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MULTIDIMENSIONAL EVALUATION OF SOCIOECONOMIC STATUS AND SUSTAINABLE DEVELOPMENT GOALS

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Abstract: Methods to measure socioeconomic status (SES) interlinked with Sustainable Development Goals (SDGs) suffer from methodological limitations. Avoiding problems of scaling and selection of weights, the paper aims at aggregating subjective and objective measures of SES and SDGs by multiplicative aggregation to get composite indices SES_t and I_{SDG_t} reflecting overall improvement in a given period over the base period. Proposed indices ensure that Index computed in stages = Index obtained in a single stage. The indices cover variables in any form like percentages, rates, simple counts, ordinal scores, composite indices of the components of SES or SDG and facilitate assessment of changes across time, identification of critical areas, ranking based on relative importance, testing of statistical hypothesis. Combining variables in different scales of measurement by monotonically increasing continuous variable is a novelty. Distance of a country from achieving SDGs can be computed by considering SDG targets in base-period figures. Empirical relationships between I_{SDG_t} and SES_t can be established by simple linear regression or relationship among constituent dimensions or targets of I_{SDG_t} and SES_t by multiple linear regression or canonical correlation analysis.

Keywords: Socioeconomic status, SDG progress, Multiplicative aggregation, Progress path, Relative importance, Critical areas.

AVALIAÇÃO MULTIDIMENSIONAL DO STATUS SOCIOECONÔMICO E DOS OBJETIVOS DE DESENVOLVIMENTO SUSTENTÁVEL

Resumo: Os métodos para mensurar o status socioeconômico (SSE) em articulação com os Objetivos de Desenvolvimento Sustentável (ODS) apresentam limitações metodológicas. Buscando evitar problemas relacionados a escalas e à atribuição de pesos, este artigo propõe agregar medidas subjetivas e objetivas de SSE e ODS por meio de agregação multiplicativa, visando obter índices compostos (SSE_t e $ISDG_t$) que reflitam a melhoria global em um determinado período em relação ao período-base. Os índices propostos garantem a equivalência entre o índice calculado em etapas e o índice obtido em uma única etapa. Eles abrangem variáveis de diversas naturezas — como porcentagens, taxas, contagens simples, pontuações ordinais ou índices compostos de componentes de SSE ou ODS - e facilitam a avaliação de mudanças ao longo do tempo, a identificação de áreas críticas, a classificação com base na importância relativa e o teste de hipóteses estatísticas. A combinação de variáveis em diferentes escalas de medição por meio de uma variável contínua

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monotonicamente crescente constitui uma inovação. A distância de um país em relação ao alcance dos ODS pode ser calculada considerando-se as metas dos ODS com base nos valores do período-base. Relações empíricas entre $ISDG_t$ e SSE_t podem ser estabelecidas por regressão linear simples, enquanto as relações entre as dimensões ou metas constituintes de $ISDG_t$ e SSE_t podem ser analisadas por regressão linear múltipla ou análise de correlação canônica.

Palavras-chave: Status socioeconômico, Progresso nos ODS, Agregação multiplicativa, Trajetória de progresso, Importância relativa, Áreas críticas.

INTRODUCTION

Multidimensional socioeconomic status (SES) indicates social standing of individuals, families, communities, based on their income, education, power, occupation, etc. and access to socio-economic and cultural resources like money, shelter, food, healthcare, education, social opportunities, etc. (Smith et al. 2011). Higher SES generally correlates with better standard of living, better access to services, and increased opportunities for personal and family, development of cognitive and socio-emotional processes (Migeot et al., 2022; Judd et al., 2020). Lower SES is associated with low level of education, poverty and financial insecurity, poorer health outcomes, greater likelihood of diseases, reduced life expectancy, etc. which affect adversely social progress involving measures of basic human well-being (Suri et al., 2011).

While SES is more concerned with social standing relative to others, social development deals with societal evolution and changes over time with emphasis on progress in societal advancement and enhancing capabilities. Major components of SES includes income, occupations, educational attainments, etc. which are associated with availability of opportunities, resources, and outcomes, etc. Social development covers factors like education, healthcare, stable family environments, access to resources, and positive social and emotional development, social and economic disparities, etc., most of which are included in Sustainable Development Goals(SDGs). SES and social development are interlinked since improvement in one can lead to improvement in the other. A nation may be benefitted by focusing on SES-inequities and reducing SES gaps which can influence progress toward the SDGs. A number of SDG goals and targets require policy implementation leading to socio-economic development including development of the disadvantaged groups and/or impoverished people (Niaz, 2021). However, there is a lack of standardized method of

assessing SES. Methodologically sound method of SES facilitates better understanding of changes in society structure with respect to professional development, employment including female labour force participation rate (FLFPR), active social participation (ASP) in community life, politics, civil society, awareness on active citizenship relating to rights and responsibilities, mutual respect and non-violence in accordance with human rights and democracy (Livingstone et al .2005; Hoskins, 2009).

SES is interlinked with the SDGs as socioeconomic inequality can hinder progress on SDGs. The top seven SDGs like: No Poverty (SDG-1), Zero Hunger (SDG-2), Good health and well-being (SDG-3), Quality Education (SDG-4), Gender equality (SDG-5), Clean water and sanitation(SDG-6), Affordable and Clean Energy (SDG-7) are primarily focused on social development including impoverished segment of the society (Sachs, 2012). SES can also influence other indicators of SDGs relating to decent work opportunities (Goal 8), infrastructure development (Goal 9), safe and inclusive human settlements (Goal 11), peaceful and inclusive societies (Goal 16), etc. (UN, 2015). The envisaged path of SDGs' till 2030 also describes path of achieving socioeconomic progress (Eisenmenger et al., 2020). However, SDGs covering various socioeconomic dimensions of sustainability, may not be comprehensive (Bissio, 2019). Accordingly, additional indicators of socioeconomic development have been considered like quality of life (QOL) (Ventegodt et al., 2005), dwelling places (Murgaš and Klobučníǩ, 2016), happiness in life (Headey and Yong, 2019), life satisfaction (Li and Raine, 2014), ethnicity (Michalos and Zumbo, 2001), etc. An index of SES status at a given year for a country was proposed in terms of relevant SDG indicators and other socio-economic indicators (Chakrabartty, 2024). However, empirical relationships of SDG progress towards a safe and just operating space for humanity are not known (O'Neill et al., 2018).

The variables considered for measurement of SES and SDGs are in ratio scales, ordinal scales and categorical. While some variables are collected from secondary data in ratio scale, many are obtained by survey using questionnaires or scales developed for the purposes resulting in ordinal data. Desirability of inclusions of more variables to measure SDGs and also SES have been discussed and likely to be continued in near future. Inclusion of a broader set of indicators and dimensions was

felt needed for effective socioeconomic strategies of local and national governments (Buettner et al., 2020). Most important issue is aggregation of these variables measured in different levels of measurement in different units, different score ranges and unknown distributions of the component variables and the resulting composite index (CI) to facilitate meaningful measurement and comparison across pace and time by parametric analysis including testing of statistical hypothesis. There is no standardized method of aggregating subjective and objective measures in evaluating SDG progress and SES status.

The paper aggregates subjective and objective measures of SES and SDGs by multiplicative aggregation to get composite index (CI) reflecting status and overall improvement in *t*-th period from the base period (0-th period) by $SES_{t0}$for SES and $\mathbb{T}_{i_{SDG-j_t}}$ for the *i*-th SDG which can be aggregated across the 17-SDGs to find overall SDG status of a country by I_{SDG_t}. Desired properties satisfied by the indices SES_{t0} and I_{SDG_t} along with application areas are addressed.

Literature survey

Few indicators of SES and SDG do not appear to have adequate coverage. For example, energy used and material-environment interactions are not covered by the SDG indicator 8.2.1. Similarly, SDG indicator 8.3.1 ignores informal employment across genders in different sectors. In addition, non-uniform definitions of employment and unemployment across surveys add to the problem. Value of domestic material consumption (DMC) for a country may depend on outsourcing material-centric industrial production to other countries.

No poverty in SDG-1 considers the international poverty line as $\leq$ \$1.25 at 2017 Purchasing Power Parity (PPP) per capita per day (UN DESA 2023). This has been revised to \$1.90 per day by the World Bank (2021) and updated to \$2.15 per day (World Bank, 2022). Separate poverty lines for rural and urban areas after adjusting inflation appear to be logical. However, poverty line approach cannot reflect deprivations in multi-dimensional set up. The multidimensional poverty index (MPI) reflecting multiple deprivations beyond the monetary dimensions considers three

dimensions, each with different number of indicators (UNDP-OPHI 2021). MPI suffers from compensatory approach and ignores food insecurity, death rate**; m**aternal mortality, access to hospitals, health insurance, etc. and inter-temporal poverty (movement of individuals in and out of poverty) (Sahasranaman, 2021). In addition, assumption of items or dimensions of MPI are independent (no correlations) is not realistic (Nicole 2011). Cut-off mark of multidimensional deprivation score $\geq 33\%$ is arbitrary. Chakrabartty (2024b) proposed an index of overall multidimensional poverty by multiplicative aggregation.

Both SES and SDGs involve subjective and objective measures. Arithmetic aggregation of scores of a chosen set of independent or correlated indicators is not meaningful since levels of items in questionnaires or scales are not equidistant with respect to trait under consideration. The psychological distance between successive levels of the *Zung Self-Rating Depression Scale* (ZSDS) (Zung, 1965) such as "*A little of the time*", "*Some of the time*", "*Good part of the time*" and "*Most of the time*" is not uniform. If distance between *i*-th and *j*-th rung of 10-rungs of the *MacArthur Scale of Subjective Social Status* is denoted by$(d_{i,j})$, then $d_{10,9} \neq d_{9,8} \neq 2^{*}d_{9,7}$ and may not show behavior of the latent construct in accurate fashion. Hierarchy of occupations in six classes suggested by Azeez et al. (2016) does not represent equal distance between successive classes. Putting housewives, unemployed educated youths and apprentices into the lowest hierarchy i.e. around 40% of working-age population (WAP) of India is unfair. Even for objective measures of SES, methods to convert people or households in a fixed score range could be non-equidistant. Assigning scores of 0 – 8 for each chosen objective measures by Zhao et al. (2023) is rather arbitrary. Other SES measuring scales have been developed considering monetary dimensions like income, wealth, assets, etc. and non-monetary dimensions like education, maternal education, occupation, household prestige, water and sanitation, etc. However, too much reliance on income-based criteria which changes with change in Consumer Price Index (CPI) only limits accurate assessment of socioeconomic disparities. Each scale with limitations may not be appropriate for comparisons across space and time (Kishore et al. 2017).

Likert-type scales are used for measuring perceptions and attitudes to assess SES like Work and Meaning Inventory (WMI) using 5-point scale and SDG indicators like 11.3.2

(urban management structures), SDG 16.7.2 (political system responsiveness), etc. Levels of ordinal items are not equidistant and thus, scale scores as sum of items are not meaningful (Lee and Soutar, 2010). Non-meaningful addition of item scores implies computation of mean, variance, correlation, etc. may be distorted. Other limitations of Likert-type scales are:

- May be biased due to social desirability which may deviated from actual situations (Fastame et al. 2017).
- Equal importance to the items contradicts different values of item parameters like item-total correlations, correlations between pair of items, factor loadings of items, etc.
- Increase in number of levels changes score distribution and influence item/test parameters like reliability, validity more than the underlying variable (Lim, 2008).

Many SES and SDG indicators are in proportions, percentages, averages, rates (like mortality rate, dropout rate, participation rate, percentage of trained teachers, number of Health Workers per 100,000 population, material footprint per capita (8.4.1 of SDG-8), water-use efficiency, count data and different sub-indicators which are unit free. However**,** addition is not admissible for variables in percentages and proportions like average speed of cars. In case $Literacy\ rate_{Males} > Literacy\ rate_{Females}$ for 50% regions and $Literacy\ rate_{Females} > Literacy\ rate_{Males}$ for the remaining regions of a country, $Literacy\ rate_{Country}$ could be zero, since percentage literacy rate $\neq$ average of percentage literacy rate of different genders.

The resulting CI needs to satisfy at least the Translation Invariance property (result is independent of order of the constituent variables) and Aggregation Consistency (Index computed in two stages = Index computed in a single stage). The SDG index adopted in the *Sustainable Development Report 2024* (Jeffrey et al. 2024) does not satisfy the above said two desirable properties. Here, each indicator (X_i) is first normalized by Min–Max transformation $y_i = \frac{x_i - Min(x)}{Max\ (x) - Min(x)}$ and then normalized indicators for each goal are averaged without weights. The approach is not beyond criticism since average scores suffer from compensability or substitutability effect where low value of indicators can be offsetted by high value of other indicators (Herrero et al. 2010), and countries with missing data $\geq$20 percent of the indicators were ignored. Moreover, probability

distribution of Y_is obtained by Min–Max transformation are not known. Meaningful addition of two variables *X* + *Y*= *Z* requires knowledge of probability distribution function (pdf) of *X* and *Y* to compute $P(X+Y\leq z)=\int_{-\infty}^{\infty}(\int_{-\infty}^{z}f_{X,Y}(x,t-x)dt)$ which also requires knowledge of pdf of *Z*. Thus, average of unit free normalized scores may not be meaningful. Polinesi (2025) considered Y_i to follow $Beta$ distribution with positive parameters α and β where the pdf of *Y* is $f(y,\alpha,\beta)=\frac{y^{\alpha-1}-(1-y)^{\beta-1}}{B(\alpha,\beta)}$ for 0< y <1. Here, $B(\alpha,\beta)$ equals $(\alpha)(\beta)\Gamma(\alpha,\beta)$ where Γ is the Gamma function. The parameters α and β were taken as maximum likelihood estimates (MLE). But MLE assumes identically distributed variables coming from a specified probability distribution. If $\alpha>1$ and $\beta>1$, the distribution could be expressed in terms of the most likely value of the distribution (mode) and concentration (absence of variability). Despite following apparently complicated approach through beta distribution, Polinesi (2025) found no significant differences in levels of well-being levels before and after the COVID 19 pandemic. Other illustrative limitations of Min–Max transformation giving relative measures are:

- It gives uniform score range for each indicator but, changes common reference point like mean (Mazziotta and Pareto, 2021).
- Sample specific $Minx_i$ and $Maxx_i$ may be outliers, and may be removed (Bidarbakhtnia, 2018). Change in either $Minx_i$or $Maxx_i$ or both can alter ranks of the indicators (Seth and Villar, 2017).
- It is sensitive to outliers and non-robustness to changing data, requiring re-computation if new data has different minimum or maximum values.
- Indicators for which score-ranges are small tend to be overestimated.
- $Targeted_{x_i}(\%)-Minx_i(\%)$ is not meaningful for indicators in percentages. Min-Max normalization in terms of logarithm of scores, used by UNDP (2010) for income component as $Income_X=\frac{log_e{}^X-log_e{}^{(X_{Min})}}{log_e{}^{(X_{Max})}-log_e{}^{(X_{Min})}}$ is influenced by change of origin and properties like Translation Invariance and Aggregation Consistency are not satisfied (Chakravarty, 2003).
- r_{xy} between raw scores (x_i) and normalized scores $(y_i)\neq 1$ since change in y resulting from increase in x i.e. $\frac{\Delta y}{\Delta x}$ is not constant.

- Example showing Country A exceeding Country B by Min–Max normalization, but reverse inequality for weighted sum was given by Chakrabartty, (2024).

OECD transformed value of an indicator x_{it} for *i*-th country at *t*-th time to $z_{it} = \frac{|x_{it} - Target_{x_{it}}|}{S_{xt}}$ where S_{xt} denotes the standard deviation(SD) of X based on all countries in the *t*-th year. But, z_{it} does not lie between 0 and 1. $z_{it} > 2$ is interpreted as the *i*-th country is far away from the target. S_{xt} is influenced by outliers which could be replaced by robust estimators (Rousseeuw; Croux ,1993). The z_{it}-score, may not perform well for highly skewed distributions (Gennari and D'Orazio, 2020). In addition, SDG targets are given either in absolute terms or in relative terms with reference to the baseline year (e.g. Target 1.2 to reduce "proportion of men, women and children of all ages living in poverty from the baseline figures" at least by half), which vary across countries. Bidarbakhtni (2020) normalized SDG indicators by a different transformation where relative value of an indicator P_{CS} was arbitrarily taken as 0 for 2000 and 100 for 2030 followed by computation of arithmetic mean $\overline{P_{CS}}$. However, denominators of P_{CS} are different and thus, average is not meaningful. Different normalization methods in general and Min-Max transformation in particular, change shape of distributions of normalizes scores and distort the results (Mazziotta; Paretoa, 2021). For SES also different transformations were used for normalizations. Oka, (2021) compared different transformations for normalizations and found different interpretations of the regression coefficients of multilevel logistic regression analyses of the effect of neighborhood SES on health.

SDG Index by ordered weighted average of all SDGs was obtained by Ruiz-Morales et al. (2021) where weights to the targets were based on subjective evaluations of experts. Weights at indicator levels may perform better than weights at target levels (Asadikia, et al. 2024). SES were also evaluated by weighted sum where weights were found following different approaches. However, properties of CI depend heavily on way the weights are found. Different selection of weights may not ensure minimum variance of the resultant CI or equal correlation of CI with the component indicators. Psaki et al. (2014) considered weighted sum approach to measure Monthly per capita income of households (HI) selecting weights from PCA, MPI, conditional random forests (RF), along with maternal education, and found linear regression equations of HI on MPI and

RF were different and concluded that RF analysis could be a better alternative to PCA for SES scores. Moreover, weighted sum approach is also associated with compensability among the targets/indicators and is undesirable (Mariani; Ciommi, 2022). Muhammad *et al.* (2021) found that asset indices using PCA weights and unweighted indices performed with similar efficiency and SES of households can be well assessed without weights. PCA weights suffer from sampling errors, ignore indictors which are weakly correlated with CI. Moreover, PCA starts with correlation matrix which may be distorted by outliers present in data, normalization methods, etc. However, selection of weights are not uniform to assess CI like SES or SDG as weighted sum (UN-DESA, 2024). Methods of measuring SDG progress by different methodologies with different underlying assumptions, statistical features, etc. may not measure the same thing since measurement of SDG progress by SDSN, UNESCAP, and OECD approaches answered differently based on aggregation methods, selection and scoring of indicators. Thus, aggregation of SDG-indicators and indicators of SES avoiding scaling and weighted sum could be desirable.

Indicators like growth rates, income, social indicators, etc. exhibit right-skewed patterns, similar to lognormal distributions, rather than a symmetric normal distribution. Thus, use of lognormal distribution is more appropriate. Lognormal distributions are common when effects multiply rather than add. Product results of throwing 4 dice for 1000 times gave rise to asymmetrical distribution (Harvey *et al*. 2025). When effects of different factors on the multidimensional index are multiplicative, the index follows a lognormal distribution i.e. if X follows lognormal then log(X) follows normal and vice versa.

Proposed method

At the start, ensure positive relationship of each indicator with CI i.e. higher value of each indicator implies better performance. Avoiding scaling and weights, it is proposed to aggregate such indicator scores by multiplicative aggregation of $\frac{Current\ period\ scores}{Base\ period\ scores}$.

Let $Y_{1t}, Y_{2t}, \ldots\ldots, Y_{mt}$ be the values in the *t*-th period of *m*-indicators (subjective and objective) of SES and corresponding values in the base period are $Y_{10}, Y_{20}, \ldots\ldots, Y_{m0}$

where $(Y_{it}, Y_{i0} > 0)$. Define $SES_t = \sqrt[n]{\frac{Y_{1t},Y_{2t},\ldots\ldots,Y_{mt}}{Y_{10}\ Y_{20}\ \ldots\ldots Y_{m0}}}$ which equivalent is to $SES_t = \frac{Y_{1t},Y_{2t},\ldots\ldots,Y_{tc}}{Y_{10}\ Y_{20}\ \ldots\ldots Y_{m0}}$ (1)

Similarly, denoting observed values of *n*-indicators of the *i*-th target of *j*-th SDG at *t*-th year by $X_{1i}, X_{2i}, \ldots\ldots, X_{ni}$ and the corresponding base period values as $X_{1i_0}, X_{2i_0}, \ldots\ldots, X_{ni_0}$, the ratios $\frac{X_i}{X_{i_0}}$ can be aggregated to obtain index of the of the *i*-th target of the *j*-th SDG as:

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

Using (2), status of a SDG (say *j*-th) at *t*-th year (I_{SDG-j_t}) is given by combining *K*-number of targets as $I_{SDG-j_t} = \prod_{i=1}^{K} \mathbb{T}_{i_{SDG-j_t}}$ (3)

Status of all the 17 SDGs at a particular year (say *t*-th year) for a country is obtained as $I_{SDG_t} = \prod_{j=1}^{17} I_{SDG-j_t}$ (4)

Global status of SDGs can be obtained by aggregating country-wise status of *p*-number of countries at *t*-th period as $Global_{SDG_t} = \prod_{r=1}^{p} I_{SDG_{t_r}}$ (5)

Multiplicative models can be easily converted to additive models by taking logarithm on both sides of each of equation (1) to (5). For example,

$log\left(\mathbb{T}_{i_{SDG-j_t}}\right) = \sum_{j=1}^{n} logX_{ji} - \sum_{j=1}^{n} logX_{ji_0}$ (6)

is differentiable and $log\left(\mathbb{T}_{i_{SDG-j_t}}\right)$ following lognormal distribution since distribution of GM approaches lognormal distribution taking only positive real values (Alf; Grossberg, 1979).

Each index can be multiplied by 100 to maintain parity of composite indices.

Properties

- Each proposed index is expressed as a monotonically increasing continuous variable, with significant reduction of trade-offs among the constituent indicators.

- Unit-free indices $\boldsymbol{SES_t, I_{SDG-j_t}, I_{SDG_t}}$ and $\boldsymbol{Global_{SDG_t}}$ satisfies translation invariance property and aggregation consistency.
- 1% increase in $\frac{X_{it}}{X_{1i_0}} \implies$ 1% increase in I_{SDG_t} and 1% increase in $\frac{Y_{jt}}{Y_{j0}} \Longrightarrow$1% increase in SES_t when all others are unchanged. Thus, ΔI_{SDG_t} and $\Delta \frac{X_{it}}{X_{1i_0}}$ curve is linear. The same is true for SES_t
- The indices of SES and SDG can be computed for disadvantaged groups, regions, genders, urban & rural, etc. satisfying aggregation consistency since: $SES_t^{Country}$=$\prod SES_t^{Regions}$ =$\prod SES_t^{Dimensions}$=$\prod SES_t^{indicatorss}$ and $I_{SDG_t}{}^{Cuntry}$ = $\prod I_{SDG_t}{}^{Regions}$= $\prod I_{SDG_t}{}^{SDG_j}$ = $\prod I_{SDG_t}{}^{Targets\ of\ SDG_j}$ = $\prod I_{SDG_t}{}^{Indicators}$
- Each proposed index satisfy Time–reversal test since $\frac{I_{SDG-j_t}}{I_{SDG-j_{t_0}}} \times \frac{I_{SDG-j_{t_0}}}{I_{SDG-j_t}} = 1$ and $\frac{Global_{SDG_t}}{Global_{SDG_{t_0}}} \times \frac{Global_{SDG_{t_0}}}{Global_{SDG_t}} = 1.$
- Chain indices can be formed since $I_{SDG-j_{20}}$= $I_{SDG-j_{21}} \times I_{SDG-j_{10}}$.
- Relative importance of *j*-th indicator of SES_t is given by partial derivatives of $logSES_t$ with respect to $logY_{jt}$. Similarly, relative importance of the targets of the SDGs can be derived.
- The SDG targets and SES-indicators can be ranked with respect to the relative importance. The targets (or indicators) getting high ranks are the main drivers of the spatial variations of SDG (or SES) of a country and help prioritizing SDG targets for targeted interventions to have significant positive impact in short run.
- $\frac{I_{SDG_t}}{Global_{SDG_t}} \times 100$ could reflect contribution registered by a country to global SDG at *t*-th period.
- $\frac{SES_t}{SES_{(t-1)}} > 1$ implies improvement of SES in successive periods. Responsiveness of SES measurement and extent of improvement is reflected by $\frac{SES_t - SES_{(t-1)}}{SES_{(t-1)}}$ * 100. Similarly, progress of I_{SDG-j_t} in successive years can be measured by $\frac{I_{SDGj_t} - I_{SDGj_{(t-1)}}}{I_{SDGj_{(t-1)}}}$*100, positive value of which indicates effectiveness of the adopted policy measures.
- Progress in successive years can be plotted across time periods to give progress path of an index with unchanged base period. Chain indices can translate progress with changing base period. Such progress paths indicates trends of progress better than trends given by CAGR considering only two terminating time periods.

- The *i*-th indicator of *j*-th SDG is critical if $\frac{\mathbb{T}_{i_{SDG-j_t}}}{\mathbb{T}_{i_{SDG-j_{(t-1)}}}} < 1.$ Similarly, *i*-th indicator of SES is critical if $\frac{SES_{i_t}}{SES_{i_{(t-1)}}} < 1.$Critical indicators merit managerial attention for necessary corrective action to arrest poor performances.
- Can be disaggregated by income, gender, age, ethnicity, disability, geographic location, or other characteristics.
- How far a country is at *t*-th period from the 2030 SDG targets can be obtained by replacing denominators of $\mathbb{T}_{i_{SDG-j_t}}$ by the corresponding SDG targets.
- Linear regression equations can be fitted between I_{SDG_t} and SES_t and find predictive power of SES_t in prediction of I_{SDG_t}. Similarly, multiple linear regression can be established with each of the proposed indices as dependent variable and $\frac{X_{it}}{X_{i0}}$ or $\frac{X_{it}}{X_{i0}}$ as independent variables where β-coefficients can be interpreted as influence of the chosen independent variable to predict the proposed indices.
- The indices are applicable for data in any forms such as Count data (like number of countries adopting national disaster risk reduction strategies (SDG 1.5.3));

Ordinal scores used for evaluation of MPI, ZSDS, MacArthur SSS Scale, etc.; Proportion (like proportion of population living below the national poverty line, by sex and age (SDG 1.2.1)), Ratios like Maternal mortality ratio (SDG 3.1.1), Rates like density of Health Workers, rate of participation, share of renewable energy, etc.; Averages (like average hourly earnings of female and male employees, by occupation, age and persons with disabilities (SDG 8.5.1)); data in other forms like change in water-use efficiency expressed in USD per cubic meter (SDG 6.4.1), Gini index for SDG 10 and even composite indices of the components like Agriculture Orientation Index for government expenditures (SDG 2.a.1), Active Participation Index, Index of Poverty, etc.

Empirical Illustration

Empirical illustration of calculation of the proposed index by multiplicative aggregation of hypothetical data on 17 goals of a country for different years was given by Chakrabartty (2026).

Limitations

Considers no missing data. Treatment of missing data may be taken up as a future study. Cautions to be exercised if value of a positive ratio is <1 since $\log(x)$<0 for $0 < x < 1$. The proposed approach assumes positive numerical values for each SDG target, since without clear targets, quantification of progress towards these targets face significant limitations. Introduction of new indicator like Indicator on imported deforestation in SDG-15 in SDG Report 2024 creates problem in comparability. To ensure comparability, value of each new indicators needs to be collected or estimated separately for the base period and subsequent periods.

Discussion

Proposed multiplicative aggregation of subjective and objective measures of SES and SDGs, irrespective of inter-correlations among the indicators and dimensions (targets) to get composite indices SES_t and I_{SDG_t} reflecting overall improvement in a given period over the base period has theoretical advantages. The approach avoiding normalization and weights restores distributional characteristics of the chosen indicators. For each index, lower achievement in an indicator is not linearly compensated by higher achievement in another indicator and thus, substitutability between indicators is reduced significantly. It also ensures that 1% increase in an indicator implies 1% increase on SES_t or I_{SDG_t}. Knowledge of probability distribution of each proposed index helps to undertake testing statistical hypothesis like H_0: SES_t = $SES_{(t-1)}$ or H_0: $I_{SDG_t} = I_{SDG_{(t-1)}}$. Rejection of H_0: SES_t = $SES_{(t-1)}$ or H_0: $I_{SDG_t} = I_{SDG_{(t-1)}}$ can be probed to identify indicator(s) showing poor performance, which provides direction of improvement. Empirical relationships can be established between I_{SDG_t} and SES_t by simple linear regression. Similarly, relationship among constituent dimension or targets of I_{SDG_t} and SES_t can be found by multiple linear regression or canonical correlation analysis. Progress path of I_{SDG_t} or $SES_t$for generate time series data indicating trend of progress better than CAGR. Similarity of progress paths of two countries can be evaluated by suitable measure of similarity like cosine similarity of

two *s*-dimensional vectors $\boldsymbol{P_1} = (Prog._{11}, Prog._{12}, \ldots, Prog._{1s})^T$ and $\boldsymbol{P_2} = (Prog._{21}, Prog._{22} \ldots Prog._{2s})^T$ (Chakrabartty; Sinha, 2022).

CONCLUSION

The proposed indices with wide coverage of data in any forms have aggregation consistency and offer significant benefits to improved aggregation of SDGs including SDG progress at national/global level are recommended. Future empirical investigations are suggested for empirical investigations of the salient features of the proposed approach along with empirical relationships among the indices and their constituent dimensions or targets, robustness for generalization of findings including treatment of missing data.

Declarations

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