

THE INTERCONNECTED NATURE OF SUSTAINABLE DEVELOPMENT GOALS: A HOLISTIC APPROACH TO GLOBAL DEVELOPMENT

Oksana Liashenko^{1*}, Olga Demianiuk²

¹Universidad de Sevilla, Seville, Spain

²West Ukrainian National University, Ternopil, Ukraine

*Corresponding author: oliashenko@us.es

The paper discusses the intricate interplay of Sustainable Development Goals (SDGs) and their impact on sustainable development. We emphasise the interconnected nature of the SDGs in terms of advancements in one area, which can lead to positive outcomes in others and the synergies and trade-offs among the goals. The research aims to unveil empirical relations among SDGs on a global country level by employing modern multivariate techniques to assess SDGs and rank them in terms of their importance in global development. The study takes a holistic approach to reveal the underlying complex governing these relationships, providing a comprehensive understanding of how these factors collectively shape sustainable development pathways. The factor analysis results reveal that one factor captures a significant portion of the variability of SDG scores. The factor and multivariate regression analyses highlight the relationships between the SDG Index scores and individual SDG scores, demonstrating the strong positive relationship between specific SDG scores and the 2023 SDG Index Score. The discussion emphasises the importance of integrated approaches that recognise the complexity of development challenges and the necessity for coordinated efforts across sectors and governance levels. The paper's findings contribute to a more comprehensive understanding of the SDGs' interdependencies, facilitating informed decision-making and policy formulation to foster sustainable and equitable development for future generations.

Keywords: Sustainable Development Goals, interconnections, factor analysis, empirical model

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Introduction

The Sustainable Development Goals (SDGs) represent a holistic framework designed to address the most critical challenges faced by humanity, ranging from eradicating poverty to preserving the environment. Central to the SDGs is recognising the profound interconnections among different aspects of sustainable development where economic, social and environmental targets are intertwined in the unified framework of 17 SDGs (Griggs et al., 2013; Nilsson et al., 2016). Implicit in the SDGs logic is that the goals and targets relate to and depend on each other but views on exactly how they are evolving (Nilsson et al., 2016).

Advancements in one area often lead to positive outcomes in others, as seen in investments in education (SDG4), yielding benefits such as improved health (SDG3), reduced inequalities (SDG 10), and progress in gender equality (SDG5). Taking a comprehensive approach to the SDGs encourages cooperation and synergies, enhancing the effectiveness of interventions. For instance, initiatives that

promote renewable energy (SDG7) not only contribute to climate action (SDG13) but also drive sustainable economic growth by creating employment opportunities (SDG8).

Understanding the interdependencies among the SDGs is crucial for crafting effective policies that can anticipate and address associated risks. Ensuring coherence and harmony in policymaking is essential to avoid conflicts between different objectives and to promote a well-rounded and inclusive approach to development. By embracing the principle of inclusivity, policymakers can guarantee that marginalised groups benefit equally from development initiatives, thereby fostering social fairness and unity. Ultimately, the interconnected nature of the SDGs highlights the significance of sustainable development strategies that harmonise economic advancement, social inclusivity, and environmental conservation, thereby nurturing resilient and fair societies for generations.

In this context, many questions arose that need to be addressed, such as: How can we ensure that progress toward achieving one SDG does not hinder progress towards other SDGs? How can policymakers balance economic growth with environmental protection and social inclusion to achieve sustainable development? What examples of successful initiatives demonstrate the benefits of a comprehensive approach to SDGs? How can we promote greater collaboration and knowledge-sharing between countries to accelerate SDG progress?

Our research aims to reveal empirical relations among SDGs globally by employing modern multivariate techniques to assess SDGs for ranking them in terms of their importance in global development.

Literature review

Many scientists have attempted to reveal the interrelations among SDGs. In a recent paper, Scharlemann et al. (2020) highlight the necessity of enhancing the efficacy of efforts targeting multiple SDGs, as there is limited time left to accomplish the global objectives by 2030. The research uses an influence matrix to evaluate the mutual relationships between all SDGs, indicating that environmental aspects and links between the environment and humans significantly impact most SDG interactions. The authors pinpoint a selection of measures associated with environment-human connections that substantially impact attaining specific SDGs, proposing that targeted environmental governance could enhance outcomes and alleviate trade-offs. The paper advocates for a comprehensive approach to SDG interactions, considering issues like knowledge deficiencies, critical points, stakeholder engagement, and site-specific factors to facilitate integrated strategising. Thus, Scharlemann et al. (2020) offer a thorough analysis of SDG interactions, underscoring the pivotal role of environmental governance in reaching the objectives. They suggest that comprehending and harnessing the links between the environment and humans is essential for fostering synergies and minimising conflicts among SDGs, thereby aiding in formulating more effective and well-informed policies and actions at national and global levels.

Previously, Nilsson et al. (2018), drawing on results from a major international research study applied to the SDGs on health, energy and the ocean, analysed how interactions depend on critical factors such as geographical context, resource endowments, time horizon and governance. Authors highlighted that insufficient coordination across political and sectoral boundaries and limitations in the capacity for data analysis or mainstreaming into policies is a significant reason for knowledge gaps. Nilsson et al. (2018) acknowledge that while there is a significant amount of case-study knowledge on interactions among SDGs, there are challenges in generalising this knowledge with quantitative and statistical data. In other words, excellent case-study knowledge exists for some

interactions, but difficulties arise when attempting to generalise these findings quantitatively. Additionally, there are instances where general statistics are available, but understanding how interactions play out in specific contexts is challenging. Therefore, while there is empirical evidence on SDG interactions, the document indicates a need for more systematic quantitative assessments and models to understand these interactions better. Simultaneously, Weitz N. et al. (2017) suggest that interactions among SDG targets can be assessed using systemic and contextual interactions, providing a more robust basis for priority setting and guiding effort allocation. Other researchers (Moallemi et al., 2021) introduce a flexible and practical systemic approach, archetype analysis, that generalises several recurring interaction patterns among the SDGs with unique drivers, behaviours, and policy implications. We review eight interaction archetypes as thinking aids to analyse significant synergies and trade-offs supported by several empirical examples. It is worth mentioning that some studies have used various quantitative methods for SDG interaction analysis, including indicator-based pairwise statistical correlation (Kroll et al., 2019; Pradhan et al., 2017), statistical modelling of interactions (Anderson et al., 2021), remote sensing tracking (Singha et al., 2021), and integrated assessment modelling (Moallemi et al., 2021).

Rather than focusing on specific interactions among SDGs, we take a holistic approach to unveil the underlying factor complex governing these relationships. By examining the intricate interplay of various SDGs as interconnected factors, our study provides a comprehensive understanding of how these factors collectively shape sustainable development pathways. That will help to facilitate informed decision-making and policy formulation by offering insights into SDG synergies and trade-offs.

Materials and Methods

The SDG indicators measure progress towards achieving the Sustainable Development Goals (SDGs). They are part of a global framework established by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and endorsed by the United Nations General Assembly (UN DESA, 2023). These indicators are transparent and methodologically robust, providing comprehensive coverage of countries to accurately represent their achievements in reaching the SDGs. All indicators have universally accepted methodologies, ensuring comparability, accuracy, reliability, and usefulness. They assess approximately 140 targets within the SDGs, and the latest global data shows that about half of these targets need to catch up to some extent or significantly. Meanwhile, more than 30% have not progressed or regressed since 2015 (UN DESA, 2023).

Overall, the SDG indicators are a set of metrics that provide a standardised way to measure and compare progress towards the Sustainable Development Goals across regions and nations. UN also constructed the SDG Index and SDG Scores for each goal. SDGs scores are constructed by first estimating scores for each of the 17 Sustainable Development Goals (SDGs) using the arithmetic mean of indicators associated with each goal. These individual goal scores are then averaged across all SDGs to derive a country's final SDG Index score. Sensitivity tests were conducted, including comparisons between arithmetic and geometric means and Monte-Carlo simulations at both the Index and Goal levels, to ensure robustness in constructing SDG scores and rankings (UN DESA, 2023).

For empirical analysis, we use SDG scores for all countries covered by the UN database and all SDGs (UN DESA, 2023).

To reveal the latent factor structure that explains variation in SDG achievement across countries globally, we use multivariate techniques, such as descriptive statistics and Factor Analysis

(FA), as explanatory scientific methods. Scientists (Haig, 2005; Watson, 2017) assert that Exploratory Factor Analysis (EFA) should be viewed as an abductive method for generating theories, leveraging the common cause principle within scientific inference. This aligns with FA interpretation as a latent variable technique, emphasising its role in theory generation. Furthermore, EFA facilitates the generation of theories with genuine explanatory power, addresses challenges such as factor indeterminacy, and can be effectively combined with Confirmatory Factor Analysis and other methods for theory evaluation. This supports our choice of Exploratory Factor Analysis in research because of its capacity for theory generation and compatibility with other analytical approaches. (Haig, 2005).

Results

Table 1 provides descriptive statistics for various SDG scores, including the 2023 SDG Index Score and individual goal scores. These statistics offer insights into the scores' central tendency, dispersion, and distribution. The average value of each score indicates the typical performance across countries in the dataset. For instance, the mean 2023 SDG Index Score is 67.55, suggesting the average performance across all SDGs of countries included in the analysis.

Table 1. Descriptive Statistics

	Mean	Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Coef.Var
2023 SDG Index Score	67.55	Multiple	38.68	86.8	60.44	75.02	15.24
Goal 1 Score	75.23	99.98350	0.00	100.0	54.36	98.96	41.43
Goal 2 Score	59.80	Multiple	19.81	83.4	53.93	67.46	17.76
Goal 3 Score	69.69	Multiple	12.95	97.1	51.84	85.64	29.21
Goal 4 Score	76.51	Multiple	1.23	99.8	61.28	95.66	30.30
Goal 5 Score	63.29	Multiple	13.05	94.0	50.97	76.15	25.91
Goal 6 Score	66.71	Multiple	32.60	95.1	55.23	76.06	21.12
Goal 7 Score	61.41	Multiple	8.70	99.6	47.20	74.37	33.16
Goal 8 Score	71.95	Multiple	39.54	93.4	66.42	79.71	14.72
Goal 9 Score	51.60	Multiple	1.65	99.1	30.18	74.72	51.48
Goal 10 Score	62.92	100.0000	0.00	100.0	41.61	84.61	43.47
Goal 11 Score	72.18	Multiple	13.83	99.9	59.96	86.57	25.24
Goal 12 Score	79.78	81.69729	37.73	98.8	68.33	94.13	20.17
Goal 13 Score	82.12	Multiple	0.00	99.9	72.24	96.75	25.79
Goal 14 Score	65.49	Multiple	36.58	90.4	57.59	73.08	17.52
Goal 15 Score	66.64	Multiple	26.48	97.8	56.51	76.66	21.27
Goal 16 Score	61.55	Multiple	29.44	93.8	48.97	73.81	25.21
Goal 17 Score	60.95	Multiple	29.35	94.0	50.85	71.67	21.31

All SDGs' scores (except for SDG 1 and 12) are multimodal, indicating that multiple distinct performance patterns may exist among different countries. For instance, the mean SDG 9 Score is 51.60, ranging from 1.65 to 99.1, indicating substantial variability in performance across different countries concerning Goal 9."

Overall, these descriptive statistics provide a comprehensive overview of the distribution and variability of SDG scores, facilitating further analysis and interpretation of performance across different sustainable development objectives.

We performed FA for seventeen SDG scores and the SDG Index using the Maximum Likelihood factor extraction method. As a result, we have one factor with an eigenvalue of 9.97, indicating that it explains approximately 55.41% of the total variance in the SDGs scores. This suggests that this factor captures a significant portion of the variability presented in the data. This factor alone accounts for 55.41% of the total variance; no additional factors are considered. Table 2 presents communalities for the SDGs' scores, computed using the Maximum Likelihood factor extraction method and an unrotated rotation. Communalities represent the proportion of variance in each observed variable that is accounted for by the factors extracted in the analysis.

Table 2. Communalities SDGs Scores (Maximum likelihood factors unrotated)

Variable	Form Factor	Multiple R-Square
2023 SDG Index Score	0.930	0.944
Goal 1 Score	0.698	0.781
Goal 2 Score	0.321	0.560
Goal 3 Score	0.861	0.870
Goal 4 Score	0.708	0.749
Goal 5 Score	0.526	0.696
Goal 6 Score	0.686	0.710
Goal 7 Score	0.712	0.763
Goal 8 Score	0.509	0.615
Goal 9 Score	0.821	0.854
Goal 10 Score	0.172	0.558
Goal 11 Score	0.711	0.758
Goal 12 Score	0.671	0.853
Goal 13 Score	0.450	0.730
Goal 14 Score	0.001	0.195
Goal 15 Score	0.094	0.368
Goal 16 Score	0.706	0.783
Goal 17 Score	0.398	0.514

For instance, the communalities for the 2023 SDG Index Score indicate that the factor extracted from the data explains approximately 92.97% of the variance in this variable. Similarly, for

the Goal1 Score, the factors account for approximately 69.78% of the variance. Higher commonalities suggest that the observed variables are well-represented by the factor extracted in the analysis.

Factor loadings represent the correlation between each observed variable and the underlying latent factor (Table 3). A factor loading more excellent than 0.7 in absolute terms is typically considered vital, indicating a significant relationship between the variable and the latent factor.

Table 3 shows that the SDG Index Score has an extreme loading in absolute terms (0.964), indicating a strong association with Factor. Similarly, most individual SDG scores have strong loadings, suggesting they are closely related to Factor.

Table 3. Factor Loadings (SDGs Scores) Extraction: Maximum likelihood factors

Variable	Factor coefficients
2023 SDG Index Score	-0.96
Goal1	-0.84
Goal2	-0.57
Goal3	-0.93
Goal4	-0.84
Goal5	-0.72
Goal6	-0.83
Goal7	-0.84
Goal8	-0.71
Goal9	-0.91
Goal10	-0.41
Goal11	-0.84
Goal12	0.82
Goal13	0.67
Goal14	-0.03
Goal15	-0.31
Goal16	-0.84
Goal17	-0.63

Table 3 shows that the SDG Index Score has an extreme loading in absolute terms (0.964), indicating a strong association with the underlying factor. This factor represents a latent variable that captures a significant portion of the variation across all SDG scores. It can be interpreted as a composite indicator reflecting overall SDG performance, as it explains over 55% of the total variance in the dataset. In essence, this factor combines the performance of individual SDGs into a single measure, highlighting how closely related the progress of different goals is within each country.

To identify the dependence of the 2023 SDG Index Score on the scores of the seventeen individual SDGs, we performed a multivariate regression analysis. While the SDG Index Score is calculated from its subindexes (i.e., the individual goal scores), this analysis aims to assess which

specific SDG scores contribute most significantly to variations in the overall Index. This approach allows us to highlight which goals substantially influence countries' overall sustainable development performance rather than assuming the Index could be independent of its components (Table 4).

The regression summary table provides important information regarding the relationship between the 2023 SDG Index Score, the dependent variable, and several independent variables represented by eight SDG Scores from seventeen included in the initial dataset. The regression model suggests a strong positive linear relationship between the independent and dependent variables, $R^2=0.94$ and Adjusted $R^2=0.93$, indicating that the independent variables in the model explain approximately 94% of the variance in the 2023 SDG Index Score. β coefficients represent the standardised coefficients for each independent variable in the regression model and indicate the change in the dependent variable (2023 SDG Index Score) associated with a one-unit change in the independent variable while holding all other variables constant.

Table 4. Regression Summary for Dependent Variable: 2023 SDG Index Score (SDGs Scores)
 $R=0.97$ $R^2=0.94$ Adjusted $R^2=0.93$ $F(17,89)=88.155$ $p<0.000$

	β	St. Err.of β	B	St. Err. Of B	t(89)	p-value
Goal 1 Score	0.15	0.05	0.06	0.02	3.00	0.00
Goal 2 Score	0.07	0.04	0.07	0.04	2.02	0.05
Goal 4 Score	0.12	0.05	0.06	0.02	2.50	0.01
Goal 7 Score	0.12	0.05	0.06	0.03	2.35	0.02
Goal 10 Score	0.14	0.03	0.05	0.01	3.87	0.00
Goal 14 Score	0.06	0.03	0.05	0.03	2.17	0.03
Goal 15 Score	0.07	0.03	0.05	0.02	2.45	0.02
Goal 17 Score	0.08	0.04	0.06	0.03	2.17	0.03

Interpreting the table, we observe that several independent variables (Goal 1 Score, Goal 4 Score, Goal 7 Score, Goal 10 Score, Goal 14 Score, Goal 15 Score, and Goal 17 Score) have statistically significant positive relationships with the 2023 SDG Index Score, as indicated by their respective p-values less than 0.05. This suggests that improvements in these specific SDG scores are associated with higher values of the 2023 SDG Index Score. However, it is essential to note that some of these goals may already be implemented at a relatively high level. Therefore, to further improve the SDG Index Score, countries should focus not only on enhancing the performance of lagging goals but also on maintaining and incrementally improving those goals that already show strong performance. This balanced approach will ensure that underperforming and well-performing SDGs contribute positively to sustainable development progress.

Discussion and Conclusions

The interconnection of the SDGs is central to achieving a sustainable and equitable future. It calls for integrated approaches that recognise the complexity of development challenges and the necessity for coordinated efforts across sectors and governance levels. By embracing this holistic perspective, we can chart a course towards a world where prosperity is shared, the planet is safeguarded, and no one is left behind.

Empirical analysis has shown that the essential SDGs that have a synergetic effect on SDG Index Score are: Goal 1 “No Poverty” (targets eradicating extreme poverty by ensuring access to resources and social protection); Goal 4 “Quality Education” (strives for inclusive and equitable education opportunities); Goal 7 “Affordable and Clean Energy” (focuses on sustainable energy access); Goal 10 “Reduced Inequalities” (aims to promote social inclusion); Goal 14 “Life Below Water” (emphasises marine conservation); Goal 15 “Life on Land,” (prioritises terrestrial ecosystem preservation); Goal 17 “Partnership for the Goals” (stresses global cooperation for sustainable development). These goals collectively address fundamental challenges toward a more equitable and sustainable future.

Policymakers can ensure that progress towards achieving one particular Sustainable Development Goal does not hinder progress towards other SDGs by adopting a comprehensive and integrated approach to policy formulation and implementation. Policymakers are involved in acknowledging the interconnected nature of the SDGs and understanding potential synergies and trade-offs between different goals. Policymakers should prioritise policies that promote cooperation and collaboration across sectors, as advancements in one area often lead to positive outcomes in others. For example, investments in education (SDG4) can yield benefits such as improved health (SDG3), reduced inequalities (SDG10), and progress in gender equality (SDG5).

Additionally, policymakers should strive to ensure coherence and harmony in policymaking to avoid conflicts between different goals and promote a well-rounded and inclusive approach to development. Such an approach must embrace the principle of inclusivity, guaranteeing that marginalised groups benefit equally from development initiatives, thereby fostering social fairness and unity.

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Conflict of interest

The authors state no conflict of interest.

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