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Better Assessment of Progress of SDG 8 and Progress of all SDGs

Melhor avaliação dos progressos do ODS 8 e dos progressos de todos os ODS

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Abstract: Background: Methods of SDG index depicting progress and extent of sustainability achieved by normalizing the indicators and weighted sum suffer from limitations and lead to different rankings.
Methods: The paper proposes multiplicatine aggregation to compute country-level Index for overall progress of SDG-8 (I_{SDG-8}) and progress of all the 17 SDGs at global level.
Results: The proposed index satisfies desirable properties and facilitates identification of critical targets requiring managerial attention for correcting policy measures, assessment of progress over time, distance from the SDG targets at a given time-point, testing statistical hypothesis of equality of I_{SDG-8_t} for two different countries for a given year and also for equality of I_{SDG-8_t} for two successive time points., plotting of progress path at country level and computing measure of similarity between such paths registered by a pair of countries.
Conclusion: The proposed method of multiplicative aggregations without scaling and choosing weights offers significant benefits and contributes to improve aggregation of SDG avoiding major limitations of existing methods of aggregations, is recommended. Future studies suggested.

Keywords: SDG Index; Sustainable Composite Index, Geometric mean, Progress path, Testing of hypothesis.

Resumo: Antecedentes: Os métodos do índice dos ODS (Objetivos de Desenvolvimento Sustentável) que retratam o progresso e a extensão da sustentabilidade alcançada através da normalização dos indicadores e da soma ponderada sofrem de limitações e conduzem a diferentes classificações.
Métodos: O artigo propõe a agregação multiplicadora para calcular o índice a nível nacional para o progresso global do ODS-8 (I_{SDG-8}) e o progresso de todos os 17 ODS a nível global.

Resultados: O índice proposto satisfaz propriedades desejáveis e facilita a identificação de metas críticas que requerem atenção gerencial para correção de medidas políticas, avaliação do progresso ao longo do tempo, distância das metas dos ODS num determinado ponto temporal, teste da hipótese estatística de igualdade de I_{SDG-8_t} para dois países diferentes para um determinado ano e também para igualdade de I_{SDG-8_t} para dois pontos temporais sucessivos.., traçar a trajetória de progresso a nível de país e calcular a medida de semelhança entre essas trajetórias registadas por um par de países.
Conclusão: O método proposto de agregações multiplicativas sem escalonamento e escolha de pesos oferece benefícios significativos e contribui para melhorar a agregação dos ODS evitando as principais limitações dos métodos de agregação existentes, recomenda-se. Sugerem-se estudos futuros.

Palavras-chave: Índice ODS; Índice Composto Sustentável, Média geométrica, Trajetória de progresso, Teste de hipóteses.

JEL classification: C43, E24, I 32

Points for Practitioners:

- Multiplicative aggregation of indicators is proposed to compute Index for overall progress of SDG-8 for a given year (I_{SDG-8_t}) at national level, satisfying desirable properties. The method can be used to find progress of all the 17 SDGs at global level.
- The proposed method avoiding scaling and choosing weights offers significant benefits and contributes to improve aggregation of SDG avoiding major limitations of existing methods of aggregations along with indication of distance of the country from SDG-8 targets at *t*-th year.
- Similarity of paths showing progress/decline of I_{SDG-8_t} over a span of years for two countries can be tested by Modified Mann-Kendall trend test, or by cosine similarity. .
- Policy makers and researchers can take advantages of the proposed method of multiplicative aggregation without scaling and choosing weights.

1. Introduction:

Inclusive sustainable economic growth with full employment and decent work across gender and quality work requires integration of economic, social and environmental dimensions of SDG-8 (Purvis et al. 2019). *Time to Act for SDG 8: Integrating Decent Work, Sustained Growth and Environmental Integrity,* ILO (2019) described a broad policy approach and encouraged countries to pursue interrelated strategies that feed a cumulative dynamic process - a positive SDG-8 “policy spiral”.

Unsatisfactory progress of SDG-8 globally and in many countries raises doubts about achieving the goals by 2030. Actions to meet the SDGs are not yet advancing at the speed required. In comparison to other SDGs, progress on SDG-8 has been weak in many dimensions and indicators and across the world. Economic growth is far from the levels envisaged in the SDG targets, unemployment rates, informality and decent work deficits remain high in many parts of the world. With little time left to fulfill SDGs, index of SDGs needs to help policy makers among others, identification of the critical areas requiring corrective action to facilitate achieving the defined goals (Caiado, et al. 2018).

However, adequacies of the SDG-8 indicators have been questioned. Due to existence of inherent inconsistencies among the indicators of SDG-8, Kreinin & Aigner, (2022) felt need of multi-indicators than single indicators to targets and suggested alternative indicator framework for SDG-8 following the approach of Foster et al. (2020) and Niemeijer and de Groot (2008) for selecting indicator sets.

"Decent work" in SDG-8 targets is different from employment generation and has been criticized most (Eisenmenger et al.2020; Rai et al. 2019), since long-term economic growth is at odds with ecological sustainability (Wiedenhofer et al. 2020). Use of GDP as a proxy for societal wellbeing has been widely criticized, but GDP continues (Stiglitz et al. 2018, 2020). Economic growth in terms of GDP has different relationships with resource uses (materials and energy) and emissions of greenhouse gases. While, resource decoupling refers to the relationship between GDP and use of biophysical resource, impact decoupling refers to the reduction of environmental impacts per unit of GDP and mitigation strategies are thus, different for different relationships (Wiedenhofer et al. 2020).

Unless SDG-8 takes into account unpaid work (not reflected in GDP) that continues to be largely performed by women, it cannot address the decent work agenda in a comprehensive and gendered way. Non-alignment of SDG-8 (decent work for all men and women and economic growth) with SDG-5 (gender equality and empowerment of all women and girls), make unequal policy framework to address both decent work and persistent gender inequality globally (Rai et al. 2019).

The paper describes a method of computations of Index for overall progress of SDG-8 (I_{SDG-8}) of a country using multiplicative aggregation of indicators satisfying desirable properties and facilitating computation of index for the global level.

2. Targets and Indicators:

Targets and indicators of SDG-8 along with brief status and limitations are shown in Table 1.

Table 1: Targets, Present status and Indicators of SDG-8

Targets	Present status	Indicators and limitations
Target 8.1. Sustain per capita economic growth with a target of at least 7% per year in least developed countries (LCDs)	Global real GDP declined in 2020. For LCDs, GDP growth may exceed 5% in 2024 and 2025, against 3.9 % during 2014–2019, but well below the target of 7%.	Indicator 8.1.1: Annual growth rate of real GDP per capita calculated as $\frac{(GDP_{t+1}-GDP_t)}{GDP_t} \times 100$. In addition to tracking Target 8.1. The indicator serves as a proxy for the average standard of living of residents in a country. Limitations: GDP does not consider social and environmental costs of production
Target 8.2. Enhance productivity through diversification, technological upgrading and innovation, and a focus on high-value added and labour-intensive sectors	Growth of output per worker has been declining over decades in countries with high-income and middle-income (ILO 2023b) Labour productivity is much less in LCDs than the high-income countries. Low productivity limits scope for increased sustained real income.	Indicator 8.2.1: Annual growth rate of real GDP per employed person. Indicator 8.2.1 for the *t*-th year (GEP_t^{GDP}) is computed as $\frac{(LP_{t+1}-LP_t)}{LP_t} \times 100$ where $LP_t = \frac{GDP_t}{Total\ employed\ persons}$ GEP_t^{GDP} is a measure of labour productivity and is a proxy for the average standard of living (well-being) of residents in a country. Limitations: reveals nothing about energy and material interactions with the environment. Different degree of coverages or no coverage of informal economic activities by different countries affect GEP_t^{GDP}.
Target 8.3. Promote decent job creation, entrepreneurship, formalization and growth of micro-small and medium-sized enterprises (SMEs)	About 80% enterprises operate in the informal economy employing around 2 billion workers in 2022 at global level i.e. 58% of those employed. In general, countries with lower per capita GDP show higher informality rates. Labour income in developing economies is adversely affected by rising inflation.	Indicator 8.3.1: Proportion of informal employment (IE) in total employment (TE), by sector and gender, calculated as: $\frac{IE\ in\ Non-agricultura\ \ activities}{TE\ in\ Non-agricultural\ activities} \times 100$ Indicators like unemployment rate (UR) and time-related under-employment do not describe the labour market completely. Statistics on the informal economy (engaging about 61% of the global employed population) (ILO 2018) are key to assess quality of employment in an economy and are relevant to both developed and developing countries. Exclusion of Informal employment in Agricultural activities could be a limitation.
Target 8.4. Improve global resource efficiency in consumption, production and endeavour to decouple economic growth from environmental de-gradation	Per capita domestic material consumption (DMC) at global level was rather stable during 2013 – 2019. However, overall consumption gets increased with growth of population. Global CO_2emissions per unit GDP in US$ (in PPT) in 2019 was down in 2010 due to faster growth of global GDP than reduction ofCO_2. Much higher rate of decline is required to achieve emissions targets.	Indicator 8.4.1: Material footprint (MF), MF per capita, and MF per GDP. Data on MF are outdated and unavailable after 2010. Indicator 8.4.2: Domestic material consumption per capita, DMC is computed as direct imports (IM) of material + domestic extraction (DE) of materials - direct exports (EX) of materials (in metric tonnes) i.e. *DMC= IM + DE- EX* and *DMC per capita=* $\frac{DMC}{Annual\ average\ population}$ DMC cannot be disaggregated to economic sectors which limits its scope in the System of National Accounts (SNA) A country with large primary production sector for export may have high or low DMC depending on the extent of outsourcing of most of the material intensive industrial process to other countries.

Target 8.5. Achieve full and productive employment and decent work for all women and men, including young people and persons with disabilities, and equal pay for work of equal value	Data on equal pay for work of equal value are rarely available. Median hourly gender pay gap across 102 countries was 14% (approx.) in 2020. However, this pay gap does not consider differences in characteristics like education, occupation or work experience. The global UR declined in 2022 to 5.8% from a peak of 6.9% in 2020. The rate is projected to decline to 5.3% in 2023. In 2023, the global jobs gap, which is broader than unemployment and captures all workers who want jobs, is projected to stand at 453 million people (11.7%), more than double the level of unemployment (ILO 2023a)	Indicator 8.5.1: Average hourly earnings of employees (AHE_{X_i}) by sex, age, occupation and persons with disabilities. AHE_{X_i} is calculated by $\frac{\sum Earnings\ of\ employees\ in\ group\ X\ in\ ,i-th\ inductey}{\sum Work\ hours\ of\ employees\ \ in\ group\ X,in\ \ i-th\ industry}$ AHE_X reflects quality of productive employment and living conditions. Information on hourly earnings is disaggregated by various Classifications (sex, age, occupation, disability status) reflecting the extent to which pay equality is respected. Indicator 8.5.2: Unemployment rate (% total labor force), by sex, age and persons with disabilities It is defined as the percentage of persons in the labour force who are unemployed, disaggregated by sex, age and disability status. It is related to SDG indicators like 1.1.1, 8.2.1, 8.3.1, 8.5.2, 10.4.1. UR is a useful (but insufficient) measure of the underutilization of the labour supply. It reflects inability of an economy to generate employment for those who are actively seeking work. It is an indicator of the efficiency and effectiveness of an economy to absorb its labour force, and of the performance of the labour market. At regional levels, UR differs widely. Different questionnaires used in surveys may differ in specific definitions of employment and unemployment and also extent of coverage of rural and urban areas.
Target 8.6. Reduce substantially the proportion of youth not in employment, education or training	In 2022, 23.5 % young persons were not in education, employment or training (NEET) at the global level. 23.5% NEET rate is far away from the target of substantial reduction. NEET rates are much higher in some sub-regions like North Africa and South Asia (ILO 2023b). People aged between 15 to 24 face much higher UR rates than adults (ILO 2022).	Indicator 8.6.1: Proportion of youth (aged 15-24 years) not in education, employment or training. It is calculated by $$NEET\ rate = \frac{Y - Y_{Emp} - Y_{UET}}{Y} \times 100$$ where Y: Total population(aged 15-24 years) Y_{Emp}: Number of youth in employment and Y_{UET}: Number of youth not in employment but in education or training. Youth NEET rate is a broader measure of youth disengaged from productive activities than measured by only youth unemployment. It has two different sub-groups (unemployed youth not in education or training and youth outside the labour force not in education or training). The prevalence and composition of each sub-group have policy implications, and thus, merits consideration when analyzing the NEET rate.
Target 8.7. Eradicate forced labour, modern slavery, human trafficking and all forms of child labour.	As per the estimate, 160 million child labours are there worldwide in 2020, with Sub-Saharan Africa contributing the maximum. In 2021, 50 million people were living in modern slavery as per the estimate; including 28 million forced labour and 22 million trapped in forced marriage (ILO 2022c).	Indicator 8.7.1: Proportion of children aged 5-17 years engaged in child labour (PCL_a) by sex and age. It is calculated as $\frac{NCL_a}{TNC_a} \times 100$ where NCL_a: Number of child labour engaged in the age group and TNC_a: Total number of children in the age group a and can be any desired age group (i.e. 5-14 years, 5-17 years etc.) Tracking statistics on child labour enables development of appropriate regulatory frameworks and policies that are required to curtail child labour practices. Country data values included in the global SDG database may differ from those published in national survey reports.

Target 8.8. Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, particularly women migrants and those in precarious employment.	Global rate of total deaths due to exposure to occupational risk factors decreased to 34.3 in 2020 from 39.9 deaths per 100,000 working age population. Similarly, global rates of total disability-adjusted life years attributable to exposure to occupational risk factors decreased. No. of international migrant workers has been continuously growing and protection require urgent policy challenges.	Indicator 8.8.1: Fatal and non-fatal occupational injuries per 100,000 workers, by sex and migrant status where Fatal occupational injury = No. of Fatal occupational injury in the reference population÷ Total No. of hours worked by the reference population. Non-fatal occupational injury= No. of Non-fatal occupational injury in the reference population÷ Total No. of hours worked by the reference population. Above computations require converting number of part-time workers to full-time equivalents. In case, number of hours worked is unavailable, use number of workers in the reference population Indicator 8.8.2: Level of national compliance with labour rights (freedom of association and collective bargaining) based on ILO textual sources and national legislation, by sex and migrant status.
Target 8.9. Promote sustainable tourism that creates jobs	Share of tourism in global GDP declined in 2021 against 2019. In 2022, tourism saw a major recovery. It is important to explore the potential of the tourism as a major driver of economic growth, enterprise development and job creation, particularly for women and youth.	Indicator 8.9.1: Tourism direct GDP as a proportion of total GDP and in growth rate. The United Nations World Tourism Organization (UNWTO) defines sustainable tourism as “tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities”. Indicator 8.9.2: The proportion of jobs in sustainable tourism industries out of total tourism jobs. (Proposal tabled in 2020 to delete Indicator 8.9.2.(IAEG-SDGs 2020)
Target 8.10. Enhance access to financial services for all:	In 2021, 76% of adults globally had bank accounts or accounts in regulated financial institutions. Direct wage payment into bank accounts is an important driver of financial inclusion.	Indicator 8.10.1: Number of commercial bank branches per 100,000 adults and number of automated teller machines (ATMs) per 100,000 adults Indicator 8.10.2: Proportion of adults (≥15 years) with accounts at bank or other financial institution or with a mobile-money-service provider.
Target 8.a: Increase aid for trade support	Includes a target to increase Aid for Trade support for developing countries, in particular LDCs, through Enhanced Integrated Framework (EIF) for trade-related technical assistance to LDCs	It has one indicator. Indicator 8.a.1 is the "Aid for Trade commitments and disbursements". The indicator 8.a.1 is measured as total Official Development Assistance (ODA) allocated to aid for trade in 2015 US$.
Target 8.b: Develop a global youth employment strategy.		Indicator 8.b.1 is the "Existence of a developed and operationalized national strategy for youth employment".

2.1 Observations:

Most of the indicators are in percentages. Strictly speaking, figures in percentages cannot be added meaningfully. For example, pooled average of 80% (16 out of 20) and 40% (as 4.8 out of 12) is 65% which is different from the average of 80% and 40%. If the indicator-1 is $I_1 = \frac{X_1}{n_1}$ and indicator-2 is $I_2 = \frac{X_2}{n_2}$ then combined proportion i.e. $I_1 + I_2 = \frac{X_1+X_2}{n_1+n_2} = \frac{n_1 I_1+n_2 I_2}{n_1+n_2}$. Moreover, the chosen indicators have different distributions. $X \pm Y = Z$ is meaningful when *X* and *Y* follow similar distribution with known or estimated values of the parameters and convolution of distributions of $X \pm Y = Z$ is derived.

3. Composite SDG Index:

To depict progress and extent of sustainability achieved, country-wise composite SDG Index, combining the indicators have been attempted either for each goal or taking all SDGs together. (Kroll, 2015) aggregated 34 indicators measured on a scale 1-10 (from "worst" to "best") on the 17 SDGs and calculated the composite index (CI) as unweighted arithmetic mean(AM) of the indicators. Similar approach was adopted by (Sachs et al., 2016) using 0-100 (from "worst" to "best") across all the SDGs. The 2017 edition of the SDG Index and Dashboards Report developed by the Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN) (Sachs et al. 2017) provided report card for country performance on the 17 SDGs and found unavailability of data on important SDG priorities or not yet counted on the official list of indicators. The report also considered AM of all the SDGs and found that global aggregate indices do not consider major factors of all pillars of sustainability and are biased towards some of them.

SDG India Index 2018 Baseline Report 2018, by NITI Aayog (2018), Govt. of India (*www.niti.gov.in*) came out with SDF India Index where scores of indicator capturing the essence of the SDG goals and data availability are normalized and arithmetic aggregation of such normalized scores is taken. The index measures indicator-wise outcomes of 62 priority indicators for all the States and UTs and combines them to measure progress of each SDG (barring the exceptions of SDG 12, 13, 14 and 17).

Steps followed by SDF India Index for a particular SDG are as follows:

Step-1: Transform scores of *i*-th indicator (x_i) to y_i by Min.- Max function by

$y_i = \frac{x_i - Min.\ x_i}{Targeted x_i - Min. x_i} * 100$ where y_i denotes the normalized value of the *i*-th indicator and $Min. x_i$ is the minimum observed value in the data set

Step-2: SDG Index Score for the *i*-th State/UT corresponding to the *j*-th goal (I_{ij}) is computed as AM of the normalized values of all indicators (with equal weights) within the Goal i.e. $I_{ij} = \sum_{k=1}^{N_{ij}} \frac{I_{ij}}{N_{ij}}$ where N_{ij} denotes number of indicators with non-zero targets.

The following points merit consideration:

- Assessment in 0-100 or 1-10 scales are subjective and produce ordinal data for which AM is not meaningful due to unequal and unknown distance between levels (Rutter and Brown, 2017).
- Additive aggregation of indicators suffers from perfect substitutability, where low value of *i*-th indicator can well compensate high value of *j*-th indicator for $i \neq j$ (Herrero et al. 2010).
- Summative SDG Index giving equal importance to the indicators and targets contradicts different correlations and factor loading of indicators and targets and mislead the results (Mikulić et al. 2015). Equal weights in the Human Development Index (HDI) were criticized (Lind, 2010; Nguefack-Tsague, 2011).
- Assigning weights to the indicators and taking weighted sum could be problematic due to no agreed method of selection of weights (Greco et al. 2019). Ruiz-Morales et al. (2021) used ordered weighted average (OWA) operators to analyze SDGs index where relative importance of the 17 SDGs was evaluated by five experts, which is subjective and ranks of countries can change depending on the weights selected. Choosing weights to indicators is difficult and not without risks of a conceptual and methodological nature (OECD, 2008). Moreover, weights serve as 'trade-offs' and changing the weights to the indicators can affect the countries being evaluated (Saisana et al. 2005) and can manipulate country rankings (Grupp and Schubert, 2010).

- Normalization using Min-Max function depends on value of $Min.x_i$. Hence, not appropriate for index comparisons across time periods since, $Min.x_i$ of an indicator gets changed with each time- period. *Y*-score of an indicator is a relative measure and not an absolute one (Sava, 2016) and is affected by outliers.
- Min-Max transformation normalizes the range of indicators and leads to loss of a common reference point like mean (Mazziotta and Pareto, 2021).
- $Targeted_{x_i}$ in percentage $- Min.x_i$ in percentage may not be meaningful. To avoid such problems, Human Poverty Index (HPI) considers 3rd root and 4th root of average of figures in percentage for HPI-1 and HPI-2 respectively (UNDP, 2007).
- Min-Max transformation tends to overestimate the impact of indicators having small score ranges and may have impact on the composite index like SDF India Index. Ranks of two indicators may be influenced by performance of a third indicator (Kasparian and Rolland, 2012). A change in $Min.x_i$ may alter ranking and relative valuations due to change in marginal rates of substitution(Seth and Villar, 2017)
- Increase in *Y* due to unit increase in *X* ($\frac{\Delta y}{\Delta x}$) is not constant and thus, *X* –*Y* curve is not linear.
- Normalizing the indicators to obtain scores lying between 0 to 1 and weighted sum may lead to markedly different rankings as shown in Table-2 below for two indicators *i* and *j* and two countries.

Table 2: Different rankings by Min – Max normalization and weighted sum

Country		Target	Raw score		Y-score by Min–Max		Weights		Weighted sum	
			X_i	X_j	Y_i	Y_j	$W_i = \frac{2}{5}$	$W_j = \frac{3}{5}$		
A		100%	90%	30%	0.889	0				
B		100%	10%	80%	0	0.714				
Total: A					0.889					
Total: B					0.714				54	80

Clearly, Country A> Country B for Min–Max normalization. But, Country A< Country B for weighted sum.

It is better to aggregate the indicators by multiplicative aggregation avoiding normalization and deciding weights which also permits modeling of realistic preference behavior like diminishing marginal utility, which are not provided by weighted or unweighted sum (Tofallis,2014). UNDP (2010) adopted multiplicative approach for aggregating the three dimensions of HDI.

4. Proposed method:

Let $X_{1i}, X_{2i}, \dots\dots, X_{ni}$ denote values of n-indicators of a SDG-8 target of a State/UT at a given year. Let us denote the corresponding envisaged numerical targets for the indicators by $X_{1i_0}, X_{2i_0}, \dots\dots, X_{ni_0}$ where $X_{ji_0} > 0 \; \forall \; j = 1, 2, \dots\dots, n.$ Assume each indicator is positively related to the respective target i.e. higher value of the indicator implies higher value of the target, which in turn implies higher value of the SDG index reflecting achievement of SDG-8 for the State/UT.

For positive values of each indicator, define target score of the *i*-th State/UT at *t*-th year as $\mathfrak{D}_{i_t} = \sqrt[n]{\frac{X_{1i}.X_{2i}\dots\dots\dots\dots X_{ni}}{X_{1i_0}.X_{2i_0}\dots\dots\dots\dots X_{ni_0}}}$ (1)

or ignoring the *n*-th root

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

$\mathfrak{D}_{i_t}$as per (2) and (1) are equivalent since the two equations have one-to-one and onto correspondence with each other.

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

Proposed index of achievement of SDG-8 for a given year (I_{SDG-8_t}) at national level can be given by multiplicative aggregation of $\mathfrak{D}_{i_t}$ i.e.

$$I_{SDG-8_t} = \prod_{j=1}^{m} \mathfrak{D}_{j_t} \quad (3)$$

Similarly, Global SDG-8 index of *k*-countries can be obtained as product of I_{SDG-4_t} across the countries i.e.

$$Global_{SDG-8_t} = \prod_{u=1}^{k} I_{SDG-8_{t_u}} \quad (4)$$

If needed, each equation (2) to (4) can be multiplied by 100 to reflect values in percentages.

The following may be noted:

Taking logarithm on both sides of (2) we get

$$ln\, \mathfrak{D}_{i_t} = \sum_{i=1}^{n} ln\, X_{p_i} - \sum_{i=1}^{n} ln\, X_{p_{i_0}} \quad (5)$$

In other words, log of a target score = Sum of log of *n*-indicators - Sum of log of indicator-wise targets i.e. an additive model.

4.1 Properties of the index I_{SDG-8_t}:

Proposed index of achievement of SDG-8 for a given year (I_{SDG-8_t}) at national level as per (3) satisfies:

- Product of all I_{SDG-8} targets = $I_{SDG-8_t}$of a country at time period *t*.
- Trade-off among the targets or indicators are significantly reduced
- Relative importance of *i*-th target to I_{SDG-8_t} can be assessed by $\frac{\mathfrak{D}_{i_t}}{I_{SDG-8_t}} \times 100$. The targets may be ranked with respect to the relative importance. Such ranking may help to focus attention to the targets with lower effects on I_{SDG-8_t}
- The *i*-th target is critical if and only 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 (2) and necessary corrective action may be initiated on the identified indicators.
- Satisfies Time–reversal test since $\frac{I_{SDG-8_t}}{I_{SDG-8_{t0}}} \times \frac{I_{SDG-8_{t0}}}{I_{SDG-8_t}} = 1$ for a particular country
- Facilitates formation of chain indices since $I_{SDG-8_{20}} = I_{SDG-8_{21}} \times I_{SDG-8_{10}}$
- From (3),$\log I_{SDG-8_t} = \sum_{j=1}^{m} \log \mathfrak{D}_{j_t}$
- From (4), $\log Global_{SDG-8_t} = \frac{1}{k}[\sum_{u=1}^{k} \log(I_{SDG-8_{t_u}})]$ (6)

- Possible to assess progress in SDG-8 over times of a country in successive years by $\frac{I_{SDG-8_t}}{I_{SDG-8_{(t-1)}}}$. Value of $\frac{I_{SDG-8_t}}{I_{SDG-8_{(t-1)}}} > 1$ reflects overall progress made by the country in *t*-th period over (*t*-1)-th period and effectiveness of policy measures. Similar ratio can be computed to reflect improvement from the base period i.e. $\frac{I_{SDG-8_t}}{I_{SDG-8_{t0}}}$
- Facilitate drawing progress path registered by a country from base period using $\frac{I_{SDG-8_t}}{I_{SDG-8_{(t-1)}}}$ and chain indices.
- $(1 - I_{SDG-8_t})$ indicates distance of the country from SDG-8 targets at *t*-th year.
- Considering logarithms of the dimensions, it is possible to test hypotheses (i) H_0: $I_{SDG-8_{t\,Country_i}} = I_{SDG-8_{t\,Country_j}}$ and (ii) H_0: $I_{SDG-8_t} = I_{SDG-8_{(t-1)}}$ by conventional *t*-tests on the logarithms of the dimensions.
- Similarity of paths showing progress/decline of I_{SDG-8_t} over a span of years for two countries can be tested by Modified Mann-Kendall trend test, which is robust in autocorrelation (Hamed and Rao, 1998), requiring appropriate choice of similarity measure. Chakrabartty and Sinha (2022) 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 $Cos\theta_{12} = \frac{{P_1}^T P_2}{\|\boldsymbol{P_1}\|\|\boldsymbol{P_2}\|}$ where θ_{12} is the angle between the vectors $\boldsymbol{P_1}$ and $\boldsymbol{P_2}$; $\|\boldsymbol{P_1}\|, \|\boldsymbol{P_2}\|$ are the length of the vectors $\boldsymbol{P_1}$ and $\boldsymbol{P_2}$ respectively. For *k*-number of countries, Rao (1973) 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 = $\sqrt{1 - [\frac{\sum Cos\varphi_j}{k}]^2 - [\frac{\sum Sin\varphi_j}{k}]^2}$

4.2 Progress of all the 17 SDGs at global level:

At the global level, progress of all the 17 SDGs at *t*-th time period is

$$Global_{SDG_t} = \prod_{v=1}^{17} Global_{SDG-v_t} \quad (7)$$

Alternatively, $Global_{SDG_t}$ can be found as follows:

For *k*-countries, it is possible to find mean and variance of $\log Global_{SDG-8_t}$ by transforming $\log Global_{SDG-8_t}$ of countries by $Z_i = \frac{logSDG\ 8_{t_{u_i}} - \overline{log_{SDG\ 8t}}}{SD(\log I_{SDG-8_t})} \sim N(0,1)$ followed by 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 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 $\log I_{SDG-8_t}$ 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 $(X + Y) \sim N(\mu_X + \mu_Y, \sigma_X^2 + \sigma_X^2 + 2\sigma_{XY})$.

The $\log Global_{SDG_t}$ for the world can also be found as AM of country-wise Y-scores. It will be easy to find relationship between $Global_{SDG_t}$ by (7) as multiplicative aggregation and $\log Global_{SDG_t}$.

5. Limitations:

The proposed method works only for targets in numerical values > 0. Missing values were not considered here since treating missing data is beyond the scope of the present paper.

6. Discussion:

Avoiding scaling and choosing weights, the paper presents multiplicative aggregation of indicators of *i*-th target of SDG-8 at *t*-th year → targets($\mathfrak{D}_{i_t}$) → country (I_{SDG-4}) → Global SDG-8 ($Global_{SDG-8_t}$) 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, etc. The index can be computed separately by choosing relevant indicators under social, economic and environmental aspects to estimate interdependence among them.

The proposed index offers the following benefits:

- Significant reduction of trade-off among the dimensions or indicators

- Multiplicative aggregation is not affected by outliers and thus produces no bias for developed or underdeveloped countries.
- Identification of relative importance of the indicators or targets and critical targets requiring managerial attention for correcting policy measures.
- Assessment of progress of SDG-8 over time avoiding methods involving CAGR with limitations.
- Assessment of distance from the SDG targets for a country at a given time-point
- Mean and variance of Global SDG-8 can be obtained in terms of $\log Global_{SDG-8_t}$
- Testing statistical hypothesis of equality of I_{SDG-8_t} for two different countries at *t*-th year and also for equality of I_{SDG-8_t} for two successive time points by conventional *t*-tests on the logarithms of the dimensions.
- Rejection of H_0: $I_{SDG-8_t} = I_{SDG-8_{(t-1)}}$ requires identification of target(s) and indicator(s) showing poor performance at country level and at the level of targets pertaining to the country giving direction of improvement. Necessary corrective actions may be formulated accordingly focusing on the identified critical target(s) and indicator(s).
- Plotting of path of progress/decline of the index at country level and computing measure of 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-8 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-8 on other SDGs like No Poverty(SDG-1), Good health and wellbeing (SDG-3), Gender equality and empowerment of all women and girls (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), Promote peaceful and inclusive societies (SDG-16), etc. However, different indicators used for Gender inequality in different SDGs may result in different approaches.

7. Conclusion:

The proposed method of multiplicative aggregations offering significant benefits contributes to improve aggregation of SDG avoiding major limitations of existing methods of aggregations and offering 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.

Empirical estimation of distribution of I_{SDG-8_t} and finding effect of progress in SDG-8 on other SDGs along with preparation of a comprehensive SDG progress report for effective monitoring the implementation of the 2030 Agenda is proposed as a future study.

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References:

Caiado, RGG, Filho, WL, Quelhas, OLG, Nascimento, DLDM, Ávila, LV (2018). A literature-based review on potentials and constraints in the implementation of the sustainable development goals. *J. Clean. Prod. 198*, 1276–1288.

Chakrabartty, SN and Sinha, D. (2022): A Single Measure of Overall Export Performance. *Margin—The Journal of Applied Economic Research* 16 : 3–4: 278–308.

Eisenmenger N, Pichler M, Krenmayr N et al (2020). The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. *Sustain Sci* 15:1101–1110. https://doi.org/10.1007/s11625-020- 00813-x

Foster G, Kreinin H, Stagl S (2020). The future of circular environmental impact indicators for cultural heritage buildings in Europe. Environ Sci Eur 32:141. https://doi.org/10.1186/s12302-020-00411-9

Greco, S., Ishizaka, A., Tasiou, M. and Torrisi, G. (2019). On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness, *Soc Indic Res* 141:61–94 https://doi.org/10.1007/s11205-017-1832-9

Grupp, H., & Schubert, T. (2010). Review and new evidence on composite innovation indicators for evaluating national performance. *Research Policy,* 39(1), 67–78.

Hamed KH and Rao AR. (1998): A modified Mann-Kendall trend test for autocorrelated data, *Journal of Hydrology*, 204; 182 196

Herrero C, Martinez R, Villar A (2010). Multidimensional social evaluation: an application to the measurement of human development. Rev IncomeWealth 56(3):483–497

IAEG-SDGs (2020). *IAEG-SDGs 2020 Comprehensive Review Proposals Submitted to the 51st session of the United Nations Statistical Commission for its consideration". United Nations, Department of Economic and Social Affairs, Statistics Division.*

ILO (2023). *Transformative change and SDG 8: The critical role of collective capabilities and societal learning*, Geneva: International Labour Office. https://doi.org/10.54394/HKDP3268

ILO (2023a). *ILO Monitor on the world of work*. 11th edition

ILO (2023b). *World Employment and Social Outlook: The value of essential work.*

ILO (2022). *World Employment and Social Outlook – Trends 2022*

ILO (2022c). *Global Estimates of Modern Slavery: Forced Labour and Forced Marriage.*

ILO (2000). The Technological Structure and Performance of Developing Country Manufactured Exports, 1985-98. *Oxford Development Studies* 28 (3): 337–369.

ILO (2019). *Time to Act for SDG 8: Integrating Decent Work, Sustained Growth and Environmental Integrity.* Geneva: International Labour Office.

ILO (2018). *Women and men in the informal economy: A statistical picture (Third edition*). https://shorturl.at/QNvtr

Kasparian, J, and Rolland, A. (2012): OECD's Better life index: can any country be well ranked? *Journal of Applied Statistics*, 39 (10),1-8. https://doi.org/10.1080/02664763.2012.706265

Kreinin, H., Aigner, E. (2022). From "Decent work and economic growth" to "Sustainable work and economic degrowth": a new framework for SDG 8. *Empirica* 49, 281–311. https://doi.org/10.1007/s10663-021-09526-5

Kroll C (2015). Sustainable Development Goals - Are the rich countries ready? Bertelsmann Stiftung. Guetersloh

Lind N (2010). A calibrated index of human development. *Soc Indic Res* 98:301–319

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

Mikulić, J., Kožić, I., & Krešić, D. (2015): Weighting indicators of tourism sustainability: A critical note, *Ecological Indicators,* 48*,* 312–314.

Nguefack-Tsague G, Klasen S, Zucchini W (2011). On weighting the components of the human development index: a statistical justification. *J Hum Dev Capabil* 12(2):183–202

Niemeijer D, de Groot RS (2008) A conceptual framework for selecting environmental indicator sets. *Ecol Ind* 8:14–25. https://doi.org/10.1016/j.ecolind.2006.11.012

OECD (2008). *Handbook on Constructing Composite Indicators. Methodology and user guide*. Paris: OECD Publications

Purvis, B.; Mao, Y. Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustain. Sci.*, *14*, 681–695.

Rai SM, Brown BD, Ruwanpura KN (2019) SDG 8: Decent work and economic growth—a gendered analysis. *World Dev* 113:368–380. https://doi.org/10.1016/j.worlddev.2018.09.006

Rao, C. R. (1973). *Linear statistical inference and its application* (2nd edition). Wiley Eastern Private Limited

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

Rutter LA and Brown TA. (2017). Psychometric properties of the generalized anxiety disorder scale-7 (GAD-7) in outpatients with anxiety and mood disorders. *J. Psychopathol. Behav. Assess.*39 140–146.

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

Saisana,M., Saltelli, A. and Tarantola, S. (2005).Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite indicators, *Jr. of Royal Statistical Society Series A*, 168(2),1-17

Sava, A. M. (2016): Weighting Method for Developing Composite Indices: Application for Measuring Sectoral Specialization. *Journal of Applied Quantitative Methods*, Vol. II, No. 3, 77-84

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

Stiglitz JE, Marcus H, Hawley DM et al (2020). GDP is the wrong tool for measuring what matters'. *Sci Am* 323:24–31

Stiglitz JE, Fitoussi J-P, Durand M (2018). Beyond GDP: measuring what counts for economic and social performance. OECD

Tofallis, Chris (2014) Add or Multiply? A Tutorial on Ranking and Choosing with Multiple Criteria. *INFORMS Transactions on Education* 14(3):109-119. http://dx.doi.org/10.1287/ited.2013.0124

UNDP (2010). Human Development Report 2010: the real wealth of nations. UN Development Programme. Palgrave Macmillan, New York

UNDP (2007): *Human Development Report*, Oxford University Press, New York

Wiedenhofer D, Virág D, Kalt G et al (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping. *Environ Res Lett* 15:063002

World Tourism Organization (2013). *Sustainable Tourism for Development Guidebook - Enhancing capacities for Sustainable Tourism for development in developing countries*, UNWTO: https://doi.org/10.18111/9789284415496