed by, X.X.; draft of the manuscript was written by, X.X., Y.Y. and Z.Z.; All listed authors have read and agreed to the published version of the manuscript. Only those who have provided substantial contribution to the submitted work are eligible for authorship. Please refer to CRediT taxonomy for an explanation of terms.

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