Sustainable development progress and challenges - Modelling SDG's based on the income level in European countries

Danijela Voza

University of Belgrade, Technical faculty in Bor, Vojske Jugoslavije 12, Bor, Serbia, dvoza@tfbor.bg.ac.rs

Abstract: Sustainable Development Goals (SDGs) present a global framework for balancing the economy, society and environment. These are management tools for national, regional and global sustainable development planning and programming until 2030. The efforts to improve sustainable development data should be aimed at fostering innovation in SDG monitoring and modelling. Identifying inter-relationships between the 17 SDGs is crucial to managing them effectively and achieving sustainability. This study aims to explore the structure and interlinkages between the SDGs and determine the SDGs that significantly differ between groups of European countries depending on their income level. The dataset was created based on the European Sustainable Development Reports from 2017 – 2022 and World Bank open data. It was processed using the principal component analysis/factor analysis (PCA/FA) and discriminant analysis (DA). PCA of the data sets yielded five Principal Components with Eigenvalues >1, accounting for 81,57% of the total variance. Results indicate that specific social and economic indicators mostly determine the success of European countries in implementing sustainable development concepts. Also, there are notable synergies between SDGs, especially when it comes to the socio-economic dimensions. Conversely, important potential trade-offs with environmental-related SDGs are identified. The findings revealed that a higher level of economic development leads to greater success in implementing the general concept of sustainability. Lower-income countries are more advanced regarding the SDGs that fall under the environmental dimension – responsible consumption and climate change. The discrimination goals of responsible consumption and partnership for goals indicate clear differences between two groups of countries and can undermine progress toward sustainable development in high-income countries. It implies that socio-economic goals are prioritised over environmental ones when achieving sustainable development.

Keywords: Sustainable Development Goals, Income level, European countries, Principal Component Analysis, Discriminant analysis

1 Introduction

Sustainable development is a fundamental concept of the contemporary world. This concept has a central place in considering the long-term perspective of the survival and progress of humanity. Sustainability, or sustainable development, is an essential prerequisite and the ultimate goal of human activities on Earth. The Brundtland Commission Report defines it as "*the development that allows meeting the needs of current generations without compromising the ability of future generations to meet their needs*" [1]. Sustainable development means striking the perfect balance between economic growth, social progress, and environmental protection. It can be seen as the intersection of three dimensions: social, economic and ecological. In the past few decades, socio-economic and environmental challenges have posed significant obstacles to the discourse on sustainable development. Climate change, environmental degradation, rapid economic development, growing human population, and the global pandemic of COVID-19 are the phenomena that have hindered the successful implementation of the concept of sustainability to the greatest extent [2-5]. As a result, sustainable development has become a burning issue among scientists, global institutions and the wider community.

To improve the understanding and management of the entire concept, in September 2015, the UN General Assembly adopted the resolution titled “Transforming our World: the 2030 Agenda for Sustainable Development”, known as “Agenda 2030”. This report specified the modern approach that provides a comprehensive and multidimensional view of development through the Sustainable Development Goals (SDGs) (Table 1). The topics of these goals cover five critical areas (the so-called 5 P's) - People, Planet, Prosperity, Peace, and Partnership [6]. SDGs are multilevel indicators directly linked to the components of sustainable development that should be pursued until 2030. The series of 17 goals is determined by 169 targets and aimed at supporting nations to achieve economic, social and environmental balance [7-11]. By addressing all dimensions, the goals built a universal, holistic framework for helping set humanity on a sustainable development course.

SDGs, targets, and indicators serve as a management tool to direct governments in creating implementation strategies and allocating resources. These monitor progress toward sustainable development at local, national, regional, and global levels. Successful policy-making and implementation require a series of efforts rather than individually focused SD paradigm initiatives, e.g. environment, society, or economy [12]. Given the multidimensionality of sustainable development goals, policymakers should be able to integrate economic, social and environmental components into a long-term strategy. Therefore, observing and analysing the SDGs as a group, not separately, is necessary. To reach the SDGs, governments and civil society need to set action priorities, detect significant implementation issues, analyse progress, enforce accountability, and identify gaps that must be filled. Therefore, a greater understanding of this issue is needed [13].

Figure 1
Sustainable Development Goals (Source: www.un.org/)

The SDGs defined within the Agenda represent a broad multinational attempt to redirect the world towards more sustainable and resilient directions while satisfying the needs of developing countries [14]. Achieving the SDGs requires implementing fundamental changes in each country and investing significant efforts in monitoring and measuring progress [15]. Agenda 2030 highlighted a need for urgent global action and cooperation between developed and developing countries.

The subject of this paper is modelling sustainable development goals to create guidelines for effective strategies and managing the concept of sustainable development at the European level. The aim is to recognize the problems in achieving sustainable development goals in European countries. Specific goals are: i) to define the most important SDG challenges in European countries depending on their development level; ii) to define the pattern of SDG structure in Europe that drive the overall SDG score; iii) to define SDGs that differentiate European countries according to their development level. These goals are pursued in the following sections. Section 2 consists of the literature review in the field of SDGs and their interlinkages, as well as the types of modelling techniques that are most frequently used. In Section 3, the study area and the methodological approach are presented. In Section 4, the obtained results of the proposed model were displayed and discussed in Section 5. Finally, Section 6 highlights the main conclusions of the research and the limitations and directions for future studies in this field.

2 Literature review

A bibliometric analysis of scientific papers on the SDGs reveals that most studies (31%) are conducted by authors from the USA, China, and the UK and concentrated in developed countries [16,17]. Research databases related to SDGs indicate that natural and engineering sciences were more prominent than social sciences [16]. Studies focused on SDGs are mostly dealing with the specific SDGs rather than the SDGs as a unified and interrelated framework outlined in the UN resolution [18-24]. At the same time, most studies deal with SDG 3 - Good health and well-being, while SDG 7 - Affordable and Clean Energy is the second [25]. However, system thinking is essential in studies on sustainable development and the SDGs [16].

Interdependencies, conflicts, and links between the SDGs require systemic thinking that incorporates the spatial and temporal interconnection of the SDGs, demanding multidisciplinary skills [13]. A significant positive correlation between SDG indicators is classified as a synergy, while a significant negative correlation is classified as a trade-off [26]. Spreading knowledge about synergies in sustainable development is important for enabling progress toward the SDGs and saving substantial resources [27]. Through various studies, researchers have investigated the relationships between the SDGs but have come to different conclusions [28]. In a study by Lusseau and Mancini (2019), they referred to the networks of SDG interactions as sustainomes [29]. Their study aimed to identify the obstacles and opportunities for achieving the SDGs through their interactions. They found that limiting climate change, reducing inequalities, and responsible consumption are significant hurdles to achieving the 2030 goals. However, focusing on poverty alleviation and reducing inequalities can accelerate the achievement of all SDGs. Dawes (2022) developed mathematical models to quantify the level of interlinkage networks that predict higher progress on particular SDGs than others [30]. The results showed that the impacts of other SDGs on goals 1-3 are more frequent than influences on later goals, and goals 6 and 7 are more dominant than the others. Scharlemann et al. (2020) concluded that environmental and environmental-human relations cause most interactions between SDGs [28].

The literature is still in the evolutionary stage in identifying the importance of social, economic and environmental sustainability indicators for more effective achievement of the SDGs [12]. However, in most of the previous studies, the fact that the interactions between the SDGs depend on the socio-economic characteristics of the countries has yet to be taken into account. A potential limitation of the SDGs is the need for more distinction between developed and developing countries [31]. For this reason, determining the spatial patterns of sustainable development and defining the factors that influence the success of establishing a balance between economic, social and environmental conditions are priority tasks by which the pursuit of maintaining development can be harmonised with the environmental conditions. In the work of the author Koehler (2016), it was pointed out that the SDGs can improve gender and climate justice [32]. According to some studies, performance in different SDG areas shows dependence on the income and geographical location of individual countries [29, 33-35]. Also, the SDGs can be used as a measure of sustainable well-being that can motivate and guide the process of global social change [36]. The availability of renewable energy sources to the population in rural areas significantly contributes to achieving the SDGs in developing countries [37,38].

The efforts to improve sustainable development data should be aimed at fostering innovation in SDG monitoring and modelling. Attempts to clarify SDG relationships using different methodologies are not negligible. However, policy-relevant modelling of sustainable development remains a challenge [39]. Authors Nilsson et al. (2016) developed a methodology for determining the interactions between the SDGs applicable at all levels – between goals and targets and global and national policies [40]. They rated seven possible types of SDG interactions from the most positive (scoring +3) to the most negative (scoring -3). Still, there is a lack of distinct modelling methodologies and model types that satisfy all the analytical requirements imposed by the new SDGs [39]. Many approaches remain complicated, time-consuming, and unintegrated [41]. Jayaraman et al. (2015) used a multi-criteria decision-making model to achieve SDGs by efficiently allocating resources [42]. Allen et al. (2016) defined contemporary modelling tools' positive and negative features and identified gaps in national sustainable development planning [39]. They found that scenario analysis and quantitative modelling are important analytical tools and have multiple benefits in developing national strategies towards achieving SDGs. Asadikia et al. (2022) applied the Gradient Boosting Machine algorithm to identify the top five SDGs that drive the overall SDG score [35]. Grochová Ladislava & Litzman (2021) used the non-parametric method of Data Envelopment Analysis to assess the level of the achievement of SDGs and evaluate the countries' progress [33]. Jabbari et al. (2020) attempted to develop a model based on the SDG index to cluster and differentiate the countries of different SD levels using non-hierarchical clustering, known as the K-means method [31]. Authors Cao et al. (2023) modelled SDGs to evaluate the causality and strength among them [43]. They constructed 1302 connections using the spatio-temporal geographically weighted regression method.

Studying the possibility of applying statistical methods in monitoring and managing sustainable development is increasingly intensive. However, further research is needed to evaluate the benefits and drawbacks of various modelling techniques [39]. To overcome this gap, the author of this study will examine the effectiveness of selected multivariate statistical techniques for modelling sustainable development goals. Multivariate statistical techniques such as Principal Component Analysis (PCA), Factor analysis (FA) and Cluster analysis (CA) have multiple benefits. The method of multivariate analysis used to reduce the data set dimensionality while keeping the maximum possible variability is called the method of principal components (PCA -Principal Component Analysis). Of all factor analyses, PCA is the most commonly used. The method of principal components was developed by Hotelling in 1933 [44]. In addition to reducing dataset dimensionality, the method of principal components is a tool of analysis by which hypotheses about the studied phenomenon are generated. PCA efficiently deals with multi-collinearity in the data as a non-parametric approach by generating factor variables [12]. This technique converts extensive interrelated variables into independent (orthogonal) variables. In this way, the number of variables is reduced, and with a slight loss of information, it represents the same amount of variance. PCA/FA usefulness proven in the modelling of sustainable development indicators in manufacturing [45], energy [46], water management [47], international food trade [48], air quality [49], etc. According to Kwatra et al. (2020), these analyses can determine the relationships between variables, the existence of a balance between different dimensions of sustainability, classify voluminous information into data sets that can be managed and share information about composite indicators with the possibility of simultaneous monitoring of individual ones [50].

The novelty of this research consists of the multivariate analysis of the interlinkages across the SDGs in European countries and the recognition of the SDGs that significantly differ between countries depending on income level. For this purpose, principal component analysis/factor analysis (PCA/FA) and discriminant analysis (DA) were used. Based on the results, it will be possible to identify fields that require additional engagement and create guidelines to accelerate SD progress.

3 Experimental

3.1 Data set

In July 2016, The Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN) jointly, founded the initial SDG Index and Dashboards with data from 149 of 193 UN member states. Annual SDG reporting is based on high-quality data from all countries and presents a quantitative assessment of the level of SDG achievement. The Report includes the SDG Indices for each goal individually and overall SDG Index. The scores are presented on a scale of 0 to 100, with zero denoting the worst performance and hundred describing the best performance in SDGs achievement. The total SDG Index has been listed among the ten composite indices useful for policymaking by the European Parliamentary Research Service. The data set used for the defined research objectives was created using the database published in the European Sustainable Development Reports from 2017 - 2022 [51]. The statistical packages SPSS v.21 and Statistica v.13 were used in their processing.

3.2 Study area

Regional monitoring and accountability ensure regional collaboration and coherence in SDG-related policies. The European Union is recognised as a global leader in improving sustainable development given that European Commission requires its members to adhere to several legal measures that uphold the principle of sustainability.

Given the assumption that the performance in the SD depends on the individual countries' income, the European countries are separated into two groups using the World Bank classification according to the income level – upper middle income (GNI3) and high income (GNI4) countries (Table 2). The GNI per capita is the dollar value of a country's annual income divided by population [52]. It should reflect the average pre-tax income of a country's population. GNI is a useful indicator of the country's economic strengths and the general standard of living experienced by the citizens. The GNI per capita correlates with many other indices that measure the country's and its people's social, economic, and environmental well-being. Based on the insight into the division according to GNI, it can be seen that the countries of the GNI3 group, except for Bulgaria, are not EU members, while the GNI4 group consists only of EU member countries.

Upper middle income countries – GNI3	**High income countries – GNI4**	
Albania	Austria	Italy
Armenia	Belgium	Latvia
Azerbeijan	Croatia	Lithuania
Belarus	Cyprus	Malta
Bosnia and Herzegovina	Czech Republic	Netherlands
Bulgaria	Denmark	Norway
Georgia	Estonia	Poland
Montenegro	Finland	Romania
Moldova	France	Slovak
N. Macedonia	Germany	Slovenia
Serbia	Greece	Spain
Turkey	Hungary	Sweden
Ukraine	Iceland	Switzerland
	Ireland	United Kingdom

Table 2.
Analysed countries and their grouping according to the GNI

3.3 Methodology

3.3.1 Principal Component Analysis/Factor Analysis

Principal component analysis (PCA) is mathematically derived from the covariance matrix, which explains the dispersion of multiple measured parameters by adding eigenvalues and vectors. The covariance matrix (Ks) is calculated by taking the mean values of each column from each variable and scaling the columns. The resulting output is the extraction of new orthogonal variables called principal components (PC's). They represent a linear combination of the original variables and provide maximum variance. In order to obtain the simplest and most effective presentation of the principal factors, it is recommended to perform the rotation of the axis of the principal components, which leads to the creation of new groups of variables called varifactors (VFs). This procedure is commonly known as factor analysis (FA). In an attempt to explain the correlation between observations of underlying factors that are not directly observable, FA is used in addition to PCA analysis. The most important difference between PC and VF is reflected in the fact that PC represents a linear combination of observed variables, while VF can take into account latent, hypothetical variables.

3.3.2 Discriminant analysis

Discriminant analysis (DA) is a multivariate technique applied to classify observed variables into one or two alternative groups based on a specific set of measurements. This analysis can also be used to determine the variables that contribute to the classification. One of its tasks is to graphically or algebraically describe the differential features between observations of different sets. Therefore, DA can have predictive and descriptive roles. Stepwise discriminant analysis is used when the researcher has no reason for assigning some predictors higher priority than others. In this research, a linear "stepwise" method, characterised by Mahalanobis's distance measure, was applied. The result of training data classification is summarised by comparing the obtained and predicted grouping. The effectiveness of the discrimination functions can be confirmed using the cross-validation method, which determines the degree of predictability of the observed sample from which the model was created. Also, the effectiveness can be confirmed with a new data set that is used together with the cross-validation model to evaluate the performance of the set functions.

4 Results

The initial step in this study was to conduct the descriptive statistics by country groups GNI3 and GNI4. Mean values of indicators of progress towards sustainable development goals are presented in Table 3.

	Group of country			
	GNI3		GNI4	
	Mean	Std.dev.	Mean	Std.dev.
SDG1 (No poverty)	96.91	4.789	99.37	.565
SDG2 (Zero hunger)	62.10	6.801	66.57	5.326
SDG3 (Good health and well-being)	78.40	3.660	91.62	4.334
SDG4 (Quality education)	84.27	11.307	96.37	3.926
SDG5 (Gender equality)	59.70	9.598	78.08	9.111
SDG6 (Clean water and sanitation)	72.25	5.707	83.30	10.480
SDG7 (Affordable and clean energy)	73.78	4.999	80.26	8.501
SDG8 (Decent work and economic growth)	71.77	6.161	82.48	4.367
SDG9 (Industry, innovation and infrastructure)	52.30	10.364	84.80	9.467
SDG10 (Reduced inequalities)	77.02	16.952	89.49	9.312
SDG11 (Sustainable cities and communities)	77.96	5.374	88.88	5.185
SDG12 (Responsible consumption and production)	80.44	5.627	56.59	10.744
SDG13 (Climate action)	86.61	6.159	65.88	13.829
SDG14 (Life below water)	62.22	12.784	70.06	10.840
SDG15 (Life on land)	72.79	13.818	82.11	10.115
SDG16 (Peace, justice and strong institutions)	69.60	5.512	82.35	7.608
SDG17 (Partnerships for the goals)	72.00	8.691	62.63	12.529
Total SDG Index	73.81	2.469	80.14	3.019

Table 3.

Descriptive statistics of SDGs indicators for groups of countries for the period 2017-2022

The results of descriptive statistics indicate that the mean value of the total SDG score for the monitoring period is lower in the GNI3 group of European countries (73.81) compared to the GNI4 group (80.14).

4.1 Data structure and the identification of the dominant SDGs

To examine the reliability of the data set for the PCA/FA, Bartlett's sphericity and the Kaiser-Mayer-Olkin (KMO) tests were conducted. The high value (close to 1) of the KMO measure of adequacy indicates that the PCA/FA is useful. In this study, the KMO value is 0,747 (Table 4). This confirms the validity of the obtained PCA/FA analysis. Bartlett's sphericity test with a significant level of 0 in this case (<0.05) indicated that there are significant relationships among the variables (Table 4).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.747
Bartlett's Test of Sphericity	Approx. Chi-Square	2902.180
	df	136
	Sig.	.000

Table 4.
Bartlett's Test and Kaiser-Mayer-Olkin coefficients

After testing the validity of the data set, principal component analysis and factor analysis (PCA/FA) were performed. In doing so, normalised values of the entire data set were used simultaneously for all analysed countries. The PCA of the data sets yielded five PCs. The Principal Components with Eigenvalues >1 account for 81,57% of the total variance. Liu et al. (2003) classified the factor loadings as "strong", "moderate", and "weak", corresponding to the absolute loading values of >0.75, 0.75–0.50 and 0.50–0.30, respectively [53]. The variable loadings and the explained variance of SDGs are presented in Table 5. Also, the strong and moderate loadings are highlighted in the following table. The PCA/FA analysis extracted a satisfactory number of the parameters with the moderate and high loadings of every varifactor. This confirms that it is feasible to identify the SDGs that correlate to each other and the groups of SDGs that mostly determine the progress towards sustainable development.

	VF1	VF2	VF3	VF4	VF5
SDG_1	.250	.125	.153	-.048	**-.826**
SDG_2	.013	.273	**.846**	-.144	-.247
SDG_3	**.859**	-.149	.329	.016	-.167
SDG_4	**.752**	-.111	.113	-.293	.429
SDG_5	**.887**	.052	.244	.141	.061
SDG_6	.281	.316	<u>.608</u>	.205	.406
SDG_7	.493	.113	-.217	<u>.600</u>	.238
SDG_8	<u>.599</u>	.486	.433	-.081	-.113
SDG_9	**.814**	-.046	.493	.085	-.108
SDG_10	<u>.705</u>	.183	-.025	.123	-.079
SDG_11	**.785**	.269	.181	-.041	.195
SDG_12	**-.901**	-.029	.101	.005	.318
SDG_13	**-.823**	-.087	.067	-.143	.247
SDG_14	.054	**.902**	.153	.095	-.026
SDG_15	.103	**.767**	.182	-.384	-.104
SDG_16	**.863**	.225	-.028	.251	.057
SDG_17	.051	-.170	.063	**.909**	-.047
Eigenvalue	6.860	2.075	1.877	1.628	1.427
% Total variance	40.352	12.208	11.040	9.577	8.397
Cumulative % variance	40.352	52.560	63.600	73.177	81.573

*Bold and underlined values indicate strong and moderate mean values, respectively

Table 5.

The factor loadings value and explained variance of SDGs

The sustainable development in Europe is mostly determined by five varifactors (VF). The VF1 explains 40.35% of the total variance. This VF is characterised by the strong positive loadings of SDG3 (0.859), SDG4 (0.752), SDG5 (0.887), SDG9 (0.814), SDG11 (0.785) and SDG16 (0.863) and strong negative loadings of SDG12 (-0.901) and SDG13 (-0.823). The moderate positive loadings are present in the case of SDG8 (0.599) and SDG10 (0.705). These results indicate the predominant social-related sustainable development goals in Europe. VF2 accounts for 12.21% of the total variance, whereas the strongest positive loadings are on SDG14 (0.902) and SDG15 (0.767), which reflects environmental-related goals. In the VF3, the strong positive loading is assigned to SDG2 (0.846), whereas the moderate positive loading is on SDG6 (0.608). Both of these SDGs are linked with the social aspect of sustainable development. The fourth VF consists of SDG17 (0.909) and SDG7(0.6), whereby SDG7, as environmentally related, dominates. Finally, VF5 consists of a strong positive loading of SDG1 (0.826) and reflects the social dimension.

4.2 Identification of discriminant SDGs between European upper-middle and high-income countries

In further research, the possibility of defining the SDGs that differentiate upper-middle and high-income European countries was examined. In Table 6 are given key measures of stepwise discriminant function analysis that indicate its' effectiveness in this research. The validity of every discriminant function was examined by Wilk's Lambda (λ) Test. Its value ranges from 0 to 1.0. The smaller λ, the more it contributes to the discriminant function. In this study, λ values are near zero (.08672, .08686, .09540) for standard, forward and backward stepwise mode, respectively, which proves high discrimination between groups. The F-ratio determines whether the variances in two independent samples are equal. In this case, the F-ratio indicates high variability between the two groups.

	Wilks' Lambda	**Approx. F**	**Sig.**
Standard stepwise	.08672	F (17,228) = 141.24	p<0.00
Forward stepwise	.08686	F (15,230) = 161.20	p<0.00
Backward stepwise	.09540	F (7,238) = 322.38	p<0.00

Table 6.
Stepwise discriminant function analysis - measures of effectiveness

	Standard stepwise mode		Forward stepwise mode		Backward stepwise mode	
SDG	**GNI3**	**GNI4**	**GNI3**	**GNI4**	**GNI3**	**GNI4**
SDG1	-0.252	0.124				
SDG2	1.885	-0.925	1.855	-0.911		
SDG3	-0.832	0.408	-0.788	0.387		
SDG4	-1.044	0.513	-0,982	0.482		
SDG5	3.28	-1.61	3.226	-1.584	2.611	-1.282
SDG6	-0.885	0.434	-0.885	0.435		
SDG7	-0.972	0.477	-0.943	0.463	-1.505	0.739
SDG8	-1.885	0.925	-1.883	0.924		
SDG9	-12.273	6.025	-12.359	6.067	-11.636	5.712
SDG10	-3.608	1.771	-3.671	1.802	-3.136	1.539
SDG11	1.395	-0.685	1.422	-0.698		
SDG12	2.137	-1.049	2.504	-1.229	1.819	-0.893
SDG13	0.166	-0.082				
SDG14	-0.822	0.404	-0.896	0.44		
SDG15	-1.320	0.648	-1.306	0.641	-1.839	0.903
SDG16	0.932	-0.458	1.146	-0.563		
SDG17	4.858	-2.385	4.818	-2.365	4.495	-2.207
Constant	**-11.75**	**-2.963**	**-11.731**	**-2.959**	**-10.69**	**-2.708**

Table 7.

Classification functions and their coefficients for DA

In Tables 7 and 8, the discriminant functions (DFs) and the classification matrices (CMs) obtained as a result of the standard, forward and backward stepwise modes of the DA are presented. The variable that provided the greatest univariate discrimination is selected, and the criterion is re-evaluated for all remaining variables. Only variables which subsequently meet this criterion value are entered into the model.

Group of countries	% Correct	Number of cases assigned by DA	
		GNI3	GNI4
GNI3	96.3	78	3
GNI4	100	0	165
Total	98.8	78	168

Table 8.

Discriminant matrix

The standard mode on the 17 analysed SDGs' constructed the discriminant functions – DFs, with approximately 98.78% correct assignation. In the forward stepwise mode, the variables were included step by step, beginning with more significant ones, whereas no significant changes were obtained. The forward stepwise mode of the DA gave the CMs with 98.8% correct assignations using 15 discriminant parameters. The backward stepwise DA mode rendered the corresponding CMs, correctly assigning 98.8% of cases, yielding seven discriminant parameters (SDG5, SDG7, SDG9, SDG10, SDG12, SDG15, SDG17).

5 Discussion

The results of descriptive statistics showed that low-income countries (GNI 3) lag behind more developed countries in meeting almost all sustainable development goals, considering the overall SDG score. Based on this, it can be concluded that the country's higher level of economic development leads to greater success in implementing the general concept of sustainability, which is confirmed by the previous studies [31,34,35].

Conversely, higher values in GNI3 countries are recorded in the cases of SDG 12 (Responsible consumption and production), SDG13 (Climate action), and SDG17 (Global partnership for sustainable development). It is confirmed by Lusseau and Mancini's (2019) study, which points out that, in contrast with low-income countries, for high-income countries, SDG13 (climate actions) and SDG12 (responsible consumption) are obstacles to other goals [29]. To combat climate change, nations must switch to renewable energy sources, halt deforestation, and modify production and consumption patterns [33].

Given that the first two goals are related to the environmental dimension of sustainability, the results of this study confirm that lower-income countries are more advanced in terms of the SDGs that fall under the environmental dimension [54,55], even though the environmental aspect is an urgent problem and a subject of discussion during the implementation of various projects all over Europe [16]. One of the explanations is that high-income countries leave a higher environmental footprint than low-income countries [56]. Global material consumption and the amount of material waste per person have increased dramatically, endangering the attainment of SDG 12. The footprint per capita of developed countries is at least double that of underdeveloped countries for every type of material, especially because of a more than four times higher material footprint for fossil fuels. According to Jabbari et al. (2020), Goal 17, which emphasises the need for global partnership, is an overarching goal providing the means of implementing all other SDGs [31]. Based on that, developing countries are on the right course in achieving sustainable development in the future, while partnerships among developed countries stagnate.

By applying PCA/FA, all SDGs are grouped into five VFs, confirming the conditions for a significant reduction in the initial data set. SDGs that belong to the same varifactor are mutually conditioned. In this manner, the first VF consists of 9

SDGs, and we can characterise it as socio-economic because it is dominated by SDGs of social (SDG3, SDG4, SDG5, SDG11, SDG16) and economic (SDG9, SDG10) nature. They are positively conditioned; that is, progress in achieving one affects progress in achieving other goals. In this VF, only SDG12 (Responsible consumption and production) and SDG13 (Climate action) are exceptions because they relate to environmental issues. Also, with the same SDGs, negative factor loadings are noticeable, which indicates that the fulfilment of other SDGs from this group causes negative consequences for climate change and responsible consumption. The second VF can be characterised as ecological because it comprises only two SDGs - Life below water and Life on land, which act synergistically.

VF3 is also made up of two SDGs, which are considered to be mutually conditioned. In this case, both are social - Zero hunger and Clean water and sanitation and represent prerequisites for satisfying basic human needs. Socio-economic SDGs are intertwined in VF4, where we simultaneously have Affordable and clean energy and Partnerships for goals. This component implies that strengthening multilateralism and global partnerships is the prerequisite for ensuring affordable, sustainable, and modern energy for all. The last VF is reflected only in SDG1 - No poverty and it is reflected as a social dimension. It can be concluded that this SDG does not interact with others because the level of poverty in the territory of Europe is very low, and its impact on others is in this area unrecognizable. It can be concluded that the success of European countries in the implementation of sustainable development concepts is mostly determined by specific social and economic indicators. Also, there are notable synergies between SDGs, especially when it comes to the socio-economic dimensions. Conversely, important potential trade-offs with environmental-related SDGs are identified and solutions for overcoming these should be considered.

In this study, a stepwise discriminant analysis was used to determine those variables (SDGs) which were best suited to differentiate between the two groups of countries – upper-middle (GNI3) and high (GNI4) income levels. The low values of this coefficient for the mentioned modes prove that the DA in this study was valid and effective. When a stepwise procedure was run, seven (SDG5, SDG7, SDG9, SDG10, SDG12, SDG15, SDG17) of the seventeen original variables remained. By analysing the SDGs that were extracted as discriminatory, it can be recognized that these are predominantly socio-economic (SDG5 – Gender equality, SDG7 – Affordable and clean energy, SDG9 - Industry, innovation and infrastructure, SDG10 - Reduced inequalities, SDG17 - Partnership for goals), while two of them are environmental related (SDG12 - Responsible consumption and production and SDG15 - Life on land).

Even though the SDGs related to the environmental dimension are more fulfilled in GNI3, it is concluded that the differences between these two groups of countries are mainly reflected in their socio-economic conditions. Through comparative analysis with the results of descriptive statistics, it was observed that the success in achieving the socio-economic SDGs is far greater in the case of high-income countries, which indicates that the goals of sustainable development aimed at the socio-economic dimensions represent a dominant factor that contributes to the greater success of GNI4 countries in reaching the concept of sustainability. The significant advantage of the GNI4 countries is reflected in a gender equality, a higher degree of industrial development and innovation, better access to affordable and modern energy for all, equal opportunities and rights for all people without discrimination and peaceful, inclusive societies with effective and accountable institutions at all levels. At the same time, it indicates a significant backlog of GNI3 countries in those areas and the necessity of strengthening measures and policies to improve these goals. On the other hand, the discrimination goals of responsible consumption and partnership for goals indicate clear differences between GNI3 and GNI4, where, unlike the previous one, countries with a low-income level are more successful in their implementation. The result, which is reflected in significantly better environmental-related SDG12 in lower-income countries, does not necessarily mean that those countries are more committed to ecology and environmental protection, but only that they do not have the prerequisites for leaving higher environmental footprint. Strong international cooperation is needed now more than ever to ensure that countries have the means to achieve the SDGs especially after the COVID19 pandemics. During the pandemic period which is covered by this research, countries began to close and all international cooperation and contacts stopped. Accordingly, this could be the reason for the poor results in the field of SDG17 (Partnership for goals).

Conclusions

In this paper, multivariate statistical techniques such as PCA/FA and discriminant analysis were conducted to determine the dominant SDG structure in Europe and whether SD priorities vary by income level. Climate action and responsible consumption and production can undermine or inhibit progress toward a range of development goals. We must reverse current trends and shift our consumption and production patterns to a more sustainable course. Multilateralism and global partnerships are more important than ever if we are to solve the problems of high-income countries. The results indicate that some countries that fall behind in social and economic sustainability (mostly developing countries in Europe) get relatively better scores in environmental goals. However, this advantage should be taken with a grain of salt because any future economic progress of these countries could slow down the achievement of environmental SDGs.

Given the broad scope of the SDGs, policymakers will need to easily assess the economic, social and environmental implications of their strategies in an integrated way over the long term. The results of this study should provide insight and direction for future efforts to promote sustainable development. The conducted analysis proved that there are common features and differences between European states depending on income level. Therefore, various and specific measures are needed to support the improvement of sustainable development. High-income countries should prioritize environmental sustainability through resource efficiency, waste reduction, sustainable management of chemicals and wastes, and the implementation of environmentally sound practices. Conversely, middle-income countries' policymakers must take action to ensure economic competitiveness and social growth, which, according to the results of PCA/FA, drive the overall SDG score and form the basis of progress in implementing the concept of sustainable development.

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References

[1] Brundtland, Gro Harlem, (1987). Report of the World Commission on Environment and Development: Our Common Future. United Nations General Assembly document A/42/427.

[2] Nerini Francesko Fuso, Sovacool Benjamin, Hughes Nick, et al., (2019) Connecting climate action with other sustainable development goals. Nature Sustainability, 2(8), pp. 674–680.

[3] Aravindaraj, K, Rajan P. Chinna, (2022) A systematic literature review of integration of industry 40 and warehouse management to achieve Sustainable Development Goals (SDGs). Cleaner Logistics and Supply Chain, 5, 100072.

[4] Guo Huadong, Liang Dong, Sun Zhongchang, et al., (2022) Measuring and evaluating SDG indicators with big earth data. Science Bulletin, 67(17), pp. 1792–1801.

[5] Zhao Wenwu, Yin Caichun, Hua Ting et al., (2022) Achieving the Sustainable Development Goals in the post-pandemic era. Humanities and Social Science Communications, **9**, 258.

[6] United Nations. Transforming our World: The 2030 Agenda for Sustainable Development. 2015.

[7] Rodríguez-Antón J. M., Rubio-Andrada L., Celemín-Pedroche M. S., Alonso-Almeida M. M., (2019) Analysis of the relations between circular economy and sustainable development goals. International Journal of Sustainable Development & World Ecology, 26(8), pp. 708–720.

[8] Coscieme Luca, Mortensen F. Lars, Anderson Sharolyn, Ward James, Donohue Ian, Sutton C. Paul, (2020) Going beyond Gross Domestic Product

as an indicator to bring coherence to the Sustainable Development Goals. Journal of Cleaner Production, 248, 119232.

[9] Carlsen Lars, Bruggemann Rainer, (2022) The 17 United Nations' sustainable development goals: a status by 2020. International Journal of Sustainable Development & World Ecology, 29(3), pp. 219–229.

[10] Pondel Hannah, (2021) An attempt to evaluate the level of sustainable development in European Union countries. Economics and Law, 20(2), pp. 383– 399.

[11] Grzebyk Mariola, Stec Malgorzata, Hejdukova Pavlina, (2023) Implementation of sustainable development goal 8 in European Union countries – A measurement concept and a multivariate comparative analysis. Sustainable Development, 31 (4), pp. 2758-2769.

[12] Lamichhane Shyam, Gökhan Eğilmez, Ridvan Gedik, M. Khurrum S. Bhutta, Bulent Erenay, (2021) Benchmarking OECD countries' sustainable development performance: A goal-specific principal component analysis approach. Journal of Cleaner Production, 287, 125040.

[13] Sianes Antonio, Vega-Muñoz Alejandro, Tirado-Valencia Pilar, Ariza-Montes Antonio, (2022) Impact of the Sustainable Development Goals on the academic research agenda. A scientometric analysis. PLoS ONE 17(3), e0265409.

[14] Caiado G. G. Rodrigo, Filho L. Walter, Quelhas L. G. Osvaldo, Nascimento de Mattos L. Daniel, Avila V. Lucas, (2018) A literature-based review on potentials and constraints in the implementation of the sustainable development goals. Journal of Cleaner Production, 198, pp. 1276-1288.

[15] Schmidt-Traub Guido, Kroll Christian, Teksoz Katerina, Durand-Declare David, Sachs D. Jeffrey, (2017) National baselines for the Sustainable Development Goals assessed in the SDG Index and Dashboards. Nature Geoscience, 10, pp. 547–555.

[16] Yeh Shin-Cheng, Hsieh Yi-Lin, Yu Hui-Ching, Tseng Yuen-Hsien, (2022) The Trends and Content of Research Related to the Sustainable Development Goals: A Systemic Review. Applied Sciences, 12, 6820.

[17] Mishra Manoranjan, Desul Sudarsan, Santos Celso Augusto Guimarães et al., (2023) A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities. Environment, Development and Sustainability, 26, pp. 11101-11134.

[18] Abad-Segura Emilio, Gonzalez-Zamar Mariana-Daniela, (2021) Sustainable economic development in higher education institutions: A global analysis within the SDGs framework. Journal of Cleaner Production, 294, 126133.

[19] Cortés D. Julian, Guix Mireia, Carbonell B. Katerina, (2021) Innovation for sustainability in the Global South: Bibliometric findings from management & business and STEM (science, technology, engineering and mathematics) fields in developing countries. Heliyon, 7, e07809.

[20] Imaz Mariana, Sheinbaum Claudia, (2017) Science and technology in the framework of the sustainable development goals. World Journal of Science, Technology and Sustainable Development, 14, pp. 2–17.

[21] Zhenmin Liu, Espinosa Patricia, (2019) Tackling climate change to accelerate sustainable development. Nature Climate Change, 9, pp. 494–496.

[22] Quinlivan Lauren, Chapman V. Deborah, Sullivan Timothy, (2020) Validating citizen science monitoring of ambient water quality for the United Nations sustainable development goals. Science of the Total Environment, 699, 134255.

[23] Lund Crick, Brooke-Sumner Carrie, Baingana Florence, et al., (2018) Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of reviews. Lancet Psychiatry, 5, pp. 357–369.

[24] Rice Brian, Boccia Delia, Carter J. Daniel et al., (2022) Health and well-being needs and priorities in mining host communities in South Africa: A mixed-methods approach for identifying key SDG3 targets. BMC Public Health, 22, 68.

[25] Pakkan Sheeba, Sudhakar Christopher, Tripathi Shubhamet al., (2023) A correlation study of sustainable development goal (SDG) interactions. Quality and Quantity, 57, pp. 1937–1956.

[26] Pradhan Prajal, Costa Luis, Rybski Diego et al., (2017). A Systematic Study of Sustainable Development Goal (SDG) Interactions, Earth's Future, 5, pp. 1169–1179.

[27] Pedercini Matteo, Arquitt Steve, Collste David et al., (2019) Harvesting synergy from sustainable development goal interactions. PNAS, 116, 46, pp. 23021-23028

[28] Scharlemann P.W. Jörn, Brock C. Rebecca, Balfour Nicholas et al., (2020) Towards understanding interactions between Sustainable Development Goals: the role of environment–human linkages. Sustainability Science, 15, pp. 1573–1584.

[29] Lusseau David, Mancini Francesca, (2019) Income-based variation in Sustainable Development Goal interaction networks. Nature Sustainability, 2, pp. 242–247.

[30] Dawes J.H.P. (2022). SDG interlinkage networks: Analysis, robustness, sensitivities, and hierarchies, World Development, 149, 105693

[31] Jabbari Mehdi, Shafiepour M. Motlagh, Ashrafi Khosro et al. (2020) Differentiating countries based on the sustainable development proximities using the SDG indicators. Environment, Development and Sustainability, 22, pp. 6405–6423.

[32] Koehler Gabriele, (2016) Tapping the Sustainable Development Goals for progressive gender equity and equality policy? Gender and Development Journal, 24, 53e68.

[33] Grochová Ladislava Issever, Litzman Marek, (2021) The efficiency in meeting measurable sustainable development goals. International Journal of Sustainable Development & World Ecology, 28 (8), pp. 709-719.

[34] Warchold Anne, Pradhan Prajal, Kropp P. Jürgen, (2021) Variations in sustainable development goal interactions: population, regional, and income disaggregation. Sustainable Development, 29, pp. 285–299.

[35] Asadikia Atie, Rajabifard Abbas, Kalantari Mohsen, (2022) Region-income-based prioritisation of Sustainable Development Goals by Gradient Boosting Machine. Sustainability Science, 17, pp. 1939–1957.

[36] Griggs David, Stafford-Smith Mark, Gaffney Owen et al., (2013) Sustainable development goals for people and planet. Nature, 495, pp. 305–307.

[37] Urmee Tania, Md Anisuzzaman, (2016). Social, cultural and political dimensions of off-grid renewable energy programs in developing countries. Renewable Energy, 93, pp. 159-167.

[38] Mboumboue Edouard, Njomo Donatien, (2016) Potential contribution of renewables to the improvement of living conditions of poor rural households in developing countries: Cameroon's case study. Renewable and Sustainable Energy Reviews, 61, 266e279.

[39] Allen Cameron, Metternicht Graciela, Wiedmann Thomas, (2016) National pathways to the Sustainable Development Goals (SDGs): A comparative review of scenario modelling tools. Environmental Science & Policy, 66, pp.199-207.

[40] Nilsson Måns, Griggs Dave, Visbeck Martin, (2016) Map the interactions between Sustainable Development Goals. Nature, 534, pp. 320-322.

[41] Stevenson Samuel, Collins Alexandra, Jennings Neil et al., (2021) A hybrid approach to identifying and assessing interactions between climate action (SDG13) policies and a range of SDGs in a UK context. Discover Sustainability, 2, 43.

[42] Raja Jayaraman, Cinzia Colapinto, Davide La Torre, et al., (2015) Multi-criteria model for sustainable development using goal programming applied to the United Arab Emirates. Energy Policy, 87, pp. 447-454

[43] Cao Min, Chen Min, Zhang Junze et al. (2023) Spatio-temporal changes in the causal interactions among Sustainable Development Goals in China. Humanities and Social Sciences Communications, 10, 450.

[44] Hotelling H., (1933) Analysis of a complex of statistical variables into principal components. Journal of Educational Psychology, 24(6), pp. 417–441.

[45] Dong Xiucheng, Guo Jie, Höök Mikael et al., (2015) Sustainability assessment of the natural gas industry in China using principal component analysis. Sustainability, 7 (5), 6102e6118.

[46] Khan Kamran Muhammad, Teng Jian-Zhou, Khan Imran Muhammad, (2019) Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. Environmental Science and Pollution Research, 26(23), 23480e23490.

[47] Voza Danijela, Vuković Milovan, (2018) The assessment and prediction of temporal variations in surface water quality—a case study. Environmental Monitoring and Assessment, 190, pp. 434,

[48] Soler Rovira José, Soler Rovira Pedro, (2009) Assessment of aggregated indicators of sustainability using PCA: the case of apple trade in Spain. In: "6th International conference on Life Cycle Assessment in the Agri-food Sector. Towards a sustainable management of the food chain.", 12-14 noviembre 2008, Zurich (Switzerland). ISBN 978-3-905733-10-5.

[49] Shihab S. Abdulmuhsin, (2022) Identification of Air Pollution Sources and Temporal Assessment of Air Quality at a Sector in Mosul City Using Principal Component Analysis. Polish Journal of Environmental Studies. 31(3), pp. 2223-2235.

[50] Kwatra Swati, Archna Kumar, Prateek Sharma, (2020) A critical review of studies related to construction and computation of Sustainable Development Indices. Ecological Indicators, 112, 106061.

[51] United Nations. The sustainable development goals reports 2017-2022. Available online: https://unstats.un.org/sdgs/report/2018/

[52] World Bank (2004) World Development Report 2004.

[53] Liu, W. X., Lia, X. D., Shena Z.G., et al., (2003) Multivariate statistical study of heavy metal enrichment in sediments of the Pearl River Estuary. Environmental Pollution, 121 (3), pp. 377–388.

[54] Saud Shah, Chen Songsheng, Haseeb Abdul et al., (2019) The nexus between financial development, income level, and environment in Central and Eastern European Countries: a perspective on Belt and Road Initiative. Environmental Science and Pollution Research, 26, pp. 16053–16075.

[55] Zhuo Jianxin, Qamruzzaman Md., (2022) Do financial development, FDI, and globalization intensify environmental degradation through the channel of energy consumption: evidence from belt and road countries. Environmental Science and Pollution Research, 29, pp. 2753–2772.

[56] Chen Sheng-Tung, Chang Hui-Ting, (2016) Factors that affect the ecological footprint depending on the different income levels. AIMS Energy, 4(4), pp. 557-573.