World Journal of Education and Humanities
ISSN 2687-6760 (Print) ISSN 2687-6779 (Online)
Vol. 7 No. 3, 2025
www.scholink.org/ojs/index.php/wjeh

Original Paper

Measurement of Social Progress by Aggregated Sustainable Development Goals

Prof. Satyendra Nath Chakrabartty[1]

[1] Indian Ports Association, Indian Statistical Institute, India

E-mail: chakrabarttysatyendra3139@gmail.com

Received: April 18, 2025 Accepted: May 28, 2025 Online Published: June 28, 2025

doi:10.22158/wjeh.v7n3p39 URL: http://dx.doi.org/10.22158/wjeh.v7n3p39

Abstract

Measurement of social progress of a nation can be best done using framework of Sustainable Development Goals (SDGs). Avoiding normalization and weights, indicators of i-th target of the j-th SDG at t-th year of a country ($\mathbb{T}_{i_{SDG-j_t}}$ *) is obtained by multiplicative aggregation which can further be aggregated to compute SDG status of a country (* I_{SDG_t} *) and Global SDG (* $Global_{SDG_t}$ *). Each proposed index enables to quantify distance of a country from the SDG targets of 2030 and testing hypothesis of equality of log(* I_{SDG_t} *) for countries i and j (* $i \neq j$ *) at t-th year and also equality of log(* I_{SDG_t} *) and (* $I_{SDG_{(t+1)}}$ *) for same country by t-tests. Similarity of path of progress and decline of for two different countries across time can be quantified meaningfully. Novelty lies in application of the proposed multiplicative aggregation of SDG indicators in proportions, percentages, averages, rates, count data, etc. and satisfaction of translation invariance and consistency in aggregation. Policy makers and researchers can take advantages of the proposed method of multiplicative aggregation avoiding problems of normalization and assigning equal weight to the indicators and equal responsibility to all countries. Future empirical investigations may be undertaken to estimate distribution of* I_{SDG_t} *and inter-linkages of various SDGs to prepare a comprehensive plan for achieving the 2030 targets.*

Keywords

Sustainable development goals, SDG Indicators, Geometric mean, Progress path, Cosine similarity, Statistical tests

JEL classification: C43, E24, I 32

Introduction

Assessment of performance of a society or a nation involves among others meeting several social and environmental dimensions of citizens enabling them to gradually reach their full potential with improved quality of life (QoL). Economic growth in terms of GDP, per capita GDP, per capita gross national income (GNI), etc. ignores environment, calls for equity, rights and justice fail to reflect social progress involving measures of basic human well-being (Suri et al., 2011). GDP includes only market transactions and does not cover any measure of welfare. Thus, GDP is not an adequate index of social progress (Fleurbaey & Blanchet, 2013). Multidimensional assessment of welfare was offered by the Human Development Index (HDI) as geometric mean of normalized indices for each of the three dimensions: education, health and standard of living (UNDP, 2020). Need for inclusion of more dimensions relating to environment, climate, biodiversity, etc. in HDI were felt (Emmerling et al. 2024). Significant impact of climate change resulting in extreme weather, droughts, floods (IPCC, 2022); increasing trend of GHG emissions intensifying further risks and affecting lives (Field et al., 2012), etc. have been addressed at international levels who agreed to limit climate change, keeping the global temperature increase below 2℃ (Paris Agreement) (UNFCCC, 2015) along with protection of at least 30% land and sea area to stop biodiversity losses (COP15 on global biodiversity) (United Nations, 2022). Other illustrative indices reflecting social performance metrics are:

-Genuine Progress Index (GPI) consisting of indicators designed to improve on GDP by including cost variables in its calculation. GPI aims to assess net benefits of economic activities on society and the environment, based on market and non-market goods and services. However, the underlying assumptions, monetary weights, methodology of data aggregation of GPI have been questioned. Non-availability of governing body to coordinate the standards and revisions put doubts on legitimacy and quality of GPI as a composite index (CI) (Fox, 2018). Methodological up-gradation and standardization of GPI 2.0 were suggested (Talberth & Weisdorf, 2017).

Better Life Index (BLI) (OECD, 2020) is an interactive web-based tool with 24 indicators related to well-being distributed in 11 dimensions. While indicators have same weights, weights to the dimensions are determined by the users. Azevedo et al. (2020) found gap in application of non-compensatory Multi-Criteria Decision-Making (MCDM) methods using BLI data.

- Social Progress Index (SPI) (Social Progress Imperative, 2022) measures the extent to which a country provides social and environmental needs to its citizens. Based on outcome measures, SPI takes arithmetic mean (AM) of scores of the three dimensions: Basic human needs, Foundations of well-being for individuals and communities to sustain their QoL, and Opportunity for all individuals to reach their full potential. Here, dimension score is AM of the component scores. SPI has been criticised on (i) large proportion of incomplete and inaccurate data, especially related to environmental hazards, energy uses, specific health issues, employment quality, income and gender inequalities, and corruption (ii) non-consideration of psychological well-being, efficiency of judicial system and transportation infrastructure, wealth concentration in the top 1 percent of the population, etc.

- Sustainable Development Goals (SDGs) with 17 goals, 169 targets and over 200 indicators provide better understanding of human development through challenges on major dimensions like economic, social, environmental, ecological at global and national levels (United Nations, 2019). Monitoring of SDG progress at global, national and sub-national levels (e.g., companies) are made by assessing current status and distance from the 2030 targets (Sachs et al., 2022).

Data-driven SDG Index (SDGI) (Sachs et al., 2017) based on universally accepted SDGs framework is useful for inter- and intra- country comparisons and can be taken as the best tool to assess social progress covering issues in broad range like poverty, hunger, health, education, gender inequality, environmental protection and provide a measurable framework for assessing social progress. However, methodologically sound method of aggregation satisfying desired properties and facilitating concrete actions at local levels are needed.

Each index of social progress involves measurements of selected dimensions and constituent indicators with varying degree of correlation and trade off, followed by transformations and aggregation of the transformed or raw variables to a single index. Large number of indicators have been suggested and are being suggested primarily due to lack of clear consensus on the definition of development and attempt to make the index comprehensive. For example, SDG Report 2024 replaced "Terrestrial and freshwater biodiversity threats" by a new indicator on imported deforestation in SDG-15 for which data can be obtained using geospatial datasets (UN-DESA, 2024).

To ensure common score ranges of the indicators in unit free fashion, SDGI uses Min–Max transformation to normalize raw scores of *i*-th SDG indicator (X_i) to a relative measure by $Y_i = \frac{X_i - Min.X_i}{Targeted_{X_i} - Min.X_i} * 100$. Here, may be an outlier influencing Y_i.

Any change in $Min.X_i$ can change ranking or regions due to change in marginal rates of substitution (Seth and Villar, 2017). Correlation between raw scores (X_i) and normalized scores (Y_i) is not perfect since change in *Y* due to unit increase in *X* ($\frac{\Delta y}{\Delta x}$) is not constant. In addition, common reference point like mean is lost by such transformation (Mazziotta and Pareto, 2021). Addition/subtraction of figures in percentages are not meaningful and thus Min–Max transformation with $Targeted_{X_i}, Min.X_i$ in percentages is problematic. Min-Max scaling in terms of logarithm of scores, used for Income component of HDI (UNDP, 2010) as changes with change of origin. Desired properties like *Translation Invariance* (to produce the same result for a given set of inputs irrespective of their locations) and *consistency in aggregation* (value of an index computed in stages equals the value obtained in a single stage) are not satisfied by logarithmic transformation (Chakravarty 2003). Different normalization methods affect the results in different ways and incorrect method of normalization can distort the results (Mazziotta and Pareto, 2021). It may be desirable to aggregate indicators of SDGs avoiding normalization or scaling.

Denoting value of an indicator in 000 by (I_{00}), current year (I_{cv}), targeted value in 2030 (I_{TV}), UNESCAP approach 2020 (Bidarbakhtnia, 2020) normalized values of the indicator as where 10 if increasing value of the indicator is desirable and ‾10 otherwise.

Indicator-wise P_{CS}'s under a target are averaged which are again averaged to find average progress made (current status) in each goal. Anticipated progress gap (P_{pg}) was approximated by where is the estimated value of the indicator for 2030 and is the actual value in 2015. Major limitations of the approach are:

- Setting for 2000 and for 2030 is mechanical and not supported by theoretical justifications.
- Value of can influence significantly the relative measure P_{CS}
- $|I_{TV} - I_{00}|$ is different for different indicators and thus, average of P_{CS}'s with different denominators is not meaningful.
- Taking average to find indicator-wise targets and further average to find current status may violate consistency in aggregation.
- $\widehat{I_{30}}$ is estimated only for the indicators which are not likely to achieve the target. Question arises on quality of the estimates by weighted regression model using time-related weights with assumption (Bidarbakhtnia, 2017).
- There is no consensus on selection of weights to different indicators (UN-DESA, 2024). Thus, progress as weighted sum differ according to the choice of weights and give distorted results, even manipulating rank of countries (Grupp & Schubert, 2010).

Ranking by Min–Max transformation and ranking by weighted sum may be contradictory. Chakrabartty (2024) gave example where rank of Country A> Country B by Min–Max scaling, but as per weighted sum, rank of Country A< Country B. It may be desirable to aggregate indicators of SDGs avoiding selection of weights.

One major problem of SDG Index (SGDI) (Sachs et al., 2016) obtained by arithmetic aggregation of SGD indicators is substitutability, where reduced rate of child mortality, HIV infections, lower cost of remittances, improved access to , energy, sanitation, water, digital connectivity, etc. can compensate growing Iinequalities, accelerated loss of biodiversity, escalation of climate crisis, disappointing progress on gender equality, etc. Weights in compensatory aggregation cannot be interpreted as relative importance of the indicators (Decancq & Lugo, 2013).

Avoiding normalizations and selection of weights, multiplicative aggregation of SDG indicators of a country is proposed to reflect current status of the *i*-th target of the *j*-th SDG at *t*-th year of a country ($\mathbb{T}_{i_{SDG-j_t}}$), which are similarly combined across the targets to find index of SDG status of the country SDG (I_{SDG_t}) and further aggregation of I_{SDG_t}'s across countries to find $Global_{SDG_t}$. Values of each such index is expressed by monotonically increasing continuous variables satisfying desired properties

Literature survey:

Indicators:

A number of SDG indicators are associated with problems. Illustrative list includes:

-The SDG-1 for elimination of all forms of poverty considers poverty line as daily income $1.25 at 2017 PPP (Purchasing Power Parity) (UN DESA 2023) against $2.15 per person per day (World Bank 2025). Poverty line fails to reflect intensity of poverty in multi-dimensional deprivations. Inflation-adjusted poverty lines, separately for urban and rural areas are considered in India.

- Definitions of unemployment and employment (Indicator 8.5.2) may vary across surveys using questionnaires. Unemployment rate (Indicator 8.5.2) varies widely at regional levels and cannot be combined by averages.

- Evaluation of domestic material consumption (DMC) per head for different economic sectors cannot be made, which limits scope of the Indicator 8.4.2. DMC of a country with large export oriented primary production may vary in case of outsourcing of industrial process to other countries.

- Occupational injuries (both fatal and non-fatal) per 100,000 workers (Indicator 8.8.1) needs to convert number of part-time workers to full-time equivalents. Non-availability of number of hours worked creates another problem area.

- Non-uniform coverage or no coverage of informal economic activities affect the Indicator 8.2.1.

- Data on sexual violence against women aged ≥15 years (Indicator 5.2.2) are not internationally comparable.

SDG indicators are in proportions, percentages, averages, rates like (growth rate, number per 100,000 population, density of Health Workers, rate of participation, water-use efficiency, share of renewable energy, etc.), count data like (Number of people requiring interventions against neglected tropical diseases (3.3.5); total net official development assistance to medical research and basic health sectors (4.b.1), volume of official development assistance flows for scholarships, presence of facilities, compliance with rights (3.b.2), number of people who died/disappeared in the process of migration (10.7.3), etc. different sub-indicators like (indicator of food price anomalies, agriculture orientation index for government expenditures, parity indices as ratio of indicator value of one group with another group, Financial Soundness Indicators etc. Different methods used to combine indicators in different units following different unknown distributions. Some SDG indicators and dimensions may compete with others (Moyer & Bohl, 2019).

Percentages, proportions, rates are not additive like average speed of cars, since pooled average of X% and Y% $\frac{X\%+Y\%}{2}$. For a country, Literacy rate (in %) sum or average of and $Literacy\ rate_{Female}(\text{in }\%)$.

If $Literacy\ rate_{Male}(\text{in }\%) > Literacy\ rate_{Female}$ (in %) for 50% of the regions then the reversed inequality holds for the rest 50% regions, implying average gender gap for literacy rate could be zero for that country. Thus, AM of SDG indicators is not meaningful for indicators expressed in percentages, proportions, averages, rates and different sub-indicators. Sum of indicators (in %) fails to satisfy linear trend assumption due to non-heteroscedasticity, non-Gaussian residuals (Gennari & D'Orazio, 2020). Moreover, existence of significant data gaps and large volume of missing data resulting in exclusion of countries where missing data exceeds 20% of the indicators, may make the assessment biased.

Indicators and goals of SDG are correlated with different degree. SDG-1 (Poverty) and SDG-10 (Inequality) were found to be associated with higher environmental impacts (SDG-13 Carbon, SDG-15 Land, and SDG-6 Water), though the interactions differed among countries (Scherer et al., 2018). Values and directions of such correlations varied in different studies both temporally and spatially, leading to an unstable structure among goals (Lusseau & Mancini, 2019). Through network analysis Swain and Ranganathan (2021) found positive and negative interlinkages between the SDG targets and opined that universal benchmarking of SDGs is not productive. Considering systematic classification framework of SDGs, Zhang, et al. (2022) assessed variation of the SDG interactions in China and found synergies and trade-offs and among SDG-1 (No Poverty), SDG-3 (Good Health and Well-being), and SDG-6 (Clean Water and Sanitation).

Aggregation methods:

SDGI follows compensatory approach giving equal weight to the indicators and equal responsibility to countries irrespective of their sizes and taking AM in each level of aggregation. Other problem areas of SDGI methodology are:

- Compensatory aggregation methods suffers from substitutability.
- Min-Max transformation distorts reference point, data structure and has several limitations.
- Taking AM in each level of aggregation is not always meaningful. In case of high variability of an indicator on the values of the aggregate indicators for a country, extreme values influence the average. Moreover, average cannot solve problems of heterogeneity and redundancies between indicators under the same goal.

-Unknown probability density function (pdf) and f_Y of SDG indicators X and Y respectively, cannot help to find pdf of Z and compute

$f_Z(z) = \int_{-\infty}^{\infty} f_X(x) f_Y(z-x)\, dx$ where $Z = X + Y$. Thus, arithmetic aggregation of SDG indicators may not be meaningful.

Several aggregation methods to assess status of all SDGs taken together by a composite index (CI) and to track progress have been criticised (Heras-Saizarbitoria et al., 2022). Such methods with different assumptions and aggregation methodologies vary with respect to statistical features and need to be interpreted differently (Bidarbakhtnia, 2020). AM was used to get composite index of 17 SDGs by Sachs et al. (2016) where each indicator was measured on a scale 1 (worst) to 10 (best) and from 0 (worst) to 100 (best) respectively. SDGI and Dashboards Report (2017 edition) and the Sustainable Development Solutions Network (SDSN) also computed aggregate indices at global level as AM across the SDGs and observed the aggregate indices are independent of major pillars of sustainability and biased. Ruiz-Morales et al. (2021) computed SDG index using ordered weighted average where weights to the 17 SDGs were obtained by experts' subjective evaluations.

The OECD approach computes mean and Standard deviation (SD) of distance of each indicator and the respective 2030 target for each country and SDG status is taken as coefficient of variation $(\frac{SD}{Mean})$ (OECD, 2017). Ranking of countries with respect to OECD approach coincides with ranking by *SDSN*'s method when normalized on a scale of 0 to10. Both OECD and SDSN approaches cannot assess rate of progress registered by a country. However, OECD gives the direction of change in terms of correlation between time and indicator values, where a positive correlation indicates progress in the right direction to meet 2030 targets.

In line with SDG convention of equal weight to every SDG indicator, Chakrabartty (2024) proposed multiplicative aggregation avoiding normalization to reduce the compensation effect. Assessment of extent of SDG implementations and examination of interactions among the SDGs were attempted through sensitivity analysis (Marta et al., 2023). Focussing attention on sustainability, Ricciolini et al. (2022) used complicated Multiple Reference Point based on Weak-Strong Composite Indicators (MRP-WSCI) and also based on Partially Compensatory Indicator (MRP-PCI) and found occurrence of economic developments at the cost of environmental protection, leading to doubt on achievement of SDGs. However, both MRP-WSCI and MRP-PCI requiring selection of weights had different objectives. For tracking progress, SDG Tracker (Our World in Data team, 2023), presents indicator-wise data in a unified way. However, adjustments of data at national level for comparability across countries may distort data-structure and give inconsistent outcomes. Nilashi et al. (2023) investigated data challenges in measuring SDG performance and suggested big-data analytics requiring collection of data from different sources and in different formats, making data integration a complex affair. Data collected from different sources like remote sensing, integrated geospatial and population data, etc. and survey data using different questionnaires may not be comparable. As per SDG Report 2024, SDG targets on track constitute only 17%, about 50% are showing moderate to minimal progress, and for the rest SDG targets, progress are either stalled or regressed.

Suggested method

For a country, let values of *n*-indicators of the *i*-th target of a SDG at *t*-th year are $X_{1i}, X_{2i}, \ldots\ldots, X_{ni}$ and corresponding values of those *n*-indicators in the base period are $X_{1i_0}, X_{2i_0}, \ldots\ldots, X_{ni_0}$ where and $\forall\, k = 1, 2, \ldots\ldots, n$. Ensure that for each indicator, higher value implies better performance. For example, average annual dropout rate at the secondary school level, higher value implies deterioration of Quality Education, consider reciprocal of the indicator. For Gender Parity Index in higher education involving different enrolment rates of male and female students, take in a particular level of education with target = 1.

CI of the *i*-th target of the *j*-th SDG at *t*-th year is defined as

$$\mathbb{T}_{i_{SDG-j_t}} = \sqrt[n]{\frac{X_{1i}.X_{2i}\ldots\ldots\ldots\ldots X_{ni}}{X_{1i_0}X_{2i_0}\ldots\ldots\ldots\ldots X_{ni_0}}} \tag{1}$$

or equivalently

$$\mathbb{T}_{i_{SDG-j_t}} = \tag{2}$$

$\mathbb{T}_{i_{SDG-j_t}}$ combines relevant indicators by a single value reflecting current status of the *j*-th target of SDG at *t*-th year of a country by (1) and (2) which have one-to-one and onto correspondence.

Status of the *j*-th SDG at *t*-th year of a country (I_{SDG-j_t}) can be computed by combining *m*-number of targets by

$$I_{SDG-j_t} = \prod_{i=1}^{m} \mathbb{T}_{i_{SDG-j_t}} \tag{3}$$

Similarly, current status of all the SDGs for the country at *t*-th year can be obtained by

$$I_{SDG_t} = \prod_{j=1}^{17} I_{SDG-j_t} \tag{4}$$

Current status of all SDGs for *p*-number of countries can be combined to get index of global SDG at *t*-th period as

$$Global_{SDG_t} = \tag{5}$$

Taking logarithm on both sides of each of equation (2) to (5) we get additive models since *logarithm* (composite target) = $\sum logarithm$ of *n*-indicators at *t*-th period - $\sum logarithm$ of the indicators at base period.

Properties and Benefits:

For the proposed index of achievement of I_{SDG-j_t} at national level for a given year as per (3) and as per (4):

- Trade-offs among the constituent indicators of indices given in (2) to (5) get reduced significantly.
- Relative importance of the *i*-th target of the *j*-th SDG for the *t*-th year can be computed by $\frac{\mathbb{T}_{i_{SDG-j_t}}}{I_{SDG-j_t}} \times 100$, enabling ranking of the targets. Such rankings help to identify main drivers of the spatial variations of an SDG (say the *j*-th SDG). Similarly, indicates relative importance of each of the17 SDGs in overall SDGs of the country and finds specific SDGs needed to be focused.

Contribution of countries to global SDG at *t*-th period can similarly be found by $\frac{I_{SDG_t}}{Global_{SDG_t}} \times 100$. The relative contributions are different for different countries. For a given country, relative contributions get changed for different years.

- The *i*-th indicator may be critical if $\mathbb{T}_{i_{SDG-j_t}} < \mathbb{T}_{i_{SDG-j_{(t-1)}}}$ requiring necessary corrective action to arrest the poor performance of the critical indicator. Similarly, critical SDG for a nation requiring attention can be identified. The countries showing poor performance of with respect to the previous year may be alerted with the need for improvement along with indication of directions for improvements.

-For a given country, progress of I_{SDG-j_t} in successive years is indicated by and helps to know effectiveness of the policy measures adopted. Similar ratio based on or $Global_{SDG_t}$ can reflect overall improvement of SDGs at national or global level.

-Each of the indices and $Global_{SDG_t}$ is consistent and adequate since each satisfies the following tests:

- Unit test: Independent of change of scales (units) of the indicators. Can be applied for data in proportions, percentages, averages, rates, count data and even several sub-indices.

- Order reversal test: Independent of order of selection of constituent factors (indicators, targets, goals, SDG status in countries)
- Time reversal test: Can move both forward and backward with respect to time satisfying Time–reversal test since and

$\frac{I_{SDG_t}}{I_{SDG_{t_0}}} * \frac{I_{SDG_{t_0}}}{I_{SDG_t}} = 1$. For the global level, $\frac{Global_{SDG_t}}{Global_{SDG_{t_0}}} \times \frac{Global_{SDG_{t_0}}}{Global_{SDG_t}} = 1$

- Chain indices: Facilitates formation of chain indices since $I_{SDG-j20}=$ to know when base year is changed and facilitates drawing path of progress or decline of individual SDG ($I_{SDG-jt})$ or all SDGs taken together ($I_{SDG_t})$ for a country or even the progress path at global level ($Global_{SDG_t})$ across time. Such graphs can show behavior of SDG-achievements of different countries over time and also zigzag path of SDG at global level. The time points showing decline of status of individual SDG or all SDGs of a country can be probed appropriately to find possible reasons and remedial action.

- For p-countries, (5) helps to find mean and standard deviation (SD) of by standardization, and further transformation of Z_i to as so that Normally distributed Y-scores in fixed score range enables meaningful addition and parametric analysis including estimation of population mean (μ), population variance (σ^2), confidence interval and testing statistical hypothesis of equality of mean log I_{SDG_t} of countries at different regions since, if and $Y \sim N(\mu_Y, \sigma_Y^2)$ then $(X+Y) \sim N(\mu_X + \mu_Y, \sigma_X^2 + \sigma_X^2 + 2\sigma_{XY}$).

Average for the world can also be found as AM of country-wise Y-scores.

- Replacing values of indicators for base period by corresponding SDG-targets in equation (2), $\mathbb{T}_{i_{SDG-jt}}$ will indicate how far the country is from the targets of j-th SDG at t-th year. $\mathbb{T}_{i_{SDG-jt}} = 1$ implies that the country has achieved the targets of the j-th SDG. Overall distance of the country from all the SDG targets can be found similarly.

- Taking logarithms of the indicators, one can use usual t-test to test statistical hypothesis:

(i) for $i \neq j$ and

(ii) $I_{SDG_t} = I_{SDG_{(t-1)}}$

since it is well known that when different factors on the multidimensional index are multiplied, it tends to follow lognormal distribution (Harvey et al. 2025). If X follows lognormal then log(X) follows normal and vice versa.

-Similarity of Progress-decline paths of I_{SDG_t} registered by two countries across years can be assessed by suitably chosen measure of similarity. One such similarity measure is cosine similarity between vectors $\boldsymbol{P_1}$ and respectively where and $\boldsymbol{P_2} = (Prog._{21}, Prog._{22}, \ldots Prog._{2p})^T$ represent progress paths of country 1 and 2. Based on the length of the vectors and being the angle between the vectors $\boldsymbol{P_1}$ and $\boldsymbol{P_2}$, cosine similarity is given by (Chakrabartty & Sinha, 2022). Denoting number of countries covered by SDGs as *k*, one can find mean and SD of angles for vectors of unit length following method given by Rao (1973).

Limitations:

The proposed method assumes positive numerical value for each SDG indicator. Missing data, a major hindrance in SDG analysis were not considered. The missMDA package given using the imputeMFA function in R to impute the missing entries of mixed data by iterative PCA algorithm performs well (Josse & Husson 2016) was used to explore main dimensions of national SDG performance (Wu et al. 2023).

Discussion

Avoiding problems of normalization and selection of weights, multiplicative aggregation of indicators of each target of a SDG at a given year of a country is proposed as $\mathbb{T}_{i_{SDG-jt}}$. Further multiplicative aggregation of gives I_{SDG-jt}reflecting status of the *j*-th SDG at *t*-th year for the country, which can be aggregated similarly across all SDGs to get SDG status of a country (I_{SDG_t}). Global SDG ($Global_{SDG_t}$) at *t*-th year is similar aggregation of across countries. Each proposed index is a monotonically increasing continuous variable satisfying desired properties of composite index like translation invariance, aggregation consistency and can be computed separately for socio-economically advantaged or disadvantaged groups. Major illustrative benefits include:

- Reduced trade-offs.
- Independent of change of scales (units) of the indicators

- Can meaningfully aggregated data in proportions, percentages, averages, rates, count data, and even several sub-indices.

-Effects of outliers in data from developed or underdeveloped countries are practically nil.

-For a given country and a given time-period, the indicators can be ranked with respect to the relative importance along with measuring how far the country is from the SDG targets.

-Can compute $Global_{SDG_t}$; mean and SD of Global SDG and facilitate testing hypothesis regarding equality of for two different countries at a given year and equality of of a country in successive years.

-In case of rejection of $I_{SDG-jt} =$ or identification of critical indicator(s) and critical goals at country level offers direction of improvement required for the country and help in formulating action plans focusing on the identified critical indicator(s) or SDGs.

-Contribution of countries to $Global_{SDG}$ at *t*-th period can be found by $\frac{I_{SDG_t}}{Global_{SDG_t}} \times 100$ facilitating ranking of countries.

-Progress/decline paths of registered by two different countries during the past *p*-years can be compared meaningfully by chain indices even if base year is changed and similarity of such paths in terms of or all SDGs taken together ($I_{SDG_t})$ for a country can be found by cosine similarity.

-Measuring SDG-wise achievements of each country may facilitate investigations of progress in interlinked SDGs.

Conclusion

The proposed indices obtained by multiplicative aggregations can be applied for data in proportions, percentages, averages, rates, count data and even several sub-indices and computed at national levels and global level in an integrated way, which is a requirement of Agenda 2030 along with measuring how far the country is from the SDG targets. Multiple aggregation method without normalization and selection of weights offers significant benefits can contribute to improved aggregation of SDGs and is recommended. Future empirical investigations are suggested towards finding distribution of I_{SDG_t} and effect of progress/decline in I_{SDG-jt}on other SDGs and preparing comprehensive plan for achieving the 2030 Agenda.

Declarations:

Acknowledgement: Nil

Competing Interests: No competing interests to declare

Funding: No funds, grants, or other support was received

Data availability: Not applicable as no datasets were generated or analyzed in the study.

Authors' contribution: The single author is involved in Conceptualization, Methodology, Writing- Original draft preparation, Writing- Reviewing and Editing

Reference:

Azevedo, G. C., Costa, H. G., & Farias, Filho, J. R. (2020). Measuring Well-Being Through OECD Better Life Index: Mapping the Gaps. *International Joint Conference on Industrial Engineering and Operations Management, Rio de Janeiro, Brazil*, 8-14. https://doi.org/10.14488/IJCIEOM2020_FULL_0006_37403

Bidarbakhtnia, A. (2020). Measuring Sustainable Development Goals (SDGs): An inclusive approach. *Global Policy*, *11*(1), 56-67. https://doi.org/10.1111/1758-5899.12774

Bidarbakht- Nia, A. (2017). *A Weighted Extrapolation Method for measuring the SDG Progress*. UNESCAP Working Paper SD/WP/04/ March 2017.

Chakrabartty, S. (2024). Better Assessment of Progress of SDG 8 and Progress of all SDGs. *RMd Revistamultidisciplinar.com*, 6(3), e202429. https://doi.org/10.23882/emss.24242

Chakrabartty, S. N., & Sinha, D. (2022). A Single Measure of Overall Export Performance. *Margin—The Journal of Applied Economic Research*, 16, 3-4, 278-308. https://doi.org/10.1177/09738010231153057

Chakravarty, S. R. (2003). A Generalized Human Development Index. *Review of Development Economics*, *7*(1), 99-114. https://doi.org/10.1111/1467-9361.00178

Decancq, K., & Lugo, M. A. (2013). Weights in multidimensional indices of wellbeing: An overview. *Econometric Reviews*, *32*(1), 7-34. https://doi.org/10.1080/07474938.2012.690641

Emmerling, J., Kornek, U., & Zuber, S. (2024). *Multidimensional welfare indices and the IPCC 6th Assessment Report scenarios, Ecological Economics*, *220*, 10.1016/j.ecolecon.2024.108182.

Field, C. B, Barros, V, Stocker, T. F., Dahe, Q., Dokken, J. D. et al. (2012). Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the intergovernmental panel on climate change. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. https://doi.org/ 10.1017/CBO9781139177245.

Fleurbaey, M., & Blanchet, D. (2013). *Beyond GDP: Measuring welfare and assessing sustainability.* Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199767199.001.0001

Fox, Mairi-Jane, V., & Erickson, J. D. (2018). Genuine Economic Progress in the United States: A Fifty State Study and Comparative Assessment. *Ecological Economics*, *147*(C), 29-35. https://doi.org/10.1016/j.ecolecon.2018.01.002

Gennari, P., & D'Orazio, M. (2020). A statistical approach for assessing progress towards the SDG targets. *Statistical Journal of the IAOS*, *36*, 1129-1142. https://doi.org/10.3233/SJI-200688

Grupp, H., & Schubert, T. (2010). Review and new evidence on composite innovation indicators for evaluating national performance. *Research Policy*, *39*(1), 67-78. https://doi.org/10.1016/j.respol.2009.10.002.

Harvey, J., Motulsky, T. H., & Paul, B. S. C.(2025). *Analyzing lognormal data: A nonmathematical practical guide, Pharmacological Reviews*, *77*(3). https://doi.org/10.1016/j.pharmr.2025.100049

Heras-Saizarbitoria, I., Urbieta, L., & Boiral, O. (2022). Organizations' engagement with sustainable development goals: from cherry-picking to SDG-washing? *Corporate Social Responsibility and Environmental Management*, *29*(2), 316-328. https://doi.org/10.1002/csr.2202

IPCC. (2022). *Summary for Policymakers. Climate Change 2022 Mitigation of Climate Change Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.1017/9781009157940.001

Josse, J., & Husson, F. (2016). missMDA: A package for handling missing values in multivariate data analysis. *J. Stat. Softw*, *70*, 1-31. http://hdl.handle.net/10.18637/jss.v070.i01

Lusseau, D., & Mancini, F. (2019). Income-based variation in Sustainable Development Goal interaction networks. *Nature Sustainability*, *2*(3), 242-247. https://doi.org/10.1038/s41893-019-0231-4

Marta Kuc-Czarnecka, Iwona, M., & Agnieszka, S. R. (2023). SDGs implementation, their synergies, and trade-offs in EU countries – Sensitivity analysis-based approach. *Ecological Indicators*, *146.* https://doi.org/10.1016/j.ecolind.2023.109888

Mazziotta, M., & Paretoa, A. (2021). Everything you always wanted to know about normalization (but were afraid to ask). *Italian Review of Economics, Demography and Statistics*, *75*(1), 41-52.

Moyer, J. D., & Bohl, D. K. (2019). Alternative pathways to human development: Assessing trade-offs and synergies in achieving the sustainable development goals. *Futures*, *105*, 199-210. https://doi.org/10.1016/j.futures.2018.10.007

Nilashi, M., Keng Boon, O., Tan, G., Lin, B., & Abumalloh, R. (2023). Critical Data Challenges in Measuring the Performance of Sustainable Development Goals: Solutions and the Role of Big-Data Analytics. *Harvard Data Science Review*, *5*(3). https://doi.org/10.1162/99608f92.545db2cf

OECD. (2020). *How's life? 2020: Executive summary*. https://doi.org/10.1787/ea714361-en

OECD. (2017). *Measuring Distance to the SDG Targets 2017: An Assessment of Where OECD Countries Stand*. OECD Publishing. https://doi.org/10.1787/9789264308183-en.

Our World in Data team. (2023). *SDG Tracker: Measuring progress towards the Sustainable Development Goals*. https://ourworldindata.org/sdgs

Rao, C. R. (1973). *Linear statistical inference and its application* (2nd ed.). Wiley Eastern Private Limited. https://doi.org/10.1002/9780470316436

Ricciolini, E., Rocchi, L., Cardinali, M. *et al.* (2022). Assessing Progress Towards SDGs Implementation Using Multiple Reference Point Based Multicriteria Methods: The Case Study of the European Countries. *Soc Indic Res*, *162*, 1233-1260. https://doi.org/10.1007/s11205-022-02886-w

Ruiz-Morales, B., Espitia-Moreno, I. C., Alfaro-Garcia, V. G., & Leon-Castro, E. (2021). Sustainable Development Goals Analysis with Ordered Weighted Average Operators. *Sustainability*, *13*(9), 5240. https://doi.org/10.3390/su13095240

Sachs, J., Kroll, C., Lafortune, G., Fuller, G., & Woelm, F. (2022). *Sustainable development report 2022* (1st ed.). Cambridge University Press. 10.1017/9781009210058Saisana

Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D., & Teksoz, K. (2017). *SDG Index and Dashboards Report 2017*. New York: Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN).

Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D., & Teksoz, K. (2016). *SDG Index and Dashboards – Global Report*. New York: Bertelsmann Stiftung and Sustainable Development Solutions Network.

Scherer, L., Behrens, P., Koning, A. D., Heijungs, R., Sprecher, B., & Arnold, T. A. (2018). Trade-offs between social and environmental Sustainable Development Goals. *Environmental Science & Policy*, *90*, 65-72. https://doi.org/10.1016/j.envsci.2018.10.002

Seth, S., & Villar, A. (2017). *Measuring human development and human deprivations*. OPHI Working Paper 110, University of Oxford.

Social Progress Imperative. (2022). *Social Progress Index 2022. Social Progress Imperative*.

Suri, T., Boozer, M. A., Ranis, G., & Stewart, F. (2011). Paths to success: The relationship between human development and economic growth. *World Dev.*, *39*, 506-522. https://doi.org/10.1016/j.worlddev.2010.08.020

Swain, R. B., & Ranganathan, S. (2021). Modeling interlinkages between sustainable development goals using network analysis. *World Development*, *138*. https://doi.org/10.1016/j.worlddev.2020.105136

Talberth, J., & Weisdorf, M. (2017). Genuine Progress Indicator 2.0: Pilot Accounts for the US, Maryland, and City of Baltimore 2012-2014. *Ecological Economics*, *142*(C), 1-11. https://doi.org/10.1016/j.ecolecon.2017.06.012

UN-DESA. (2024). *Sustainable Development Report 2024*. New York, USA https://unstats.un.org/sdgs/report/2024/

UN DESA. (2023). *The Sustainable Development Goals Report 2023: Special Edition* - New York. USA: UN DESA. © UN DESA. https://unstats.un.org/sdgs/report/2023/

UNDP. (2020). *Human Development Report 2020: The Next Frontier: Human Development and the Anthropocene*. New York. http://report2020.archive.s3-website-us-east-1.amazonaws.com/

UNDP. (2010): *Human Development Report 2010: The Real Wealth of Nations—Pathways to Human Development*. New York. http://hdr.undp.org/en/content/human-development-report-2010

UNFCCC. (2015). *Adoption of the Paris Agreement, Conference of the Parties on its Twenty-first Session*. https://unfccc.int/resource/docs/2015/cop21/eng/10.pdf

United Nations. (2022). *Nations Adopt Four Goals, 23 Targets for 2030 in Landmark UN Biodiversity Agreement*. Press Release.

United Nations. (2019). *The Sustainable Development Goals Report 2019*. *New York*. https://doi.org/10.18356/55eb9109-en

World Bank. (2025). *Poverty and Inequality Platform (20240627_2017_01_02_PROD)* [data set]. pip.worldbank.org. Accessed on 2025-05-23

Wu, X., Fu, B., Wang, S., Liu, Y., Yao, Y. et al., (2023). Three main dimensions reflected by national SDG performance. *The Innovation*, *4*(6). https://doi.org/10.1016/j.xinn.2023.100507

Zhang, J., Wang, S., Pradhan, P., Zhao, W., & Fu, B. (2022). Untangling the interactions among the Sustainable Development Goals in China. *Science Bulletin*, *67*(9), 977-984. https://doi.org/10.1016/j.scib.2022.01.006