MedCrave
Step into the World of Research

Sociology International Journal

Research Article

Open Access

CrossMark

Better measurement of progress in SDG with emphasis on SDG-4 in India

Abstract

Avoiding scaling and selection of weights and replacing zero target of each indicator by a small value say 0.0001, the paper provides a simple method of multiplicative aggregation of indicators of *i*-th dimension of SDG-4 at *t*-th year → dimension scores $(\mathfrak{D}_{i_t})$ → country score (I_{SDG-4t}) → Global SDG-4 $(Global_{SDG-4t})$. I_{SDG-4t} reflects position of *i*-th country at *t*-th year by a continuous monotonically increasing variable as an absolute measure satisfying desired properties like meaningful aggregation, Time-reversal test, formation of chain indices, etc. and offering significant benefits. The index is not affected by outliers and produces no bias for developed or underdeveloped countries. It helps to identify relative importance of the dimensions and critical dimensions/indicators requiring managerial attention, assess progress of SDG-4 over time, find distanceof I_{SDG-4t} from the SDG targets. It enables testing hypothesis of equality of I_{SDG-4t} across time and space, and is applicable to other SDGs.

The proposed method contributes to improve aggregation of SDG indicators avoiding major limitations of existing methods. Policy makers and researchers can take advantages of the multiplicative aggregation. Future studies may empirically estimate distribution of I_{SDG-4t} and find effect of progress in SDG-4 on other SDGs for a comprehensive SDG progress report for effective monitoring the implementation of the 2030 Agenda.

Keywords: SDG indicators, geometric mean, progress assessment, progress path, cosine similarity, statistical tests, global SDG-4 index

Volume 8 Issue 3 - 2024

Satyendra Nath Chakrabartty
Indian Statistical Institute, India

Correspondence: Satyendra Nath Chakrabartty, Professor at Indian Statistical Institute, Flat 4B, Cleopatra, DC 258, Street No. 350, Action Area 1, New Town, Kolkata 700156, India, Tel 91-9831597909, Email chakrabarttysatyendr3139@gmail.com

Received: May 25, 2024 | **Published:** June 12, 2024

Introduction

India, as a signatory to the Sustainable Development Goals (SDGs) is committed to provide quality education for all, irrespective of gender, caste and creed, disabilities up to secondary level by 2030. The goal 4 of SGD (SDG-4) focusing on Quality, Access, Equity and Inclusion (QAEI) are extremely significant in the context of India due to its large young population, with an median age of 28.7 years where 25.68% are up to 14 years age and 67.49% are in the age group 15-64 years i.e." working age population". The demographic dividend can be harnessed with improvement in education, health and skill development.[1] In addition, significant gender gap, lack of access to digital learning resources, etc. are challenges to achieve SDG-4 goals by India.

Achievement of progress of SDG-4 is multidimensional in nature. Achievement of a country at a particular time-point (say year) can be divided into a finite number of dimensions where each dimension consists of different number of measurable indicators in different units. This requires a methodologically sound method of aggregation of indicators to obtain dimension scores which again are aggregated to get scores of achievement of SDG-4 or index of achievement of SDG-4 for a given year (I_{SDG-4t}) at national level.

Usually, indicators are evaluated at state-levels. Thus, the aggregation methods need to ensure meaningful aggregation of the indices at state-levels and further aggregation of at state-level indices to find I_{SDG-4t} at the national level at *t*-th year to facilitate.

Better comparison and ranking of several countries at a given year with respect to I_{SDG-4t} along with test of equality of I_{SDG-4t} for two or more countries

Assessment of overall progress at time-period (t+1) over the period t and test $H_0: I_{SDG-4t} = (I_{SDG-4t+1})$.

Drawing path of improvements/deteriorations of I_{SDG-4t} across time for each country

(i) Identification of relative importance of dimensions and indicators to aggregated scores

(ii) Identification of critical dimensions or indicators showing poor performances for necessary corrective policy action

(iii) Measure how far a country is from the SDG-4 targets to be achieved by 2030. Countries can also be ranked in terms of distance from the set of SDG-4 targets

(iv) Global SDG-4 index

Focusing attention to SDG-4 only, the paper proposes simple methods of aggregating indicators avoiding normalizations and assigning weights to SDG-4 indicators and discusses properties of the proposed methods.

Outcome targets of SDG-4

Seven outcome targets of SDG-4 to be achieved by 2030 are:

Universal primary and secondary education

All girls and boys to complete free, equitable and quality education (primary and secondary) leading to effective learning outcomes.[2]

Early childhood development and universal pre-primary education

All girls and boys have access to quality early childhood development, care and pre-primary education to make them ready for primary education.[3]

Equal access to technical/vocational and higher education

All women and men to have equal access to affordable and quality technical, vocational and tertiary education, including university education.[4]

Relevant skills for decent work

Increase significantly the number of youth and adults with relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.[5] Computer-assisted learning had more positive effect compared to having new teaching materials.[6]

Gender equality and inclusion

Eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerables, including persons with disabilities, indigenous peoples and children in vulnerable situations.[7]

Universal youth literacy

To ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy.[8]

Education for sustainable development and global citizenship

To ensure that all learners acquire knowledge and skills needed to promote sustainable development, including among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.

Progress made by India towards SGD-4

To achieve SDG-4, the government needs to enact relevant Acts, implement programmes and invest more in education, including early childhood education, teacher training, digital infrastructure, etc. Private sector partnerships can also play important roles in improving access to quality education.

Illustrative list of initiatives taken by the Government of India towards achieving the SDG-4.

Samagra Shiksha in 2018 by subsuming the erstwhile three schemes Sarva Shiksha Abhiyan (SSA), Rashtriya Madhyamik Shiksha Abhiyan (RMSA) and Teacher Education (TE) to ensure inclusive and equitable quality education at all levels of school education. It covers school education from pre-school level to class XII. It has now been aligned with the National Education Policy (NEP) 2020 in order to ensure inclusive and equitable, quality and holistic school education.

National Skill Development Corporation (NSDC) in 2008 to provide vocational education and training to young people so as to improve their employability and meet the demands of the Indian economy.

Mid-Day Meal Scheme in 1995 to provide free meals to children in government schools to improve enrollment, attendance, and retention rates.

Digital India in 2015 for better digital infrastructure and digital literacy and skill trainings to help transform India into a digitally empowered society and knowledge economy.

National Educational Policy (NEP) in 2020 to meet the changing dynamics of the present day requirement with regard to quality education, innovation and research. NEP 2020 aims to restructure and reorient the education system and achieve universalization of education from pre-school to secondary level with 100% Gross Enrolment Ratio (GER) in school education, and also to eliminate discrimination in education and bring out-of-school children back into the mainstream through an open schooling system and thus make India a knowledge hub by equipping its students with skill development and up gradation including ICT and vocational training. The policy aims at increasing supply of qualified teachers by developing a Common National Professional Standards for Teachers.

Structured Assessment for Analyzing Learning levels (SAFAL) developed by CBSE and launched in 2021 in CBSE schools for grades 3, 5 and 8. As per NEP 2020,this assessment will focus on testing for core concepts, application-based questions and higher-order thinking skills. To ensure progress, SAFAL will provide diagnostic information about students' learning to schools and thus, support school education to move towards competency-based education. For class IX and X, Learning outcomes developed by NCERT have been disseminated across States/UTs. Learning Outcomes document for the senior secondary level has been developed and the draft document has been shared with States and UTs for feedback.

India has achieved substantial progress towards the Goal-4 of SDG. Total number of students enrolled in school education in India (primary to higher secondary) stood at 25.57 crore in 2021-22 against 25.38 crore in 2020-21, implying an increase of 19.36 lakh enrolments. Similar increasing trends were also observed for Scheduled caste, Scheduled Tribe, other backward students and Children with Special Needs (CWSN) (http://dashboard.udiseplus.gov.in).GER in 2021-22 also improved at primary, upper primary, and higher secondary levels of school education, as compared to 2020-21. Notably, GER in higher secondary has made significant improvement from 53.8% in 2020-21 to 57.6% in 2021-22. Details are shown in Table 1.

Table 1 Gross enrollment ratio (in percentage) in India in 2021-22 and 2020-21

2021 - 22						2020-21					
Elementary School			**Secondary School (IX to X)**			**Sr. Secondary School**			**Higher Education**		
Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
99.3	101.1*	100.1*	79.7	79.4	79.6	57	58.2	57.6	26.7	27.9	27.3

Source: Unified District Information System for Education (UDISE +) for 2021-22 and All India Survey on Higher Education (AISHE) for 2020-21. GER >100 % indicate presence of over- or under-age children at a particular level.

The overall dropout rate as percentage of students who leave school before completing their level or grade also improved in 2021-22 to 1.5% from 1.8% in comparison to the previous year. As per the UDISE+ 2021-22 data, the dropout rate is highest at the secondary level (IX-X) with 12.6%, followed by upper primary (VI - VIII) with 3% and primary (I-V) with 1.5%. The data further reveals that the dropout rate is higher for girls than boys at all levels of education. The rate is slightly higher for upper primary students (Classes VI-VIII), with an average of 3%. However, the dropout rate for secondary school students (Classes IX-X) is significantly higher at 12.6%. However, the rate for girls is significantly higher than for boys and the rate is still a concern, especially in certain states (Table 2).

Citation: Chakrabartty SN. Better measurement of progress in SDG with emphasis on SDG-4 in India. *Sociol Int J.* 2024;8(3):141–147.
DOI: 10.15406/sij.2024.08.00387

Table 2 Dropout rate, basic infrastructure & pupil-teacher ratios: 2018-19

Description	State	Indicators			
		Average Annual Dropout Rate: Secondary Level (Grades 9-10)	**Percentage of Schools with Access to Basic Infrastructure : Electricity & Drinking Water**	**Percentage of Trained Teachers at Secondary Level (Grades 9-10)**	**Pupil-teacher ratio at Secondary Level (Grades 9- 10)**
TOP States/UTs	Kerala	9.14	99.24	94.53	16
	Himachal Pradesh	7.81	97.59	79.55	9
	Tamil Nadu	13.02	96.08	93.31	18
	Chandigarh	4.52	100	89.49	12
Bottom States/ UTs	Arunachal Pradesh	35.98	50.94	79.04	14
	Bihar	28.46	88.66	78.44	58
	Jammu and Kashmir	17.81	80.14	80.09	12
	Madhya Pradesh	24.85	75.34	81.19	36
	Assam	31.47	59.51	29.29	11
	All India	17.87	84.76	82.62	21
	Targets	8.8	100	100	30

Source: Grouped as per SDG: 2020-21, NITI Aayog, Government of India (June 2021).

Literacy Assessment Tests conducted by the National Literacy Mission Authority (NLMA) in consultation with the National Institute of Open Schooling (NIOS), literacy rate is calculated based on Census data. Table 3 depicts Adult Literacy Rate for male and female and corresponding gender-gap. The table revels Adult Literacy Rate for female improved and Gender gap was narrowed down in India during 2001 to 2011. Dimensions and indicators may get changed with time. For example, computation of Educational Development Index (EDI) by NIEPA covered a set of 24 dimensions and two more dimensions were subsequently added viz. School Education Quality Index (SEQI) and Performance Grading Index (PGI). For the dimension Quality Education, indicators used, SDG targets etc. are shown in Table 4.

Table 3 Adult literacy rate (in percentage) in India (Age≥ 15 years)

Year	Male	Female	Total	Gender Gap
2001	73.4	47.8	61	25.6
2011	78.8	59.3	69.3	19.6

Source: GOI, MHRD, Educational Statistics at a Glance, 2016.

Table 4 Quality education indicators used in SDG Index 2020-21

Indicator	Source	Present value	Target	Justification
Adjusted Net Enrolment Ratio (ANER) in elementary education(I - VIII)	UDISE, 2018-19	87.26	100	This corresponds to the SDG 4.1 to ensure that all girls and boys complete free, equitable, & quality primary and secondary education.
GER in higher secondary (XI-XII)	UDISE, 2018-19	50.14	100	NEP 2020 aims at universal, free and compulsory access to high-quality and equitable schooling from early childhood care and education (≥ 3 years) till XII for all students
GER in higher education (18-23 years)	All India Survey of Higher Education, 2018-19	26.3	50	GER in higher education to reach 50% by 2035 - NEP 2020 aims
Average annual dropout rate at the secondary level (IX-X)	UDISE, 2018-19	17.87	8.8	The target corresponding to SDG 4.1 ensures that all girls and boys complete free, equitable & quality primary and secondary education. NEP 2020 aims to achieve 100% GER at school education by 2030.
Percentage of students in Grade VIII achieving a minimum proficiency level through nationally defined learning outcomes to be attained by the pupils at the end of the grade.	Dep. of School Education & Literacy. NIF Progress Report 2020 V2.1, MoSPI, GoI.	71.9	100	The target corresponds to the SDG 4.1 to ensure that all girls and boys complete free, equitable, & quality primary and secondary education with relevant and effective learning outcomes.
Gender Parity Index (GPI) for higher education (18-23 years)	AISHE, 2018-19	1	1	The target is aligned with the SDG 4.5 which aims to eliminate gender disparities in education.
Percentage of literate persons (≥)	Periodic Labour Force Survey 2018-19	74.6	100	The target is aligned with the SDG 4.6 to ensure that all youth and a substantial proportion of adults achieve literacy and numeracy, by 2030.

Citation: Chakrabartty SN. Better measurement of progress in SDG with emphasis on SDG-4 in India. *Sociol Int J.* 2024;8(3):141–147.
DOI: 10.15406/sij.2024.08.00387

Table 4 Continued...

Indicator	Source	Present value	Target	Justification
15 years)				
Percentage of schools with access to basic infrastructure	Ministry of Education, 2018-19	84.76	100	NEP 2020 aims to provide effective and adequate infrastructure for all students to have access to safe and engaging school education from preprimary to XII ensuring that no school remains deficient in infrastructure support
Percentage of trained teachers at the secondary level (IX- X)	Ministry of Education, 2018-19	82.62	100	The target is aligned with SDG 4c which aims to substantially increase the supply of qualified teachers.
Pupil-Teacher Ratio (PTR) at the secondary level	Ministry of Education and UDISE, 2018-19	21	30	NEP 2020 proposes PTR of under 30:1 at each level of school education
(IX - X)				

Source: SDG 2020-21, NITI Aayog.

Observations

Figures in percentages are not additive. Literacy Rate of India (in percentage) is different from sum or average of percentage Literacy Rate of males and the same for females. Thus, arithmetic aggregation of the indicators is not meaningful. The indicators for Quality Education cannot be added in meaningful fashion. Computation of Gender Gap in Adult Literacy Rate as difference of Literacy Rate of males (in%) minus percentage Literacy Rate of females in Table 3 is also not meaningful.

Instead of Gender Gap, Gender Parity Index (GPI) in education is taken as the ratio of number of male students enrolled in a particular level of education and the number of female students enrolled in the same level of education. However, in case of higher enrollment of females than males, $GPI > 1$ implying education access in favor of female students. As per AISHE, 2020-21 data, *GPI* for Higher Education (18-23 Years) exceeded unity in large number of States/UTs like Andaman & Nicobar Islands, Assam, Chandigarh, Chhattisgarh, Delhi, Goa, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Ladakh, Lakshadweep, Manipur, Meghalaya, Mizoram, Nagaland, Puducherry, Punjab, Sikkim, Tamilnadu, Telangana,, Dadra and Nagar Haveli and Daman and Diu, Uttar Pradesh, Uttrakhand, West Bengal and at All India level.[9]

However, such GPI may not guarantee increase in enrolment rates and fails to identify barriers to Gender Equality. Theoretically speaking, if literacy rate of male and female are M_L and F_L respectively, $M_L > F_L$ for 50% of the States/UTs of India and for the rest, $F_L > M_L$, then the country average of gender gap with respect to literacy rate could be zero.

Meaningful application of statistical approach to $Z = X + Y$ demands knowledge of distributions of X and Y with known or estimated probability density function f_X and f_Y respectively and finding f_Z so that $f_Z(z) = \int_{-\infty}^{\infty} f_X(x) f_Y(z-x)\, dx$ for continuous variables. Similar convolution of discrete variables can be defined.[10] Methodological limitations and empirical inconsistencies of arithmetic aggregations have been discussed by various researchers like.[11-13] For arithmetic aggregation, indicator scores may be converted to continuous monotonic scores following Normal Distribution.[14]

Aggregation of Indicators

SDG-4 indicators are in percentages or in ratios which do not allow meaningful application of addition and subtraction. It is difficult to maintain the linear trend assumption of such indicators because of the well-known problems of non-heteroscedasticity, non-Gaussian residuals and non-linear relationships close to the interval boundaries.[15] However,[16] normalized scores of i-th indicator (x_i) by Min- Max function i.e.

$$y_i = \frac{x_i - Min.x_i}{T_{argetedx_i} - Min.x_i} * 100 \quad (1)$$

where y_i is the normalized value of the i-th indicator and $Minx_i$ is the minimum of observed values in the data set. This is followed by SDG Index Score for the i-th State/UT corresponding to the j-th goal (I_{ij}) as arithmetic mean (AM) of the normalized values of all indicators (with equal weights) within the Goal i.e.

$$I_{ij} = \sum_{k=1}^{N_i j} \frac{I_{ij}}{N_{ij}} \quad (2)$$

where N_{ij} denotes number of indicators with non-zero targets and obtain composite SDG India Index as AM of $I_{ij}s$ of all SDGs.

It may be noted that $(x_i - Minx_i)$ or $(T_{argetedx_i} - Minx_i)$ are not meaningful when $x_i's$ are in percentages or ratios. To avoid the problem of data in percentages, 3rd root and 4th root of average of figures in percentage were considered in Human Poverty Index (HPI) for HPI- 1 and HPI – 2 respectively.[17] Further analysis of 3rd root and 4th root of average of figures in percentage are problematic. For the Income component,[18] used

$$Income_X = \frac{log_e{}^X - log_e{}^{(X_{Min})}}{log_e{}^{(X_{Max})} - log_e{}^{(X_{Min})}} \quad (3)$$

However, such transformation using natural logarithm is not beyond criticism. For example, $Income_X$ is not invariant under change of origin. Logarithmic transformation does not satisfy properties like Translation Invariance and consistency in aggregation.[19] Normalization using Min.- Max function depends heavily on $Minx_i$ and changes distribution of Y scores and may affect the composite index. The $X-Y$ curve is not linear. *Y*-score of an indicator is a relative measure and not an absolute one.[20] Un-weighted AM suffers from substitutability effect i.e. low value of an indicator gets compensated by higher value of another indicator. [21]Suggested normalization transformation

$$Z_{it} = \frac{|X_{it} - X^*|}{S_{xt}} \quad (4)$$

where X_{it} denotes value of the i-th generic indicator at time t of a country, X^* is the target value for the indicator for the country and S_{xt} is the standard deviation of X_{it} based on all countries in year t. The formula by SDSN/Bertelsmann Stiftung report,[22] involves value of the "worst" case among the countries in t-th year. Here, range of the transformed variable gets affected by the presence of outliers.

Citation: Chakrabartty SN. Better measurement of progress in SDG with emphasis on SDG-4 in India. *Sociol Int J.* 2024;8(3):141–147.
DOI: 10.15406/sij.2024.08.00387

However, values of an indicator in a year for all the countries may not be readily available and it could be desirable to compute composite SDG-4 index of a country for a year based on data relevant to the country only. Baseline status index approach was suggested,[23] to measure progress made by each region/sub-region compared to the distance between its starting point and the target. Such indicator cannot be found for a region that has already achieved the target in the baseline year, even if it may be away from the target in subsequent years.[15]

Progress over time

Measurement of progress in SDG-4 over times is desirable. Time series analysis requiring large numbers of data points are not used for SDG data due to short length, at best starting from 2015 with time lag of two years (approx.) from data collection to data dissemination. Other methods used include: Compound annual growth rate (CAGR) based on the initial and final values only is calculated as

$$CAGR_{Ai} = \left(\frac{x_{it}}{x_{it_0}}\right)^{\frac{1}{t-t_o}} - 1 \quad (5)$$

The required CAGR to achieve the target is:

$$CAGR_{Ri} = \left(\frac{x_i^*}{x_{it_0}}\right)^{\frac{1}{T-t_o}} - 1 \quad (6)$$

The ratio of observed CAGR and required CAGR i.e. $CR_i = \frac{CAGR_{Ai}}{CAGR_{Ri}}$ was used as the assessment.[24-26] $CR_i \approx 1$ implies that the i-th country is "on track" to reach the target. Eurostat (2019) classified EU countries on the basis of CR_i as follows:

$CR_i < 0$: Away from the target

$0 \le CR_i < 0.6$: insufficient progress towards the target

$0.6 \le CR_i < 0.95$: Moderate progress towards the target

$CR_i \ge 0.95$: Significant progress towards the target

The threshold values of the classification based on 36 SDG indicators were slightly different for UN 2020 progress chart.

Consideration of only two data points and ignoring data of in-between years is a criticism against CAGR approach. Better will be a method of estimating country-wise I_{SDG-4t} which facilitate drawing path of improvements/deteriorations of I_{SDG-4_t} across time for each country.

Proposed method

Let $X_{1i}, X_{2i}, \ldots\ldots, X_{ni}$ are values of n-indicators of the i-th dimension of SDG-4 of a State/UT at a given year. Let $X_{1i_0}, X_{2i_0}, \ldots\ldots, X_{ni_0}$ are the corresponding targets for the indicators of the dimension. Assume each indicator is positively related to the corresponding dimension i.e. higher value of the indicator gives higher value of the dimension. Similarly, assume each dimension is positively related to the higher value of the index of achievement of SDG-4. For example indicator like higher value of average annual dropout rate at the secondary level (IX-X) will deteriorate the dimension Quality Education. For such indicators consider the reciprocal of the indicator. In the instant case, modified indicator will be reciprocal of dropout rate. Indicator like Gender Parity Index (GPI) for higher education (18-23 years) involving different enrolled rate of males and females with the target = 1, take ratio of number of male students enrolled in a particular level of education and the number of female students enrolled in the same level of education.

For positive values of each indicator and each target, define dimension score at t-th year as

$$\mathfrak{D}_{i_t} = \sqrt[n]{\frac{X_{1i}.X_{2i}\ldots\ldots\ldots\ldots X_{ni}}{X_{1i_0}.X_{2i_0}\ldots\ldots\ldots\ldots X_{ni_0}}} \quad (7)$$

or ignoring the n-th root

$$\mathfrak{D}_{i_t} = \frac{X_{1i}, X_{2i}, \ldots\ldots, X_{ni}}{X_{1i_0}, X_{2i_0}, \ldots\ldots, X_{ni_0}} \quad (8)$$

$\mathfrak{D}_{i_t}$ as per (7) is equivalent to $\mathfrak{D}_{i_t}$ as per (8). Computation of $\mathfrak{D}_{i_t}$ as per (7) or (8) requires replacement of zero target/achievement of each indicator by a small value say 0.0001

$\mathfrak{D}_{i_t}$ gives a single value of achievement of a State/UT for the i-th dimension at t-th period by multiplicative aggregation of the n-chosen indicators.

Proposed index of achievement of SDG-4 for a given year (I_{SDG-4_t}) at national level is given by a function of geometric mean (ignoring m-root) of m-number of fixed dimensions

$\mathfrak{D}_{1_t}, \mathfrak{D}_{2_t}, \ldots\ldots\ldots, \mathfrak{D}_{m_t}$ i.e.

$$I_{SDG-4_t} = \prod_{j=1}^{m} \mathfrak{D}_{j_t} \quad (9)$$

Similarly, Global SDG-4 index of all the k-countries considered can be obtained as geometric mean of I_{SDG-4_t} i.e.

$$(Global_{SDG-4t}) = \sqrt[k]{\prod_{u=1}^{k} I_{SDG-4_t u}} \quad (10)$$

The following may be noted:

Taking logarithim on both sides of (8) we get

$$lnD_{(i_t)} = \sum_{(i=1)}^{n} lnX_{(p_i)} - \sum_{i=1}^{n} ln\, X_{p_{i_0}} \quad (11)$$

In other words, log of a dimension score = Sum of log of n-indicators - Sum of log of the targets

i.e. an additive model.

Properties of the index I_{SDG}-4t

Proposed index of achievement of SDG-4 for a given year (I_{SDG-4t}) at national level as per (9) satisfies:

Product of all I_{SDH-4} dimensions = I_{SDG-4_t} of a country at time period t.

Trade-off among the dimensions or indicators are significantly reduced

Relative importance of i-th dimension to I_{SDG-4_t} can be assessed by $\frac{D_{(i_t)}}{I_{SDG-4t}} * 100$. The dimensions may be ranked with respect to the relative importance.

The i-th dimension will be critical if $\mathfrak{D}_{i_t} < \mathfrak{D}_{i_{(t-1)}}$. Identification of indicator(s) contributing to deterioration of $\mathfrak{D}_{i_t}$ can be made using (8) and necessary corrective action may be initiated on the identified indicators.

Satisfies Time–reversal test since $\frac{I_{SDG-4_t}}{I_{SDG-4_{t0}}} \times \frac{I_{SDG-4t0}}{I_{SDG-4_t}} = 1$ for a country

Citation: Chakrabartty SN. Better measurement of progress in SDG with emphasis on SDG-4 in India. *Sociol Int J.* 2024;8(3):141–147.
DOI: 10.15406/sij.2024.08.00387

Facilitates formation of chain indices since $I_{SDG-4_{20}} = I_{SDG-4_{21}} \times I_{SDG-4_{10}}$

From (9), $\log I_{SDG-4_t} = \sum_{j=1}^{m} \log \mathfrak{D}_{j_t}$

From (10), $\log Global_{SDG-4_t} = \frac{1}{k}[\sum_{u=1}^{k} \log(I_{SDG-4_{t_u}})]$ (12)

For k-countries, (11) helps to find mean and variance of $\log Global_{SDG-4_t}$ by transforming $\log Global_{SDG-4_t}$ of countries by $Z_i = \frac{\log I_{SDG-4_{t_u}i} - \overline{\log I_{SDG-4_t}}}{SD(\log I_{SDG-4_t})} \sim N(0,1)$ and further linear transformation of Z_i to Y_i by $Y_i = (99)\left[\frac{Z_i - Min_{Z_i}}{Max_{Z_i} - Min_{Z_i}}\right] + 1$ so that $Y_i \in [1,100]$.

Normally distributed Y-scores in fixed 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 $\log I_{SDG-4_t}$ of countries at different regions since, if $X \sim N(\mu_X, \sigma_X^2)$ 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 $\log I_{SDG-4t}$ for the world can also be found as AM of country-wise Y-scores.

Progress in SDG-4 of a country in successive years is given by $\frac{I_{SDG-4_t}}{I_{SDG-4_{(t-1)}}}$. Effectiveness of policy measures is reflected if $\frac{I_{SDG-4_t}}{I_{SDG-4_{(t-1)}}} > 1$ indicating overall progress made by the country in t-th period over (t-1)-th period. Similar ratio can be computed to reflect improvement from the base period i.e. $\frac{I_{SDG-4_t}}{I_{SDG-4_{t0}}}$

Facilitate drawing progress path registered by a country from baseline period using $\frac{I_{SDG-4_t}}{I_{SDG-4_{t0}}}$ and chain indices.

- If dimension scores are replaced by corresponding targets, $I_{SDG-4_t} = 1$ implying the country has achieved the SDG-4 targets. Thus, $(1 - I_{SDG-4_t})$ indicates distance of the country from SDG targets at t-th year.

-Hypotheses H_0: $I_{SDG-4_t\ Country_i} = I_{SDG-4_t\ Country_j}$ and H_0: $I_{SDG-4_t\ Country_i} = I_{SDG-4_{(t-1)}\ Country_i}$ can be tested by conventional t-tests on the logarithms of the dimensions.

Similarity of paths showing progress/decline of I_{SDG-4_t} over a span of years for two countries can be tested by Modified Mann-Kendall trend test, which is robust in autocorrelation,[27] requiring appropriate choice of similarity measure.[28] suggested cosine similarity of progress paths of two countries represented by two p-dimensional vectors covering p-number of years $\boldsymbol{P}_1 = (Prog._{11}, Prog._{12}, \ldots, Prog._{1p})^T$ & $\boldsymbol{P}_2 = (Prog._{21}, Prog._{22}, \ldots Prog._{2p})^T$. Similarity is defined as $Cos\theta_{12} = \frac{P_1^T P_2}{\boldsymbol{P_1 P_2}}$ where θ_{12} is the angle between P_1 and P_2; $\|\boldsymbol{P_1}\|, \|\boldsymbol{P_2}\|$ are the length of the vectors P_1 and P_2 respectively. For k-number of countries,[29] gave method of computation of mean and dispersion of angles $\varphi_1, \varphi_2, \ldots\ldots, \varphi_k$ for vectors of unit length can as $\bar{\varphi} = Cot^{-1}\frac{\sum_{j=1}^{k} Cos\varphi_i}{\sum_{j=1}^{k} Sin\varphi_j}$ and

Dispersion = $\sqrt{1 - [\frac{\sum Cos\varphi_j}{k}]^2 - [\frac{\sum Sin\varphi_j}{k}]^2}$

Limitations

Existences of targets in numerical values were assumed. Missing values were not considered, for which several methods are there to tackle the problem of missing value.

Discussion

Avoiding scaling and selection of weights, and replacing zero target of each indicator by a small value say 0.0001, the paper presents a simple method of multiplicative aggregation of indicators of i-th dimension of SDG-4 at t-th year $\rightarrow$ dimensions $(\mathfrak{D}_{i_t}) \rightarrow$ country $I_{SDG-4t} \rightarrow$ Global SDG-4 ($Global_{SDG-4t}$) to reflect position of i-th country by a continuous variable as an absolute measure which increases monotonically and satisfy desired properties like Time-reversal test, formation of chain indices with benefits like:

Significant reduction of trade-off among the dimensions or indicators

Less affected by outliers and produces no bias for developed or underdeveloped countries

Identification of relative importance of the dimensions and critical dimension(s) requiring managerial attention

Assessment of progress of SDG-4 over time avoiding methods involving CAGR with limitations.

Assessment of distance from the SDG targets for a country at a time-point

Mean and variance of Global SDG-4 can be obtained in terms of $\log Global_{SDG-4_t}$

Testing statistical hypothesis of equality of I_{SDG-4_t} for two different countries at t-th year and also for equality of I_{SDG-4_t} of a country at successive years by conventional t-tests on the logarithms of the dimensions.

$I_{SDG-4_t\ Country_i} < I_{SDG-4_{(t-1)}\ Country_i}$ requires identification of dimension(s) and indicator(s) showing poor performances giving direction of improvement. Necessary corrective actions may be formulated accordingly focusing on the identified critical dimension(s) and indicator(s).

Possible to plot path of progress/decline of the index at country level and measure similarity between such paths registered by a pair of countries during the last p-number of years. If k-countries are considered, (k_{c_2})-pairs are possible. Mean and variance of similarities of progress paths of (k_{c_2})-pairs of countries can be computed.

The method emphasizing SDG-4 can be applied to other SDGs also. Measuring country level achievements by the proposed method in each other SDGs will help in investigations of progress in SDG-4 on other SDGs like No Poverty(SDG-1), Good health and wellbeing(SDG-3), Gender equality and empowerment of women(SDG-5), Sustained, inclusive and sustainable economic growth and decent work for all (SDG-8), Resilient infrastructure and promotion of sustainable industrialization and foster innovation (SDG-9), Reduced inequalities within and among countries (SDG-10), Sustainable Cities and Communities (SDG-11), Responsible Consumption and Production(SDG-12), Education and awareness toward combating climate changes and their impacts (SDG-13),

Citation: Chakrabartty SN. Better measurement of progress in SDG with emphasis on SDG-4 in India. *Sociol Int J.* 2024;8(3):141–147.
DOI: 10.15406/sij.2024.08.00387

Promote peaceful and inclusive societies (SDG-16), etc. However, different indicators used for Gender inequality in different SDGs may result in different approaches.

Conclusion

The proposed method of geometric aggregations offering significant benefits contributes to improve aggregation of SDG avoiding major limitations of existing methods of aggregations and offering answers to natural questions like assessment of the index at global level, test of statistical hypothesis on equality of the index at national levels, progress-path across time, similarity of progress-paths, etc. Policy makers and researchers can take advantages of the proposed method of multiplicative aggregation without scaling and choosing weights. The proposed aggregation method is recommended.

Simulation studies may be undertaken to empirically estimate distribution of I_{SDG-4_t} and to find effect of progress in SDG-4 on other SDGs along with preparation of a comprehensive SDG progress report for effective monitoring the implementation of the 2030 Agenda.

Acknowledgments

None.

Competing Interests

The authors report there are no competing interests to declare.

Funding

No funds, grants, or other support was received. The author has no relevant financial or non-financial interests to disclose.

References

1. Pandey B. Achieving SDG 4 in India: moving from quantity to quality education for all. RIS Discussion Papers number 232. 2018.
2. Miles S, Singal N. The education for all and inclusive education debate: Conflict, contradiction or opportunity?. *International Journal of Inclusive Education.* 2010;14(1):1–15.
3. Haslip MJ, Gullo DF. The changing landscape of early childhood education: Implications for policy and practice. *Early Childhood Education Journal.* 2018;46(3):249–264.
4. Owens TL. Higher education in the sustainable development goals framework. *European Journal of Education*. 2017;52(4): 414–420.
5. Hamburg I. Facilitating lifelong learning in SMEs towards SDG4. *Advances in Social Sciences Research Journal.* 2020;7(9):262–272.
6. Krishnaratne S, White H, Ella Carpenter E, et al. Quality education for all children? What works in education in developing countries. International Initiative for Impact Evaluation; New Delhi: 2013.
7. Koehler G. Tapping the sustainable development goals for progressive gender equity and equality policy? *Gender & Development.* 2016; 24(1):53–68.
8. Grotlüschen A, Nienkemper B, Duncker Euringer C, et al. International assessment of low reading proficiency in the adult population: A question of components or lower rungs? *International Review of Education.* 2020;66(2):235–265.
9. Ghara TK. Higher education status of the states as in AISHE 2020-21. *International Journal of Humanities and Social Science Invention*. 2022;11(6):57–61.
10. Chakrabartty Satyendra Nath. Methodological issues: gender related indices. *Discover Global Society*. 2023;1(4).
11. Barnat N, MacFeely S, Peltola A, et al. Comparing global gender inequality indices: How well do they measure the economic dimension? *J Sustain Res*. 2019;1:e190016.
12. Stoet Gijsbert, Geary David C. Sex differences in academic achievement are not related to political, economic, or social equality. *Intelligence*. 2015;48:137–151.
13. Hsu Angel, Esty Daniel, Levy Marc, et al. Environmental Performance Index (EPI). 2016.
14. Chakrabartty SN. Disability and Quality of Life. *Health Science Journal*. 2022;16(12):1–6.
15. Gennari P, D'Orazio M. A statistical approach for assessing progress towards the SDG targets. *Statistical Journal of the IAOS.* 2020;36:1129–1142.
16. NITI Aayog. SDG India Index and Dashboard 2020–21: Partnerships in the Decade of Action; 2021.
17. UNDP. Human Development Report. Oxford University Press; New York: 2007.
18. UNDP. Human Development Report 2010: The Real Wealth of Nations: Pathways to Human Development. New York: 2010.
19. Chakravarty SR. A generalized human development index. *Review of Development Economics*. 2003;7(1):99–114.
20. Sava AM. Weighting method for developing composite indices: application for measuring sectorial specialization. *Journal of Applied Quantitative Methods*. 2016;II(3):77–84.
21. OECD. Measuring distance to the SDG targets: An assessment of where OECD countries stand. Paris: *OECD Publishing;* 2019.
22. Sachs J, Schmidt Traub G, Kroll C, et al. Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN). 2019.
23. Bidarbakhtnia A. Measuring sustainable development goals (SDGs): An inclusive approach. *Global Policy*. 2020;11(1):56–67.
24. World Health Organization and the United Nations Children's Fund (UNICEF). Methodology for monitoring progress towards the global nutrition targets for 2025. Technical Report WHO-UNICEF Technical Expert Advisory Group on Nutrition Monitoring (TEAM). 2017.
25. Eurostat. Sustainable development in the European Union, Monitoring report on progress towards the SDGs in an EU context (2019 edition). Publications Office of the European Union; Luxembourg: 2019.
26. UN Sustainable development goals progress chart 2020 - Technical Note. New York: 2020.
27. Hamed KH, Rao AR. A modified Mann-Kendall trend test for autocorrelated data. *Journal of Hydrology*. 1998;204:182–196.
28. Chakrabartty SN, Sinha D. A single measure of overall export performance. *The Journal of Applied Economic Research*. 2022;16(3–4):278–308.
29. Rao CR. Linear statistical inference and its application (2nd edition). *Wiley Eastern Private Limited*. GOI (2017). Economic Survey 2016-17. Ministry of Finance. 1973.