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Methodology of Comprehensive e-participation Index.

Metodologia do Índice Abrangente de e-Participação Eletrónica

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Abstract: e-participation refers to participation of citizens in the governance process through ICTs. Importance of e-participation is growing with rapid technological changes and increasing use of Information and Communication Technology (ICT), overcoming limitations of physical participations in terms of time and distance. Ignoring the issues relating to augmentation of dimensions and indicators, the paper describes methodological shortcomings of existing measures of e-participation and suggests a method of comprehensive e-participation index ($CEPI$) covering both supply and demand sides. *CEPI* involves transformation of each sub-indices and component indices to normally distributed scores. Normality enables meaningful arithmetic aggregation of scores of sub-indices, dimensions and *CEPI* as sum of dimension scores. The proposed *CEPI* avoids scaling and satisfies desired properties enabling meaningful comparisons, better ranking, classification of countries and also facilitates testing hypothesis of equality of *CEPI* means for two countries, assessment of progress and testing significance of $CEPI$ growth registered by a country or a group of countries. Elasticity of dimension as ratio of change in *CEPI* due to unit change in the dimension can be used to rank the dimensions. Policy makers and researchers may take advantages of the proposed method to find relationship between supply and demand sides of e-participation.

Keywords: Comprehensive e-participation index, Normal distribution, Absolute measure, Progress path, Equivalent scores.

Resumo: A e-participação refere-se à participação dos cidadãos no processo de governação através das TIC. A importância da participação eletrónica está a aumentar

com as rápidas mudanças tecnológicas e a utilização crescente das tecnologias da informação e da comunicação (TIC), ultrapassando as limitações da participação física em termos de tempo e distância. Ignorando as questões relacionadas com o aumento das dimensões e dos indicadores, o documento descreve as deficiências metodológicas das medidas existentes de participação eletrónica e sugere um método de índice abrangente de participação eletrónica (CEPI) que abrange tanto o lado da oferta como o da procura. O CEPI envolve a transformação de cada um dos subíndices e índices componentes em pontuações normalmente distribuídas. A normalidade permite uma agregação aritmética significativa das pontuações dos subíndices, das dimensões e do CEPI como soma das pontuações das dimensões. O CEPI proposto evita o escalonamento e satisfaz as propriedades desejadas, permitindo comparações significativas, uma melhor classificação dos países e também facilita o teste da hipótese de igualdade das médias do CEPI para dois países, a avaliação do progresso e o teste da significância do crescimento do CEPI registado por um país ou um grupo de países. A elasticidade da dimensão como rácio da variação do CEPI devido a uma variação unitária na dimensão pode ser utilizada para classificar as dimensões. Os decisores políticos e os investigadores podem tirar partido do método proposto para encontrar a relação entre os lados da oferta e da procura da participação eletrónica

Palavras-chave: Índice abrangente de e-participação, Distribuição normal, Medida absoluta, Trajetória de progresso, Pontuações equivalentes.

Points for Practitioners:

- A method of comprehensive e-participation index ($CEPI$) is suggested covering both supply and demand sides where each sub-indices and component indices are transformed to follow normal distribution.
- Calculation of $CEPI$ avoids scaling and involves no selection of weights. Normality enables meaningful arithmetic aggregation of scores of sub-indices, dimensions and $CEPI$ as sum of dimension scores.
- The proposed $CEPI$ following normal distribution satisfies desired properties for better comparisons, ranking and classification of set of countries, assessing progress of$CEPI$ and statistical parametric analysis including testing of equality of means of $CEPI$ for a pair of countries,

whether improvement of $CEPI$ by a country or by a group of countries from previous year is significant or not, etc.

- $CEPI$ helps to assess e-participation in expanded areas to cover broader political, administrative and other socio-economic contexts, with emphasis on inclusive design including e-inclusion

1. Introduction:

Rapid technological changes and increasing use of Information and Communication Technology (ICT) in areas like internet, social media, e-commerce, etc. overcoming limitations of physical participations in terms of time and distance, have given rise to a number of socio-political issues and emergence of e-empowering, e-consulting, sustainable e-participation, etc. Such significant changes require consideration of new indicators and new dimensions of *e*-Participation Index. Thus, methodology of arriving at *e*-Participation Index need to consider such indicators measured by variables in ratio scale and also in ordinal scale. The e-participation concept and associated measurement issues have been investigated widely by scholars and international organizations (e.g. Saebø, et al. 2011; Susha & Grönlund, 2014; OECD, 2021; UN, 2019).

Participation is one of the pillars of sustainable development. The target 7 of Sustainable Development Goal (SDG)-16 calls for ensuring responsive, inclusive, participatory and representative decision-making at all levels (UN DESA, 2016). e-participation as a branch of e-government deals with use of information and (ICTs) by the citizens for deliberation, decision-making and public service delivery (Medaglia, 2012; Welch, 2012). Basically, e-participation is a social activity, mediated by ICT involving interactions among citizens, public administration and may be politicians (Saebø, et al. 2008). UN (2014) defines it as the process where citizens are engaged in policy, decision-making, and delivery through ICTs to make it participatory, inclusive and deliberative. Major data sources of e-Participation are the E-Government surveys by the United Nations covering large number of countries which primarily measures

"supply" side of e-participation without giving importance to the socio-political contexts. Due to changes introduced in subsequent surveys either in dimensions or scoring methods, results of 2022 survey are not comparable to previous surveys in all respects.

Based on nature of stakeholders, e-government can be classified into following headings:

- Government-to-citizens (G2C): government institutions provide services to citizens through ICTs as a strategic tool (Bwalya and Mutula, 2014).
- Government-to-business (G2B): e-services are provided electronically by government to businessmen and companies under private-sector, like business information, inline business licenses, e- tax services, etc. (Alshehri and Drew, 2019).
- Government-to-government (G2G): e-transactions among government institutions and departments (Bwalya and Mutula, 2014).

The e-Participation Index (EPI) is considered as a supplementary index to the UN E-Government Survey. EPI of a country is computed based on:

- Sharing of e-information: Citizens are provided with public information and access to information as and when demanded.
- e-consultation: Citizens can contribute and deliberate on public policies and services
- Decision-making: Citizens are engaged in decision-making processes

EPI of a country indicates use of online tools in the country for promoting interactions among G2C, G2B, G2G and people. EPI is a relative measure indicating broad performance of a country in e-participation at a given time point, since EPI of *i*-th country is obtained as $EPI_i = \frac{Z_i - Z_{min}}{Z_{max} - Z_{min}}$ where Z_i denotes normalized score of the *i*-th country. EPI has been criticized for exclusion of society-side of e-participation initiatives (Kabanav, 2022) who included *Engaged society* indicators, part of the V-Dem *Deliberative Democracy Index,* exploring a number of variables including those

in ordinal level pertaining to public deliberation in policymaking (Coppedge et al., 2021). Waheduzzaman and Khandaker (2022) considered citizens' voice and accountability, control of corruption, and government effectiveness and found relationship between e-participation and corruption-perception, and government effectiveness were significant.

E-Government Development Index (EGDI) indicates progress of e-government at national level. EGDI is a composite index (CI) calculated as the weighted mean of normalized values of three composite measures of a country:

- Telecommunications Infrastructure Index (TII): To assess extent of use of Internet, broadband, mobile/landline telephone by the population;
- Human Capital Index (HCI): Combines three sub-indices viz. adult literacy rate, gross enrolment ratio, and years of schooling
- Online Service Index (OSI): To assess provisions of national websites and online e-government services.

Ranging from 0 to 1, EGDI reflects capacity and readiness of a country in using ICTs for delivering public services and facilitates government officials, policy makers, civil society to gain better understanding of the position of the country regarding public services through
e-government.

Measurement and Evaluation Tool for e-Participation (METEP) by the United Nations Department of Economic and Social Affairs (UNDESA) use *Citizen Engagement Self-Assessment Questionnaire (CESAQ*) to find success/failure of e-participation initiatives taken by governments at national, regional and local levels with respect to the indicators under political**,** social and technical blocks. The questionnaire to assesses knowledge of Regulatory Framework, Agency-specific questions by 3-point scales (Yes-No-Don't know); Experience based Assessment including one item 6-point item (0 – 5) on satisfaction of citizens with existing engagement mechanisms. However, there could be other frameworks of e-participation like institutions influence, integration and interaction, etc.

Local Online Services Index (LOSI) measures progress made in development of e-government at local level using questionnaire. Raw LOSI score is for a city is obtained by sum binary responses (0 – 1 type) of 86 indicators where a score of 1 is assigned if the provision exists in the website of the city/municipality and 0 otherwise. LOSI score of a city = $\frac{Total\ raw\ score}{86}$ lies between 0 and 1. Values of LOSI were higher in cities with higher population size. There was no direct relationship between LOSI and per capita GDP.

In general, evaluation of e-participation depends on survey questionnaires involving variables in ratio scale like number of free public Internet access points and also ordinal variables like citizen satisfaction and dimensions covering both demand and supply sides. Rapid technological changes and increasing use of ICT along with associated socio-political issues and emergence of e-empowering, sustainable e-participation, etc. may give rise to new indicators like service quality and new dimensions of *e*-Participation Index. Thus, methodology of *e*-Participation Index needs to consider such indicators measured by variables in ratio scale and also in ordinal scale.

Major purpose of e-government indices are to help in understanding status of e-government, both nationally and internationally. While the former requires aggregation of indicators to a single value reflecting e-government score of a country and for the later, e-government score of different countries are to be aggregated. Evaluation of the index for i-th country $Index_i$ as aggregation of chosen components (dimensions) $D_1, D_2, \dots\dots, D_k$. The index needs to satisfy the following desirable properties:

P_1: $Index_i$ to reflect position of i-th country by a continuous variable

P_2: $Index_i$ to increase monotonically i.e. increase in a dimension implies increase in the $Index_i$

P_3: Meaningful aggregation of $D_i's$ and meaningful aggregation of sub-indices to get score of a dimension

P_4: Evaluation of contribution of each D_i to $Index_i$ showing relative influence of the $D_i's$ such that sum of the contributions is equal to 1 (100%).

P_6: Facilitate finding distributions of $D_i's$ and $Index_i$

P_7: Facilitate computation of mean and standard deviation (SD) of $Index_i's$ for a group of countries at a given time period.

P_8:Quantification of progress made by a country over time and to help drawing path of progress/decline of a country since the base period

Ignoring the issues relating to augmentation of dimensions and indicators, the paper describes methodological shortcomings of existing measures of e-participation and suggests a method of comprehensive e-participation index ($CEPI$) covering both supply and demand sides involving transformation of each sub-indices and component indices to follow normal distribution. The proposed $CEPI$ avoids scaling and satisfies at least properties P_1 to P_8 for better comparisons of countries and assessing progress of$CEPI$.

2. Literature survey:

2.1 Format of Questionnaires:

Questionnaires have different number of items (length) and different number of response-categories (width). Higher values of length and width result in higher mean, SD and qualities of questionnaires like reliability, validity, etc. The questionnaire to measure OSI has large number of binary items scored as 0 (if the targeted feature is absent) or 1 (if the targeted feature is present). OSI in the 2022 UN Survey had binary and 4-point items (0 to 3) relating to ability to complete transactions with respective government, where 0: non-availability of the targeted service through an official online service channel; 1: availability of relevant information/form but other aspects of the transaction require channels other than online; 2: when online availability of the full service including application procedure is there and 3: when through an online channel, users can manage the full transaction , including payment and receipt of documents. Tambouris et al. (2007) used 5-point scales against popular 3-point scales as e-enabling, e-engaging, and e-empowering (Macintosh, 2004). Desirability of 4-point

scale of e-participation distinguishing (A) provision of information; (B) consultation; (C) collaboration and (D) empowerment was suggested (Blanc, 2020).

2.2 Scaling and selection of weights:

To find Country-wise TII, first stage is to compute composite value (CV) as average of Z-scores of (i) Internet users, (ii) Mobile/Cellular telephone subscriptions (iii) Active mobile broadband subscriptions, and (iv) Fixed broadband. For the *i*-th country, TII is computed by

$$TII_i = \frac{CV_i - CV_{Min}}{CV_{Max} - CV_{Min}} \quad (1)$$

HCI also consider Z-scores of each of four sub-indicators and CV is computed as weighted sum where weights for Z-scores of the sub-indicators are as follows:

- Adult literacy rate: $\frac{1}{3}$
- Gross enrolment ratio: $\frac{2}{9}$
- Years of schooling (estimated): $\frac{2}{9}$
- Mean years of schooling: $\frac{2}{9}$

HCI of i-th country is computed by $HCI_{i-th\ country} = \frac{CV_i - CV_{Min}}{CV_{Max} - CV_{Min}}$ (2)

Components of OSI contain five categories (sub-indices) of assessment questions. The sub-indices and their respective weights are as follows:

- Institutional framework (IF):10%,
- Services provision (SP):45%,
- Content provision (CP):5%,
- Technology (TEC):5%
- e-participation (EPI):35%.

Selection of such weights showing relative importance of the sub-indices may give rise to controversies. However, relative importance of variables may be different from what the weights imply (Paruolo et al. 2013). OSI of a country is calculated as a

weighted sum of the normalized values for each sub-index followed by normalization using Max-Min function so that OSI lies between 0 – 1. Number of yes-No type items vary: 180 in 2022 UN Survey against 148 in 2020 Survey. Overall EGDI is weighted arithmetic mean of OSI, TII and HCI.

Equal weight of $\frac{1}{3}$ is assigned to TII HCI and OSI in computation of EGDI. Thus, for EGDI, justification of treating the three component indices as equally important may be questioned. Assigning equal weights to normalized scores of the component indices gave rise to complex situations, where contribution of a component index exceeded 100%. Contributions of TII, HCI and OSI scores varied differently for different countries as shown below:

Table 1: Contributions of scores of component indices in EGDI

Country	**EGDI rank**	**Contributions**			**EGDI (2022)**
		OSI	**HCI**	**TII**	
USA	10	101.6719%	101.366%	96.97301 %	100%
Colombia	70	102.1622 %	108.346 %	89.49181 %	100 %

Source: Compiled by Author from 2022 United Nations E-government survey: Future of Digital Government

In 2022 Survey, 121 out of the 193 countries had tied EGDI score and OSI scores of 72 countries were greater or lower than their respective EGDI scores indicating different contributions of OSI to EDGI. For a country, OSI > EDGI implies higher development of online services provision than development of telecommunications infrastructure and human capital for that country.

Min-Max functions of the form $\frac{Z_i - Z_{min}}{Z_{max} - Z_{min}}$ in the range [0, 1] used in HCI, TII, OCI etc. suffer from limitations. Here, $Z \sim N(0,1)$ and $-\infty < Z_i < \infty$. Such Z-score

may be further transformed to have non-negative values from 0 to 1 by Min –Max function or from 1 to 100 by $\left[\frac{99(Z_{ij}-Min_{Z_{ij}})}{Max_{Z_{ij}}-Min_{Z_{ij}}}\right]+1$(Chakrabartty, 2022). Min-Max transformation depends on two extreme values of the data, which could be outliers. Transformed score of i-th country may improve in subsequent year even if Z_i remains unchanged but Z_{min} is reduced. Ranks of two countries may be influenced by performance of a third country. A change of X_{Min}may change ranking and relative valuations of the countries since, marginal rates of substitution get changed (Seth and Villar, 2017). Gain in $\frac{Z_i-Z_{min}}{Z_{max}-Z_{min}}$ due to unit increase in Z_i is different at different values of Z_i. Distribution of each of HCI, TII, OCI computed by Min-Max function get changed and may have impact on EDGI. Min-Max transformation may fail to show responsiveness of EDGI. For the Income component, Human Development Index (HDI) (UNDP, 2010) used Min-Max transformation taking logarithms as $Income_X=\frac{log_e{}^X-log_e{}^{(X_{Min})}}{log_e{}^{(X_{Max})}-log_e{}^{(X_{Min})}}$. However, such logarithmic transformation violates Translation Invariance property and aggregation is not consistent (Chakravarty, 2003). Moreover, rate of increase of $Income_X$ gives different values at different values of *X* and $Income_X$ may get changed with change of origin.It may be better to find EGDI scores avoiding scaling and weights not based on data.

2.3 Scoring of questionnaires:

EGDI scores suffer from substitution effect. High value of one index (say OSI) of a country may compensate low value of TII or HCI of that country. Zero value in item lowers mean and variance. Frequent zero responses to an item reduces value of correlation with that item. Expected value (product of score and corresponding probability) gets distorted when responses are marked as “zero”. If each respondent of a sub-group selects the response-category with zero value to an item, then mean = variance = 0 for the sub-group and correlation with that item cannot be defined. Better

is to assign values 1, 2, 3… and so on as anchor values of an item, without disturbing structure of data.

Questionnaires involve variables in ratio scale like number of free public Internet access points and also ordinal variables like citizen satisfaction and other dimensions. Major problem areas of data resulting from such questionnaire are:

- Additions of variable in ratio scale with fixed zero point like number of demand posted, number of Mobile-cellular subscriptions, etc. and variable in ordinal scales are problematic.

- Addition or arithmetic mean (AM) is not meaningful for ordinal data since equidistant property is not satisfied (Hand, 1996; Jamieson, 2004). Thus, descriptive statistics like mean, SD, correlation, and techniques like Analysis of variance, Structural equation modeling(SEM), Principal component analysis (PCA), Factor analysis (FA), statistical inferences like estimation and testing of hypothesis, etc. (assuming normal distribution) are not meaningful. Meaningful interpretation of sum of two random variables X and Y like item/dimension scores demands to find distribution of X, Y and their convolution to find joint distribution of (X + Y).

- Questionnaire scoring does not consider distribution of item scores, dimension scores and scale scores. Different item formats like “Yes-No” type, 3-point, 4-point, 5-point, etc. five different distributions and different values of reliability, validity, etc. (Preston & Colman, 2000).

- Scores emerging from questionnaire have often been found to be skewed and deviated from normal distribution, the common assumption of most of statistical techniques (Montgomery & Runger 2013).

- Number of levels (response-categories) can influence psychometric properties of questionnaire more than the underlying variables. Chakrabartty (2021) concluded that there is no optimum number of levels to maximize reliability, validity, discriminating value of a questionnaire.

2.4 Statistical analysis:

Based on EGDI, countries are classified into following four groups:

-Very High group: EGDI ≥ 0.75

- High group: EGDI ≥ 0.50 but < 0.75
- Middle group: EGDI ≥ 0.25 but < 0.50
- Low group: EGDI < 0.25

Classifications of cities/municipalities are also done similarly with respect to LOSI scores. Threshold values i.e. boundary points of such classification are not based on distribution of EGDI scores and may fail to assess efficiency of such classification showing low value of within-group variance and high value of between-group variance.

Strictly speaking, this is not quartile clustering since it may fail to represent 25% of data in each cluster. For example, in 2022 survey, 60 countries with EGDI ≥ 0.75 constituted 31.09% of data and 7 countries with EGDI < 0.25 covered only 3.63% of total countries covered in the survey.

Whitmore (2012) did confirmatory factor analysis (CFA) with raw data of UN E-Government Survey. But, CFA assumes among others multivariate normality of data which may not be satisfied by raw data or by e-participation indices.

3. Proposed method:

Assessment of multi-dimensional e-participation can be looked as a battery with a number of dimensions where each dimension has several sub-indices which are evaluated by different questionnaires.

Let X_{ij} denote the raw score (discrete and ordinal) of a country in the *i*-th item of the *j*-th response-category of a questionnaire. If the *i*-th item is 5-point, weights satisfying $W_{ij} > 0$ and $\sum_{j=1}^{5} W_{ij} = 1$and weighted scores W_{i1}, $2W_{i2}$, $3W_{i3}$, $4W_{i4}$ and $5W_{i5}$ will be equidistant and monotonic if the weighted scores satisfy $kW_{ik} - (k-1)W_{i(k-1)} = \alpha > 0 \; \forall \; k = 2, 3, 4, 5$

One way of find such data-based weights is as follows:

Find maximum ($f_{i\,max}$) and minimum frequency ($f_{i\,min}$) of the response-categories. Let initial weights are $\omega_{ij} = \frac{f_{ij}}{n}$. Arrange the $\omega_{ij}^{'}s$ so that $\omega_{i1} < \omega_{i2} < \omega_{i3} < \omega_{i4} < \omega_{i5}$ where $\omega_{i1} = \frac{f_{i\,min}}{n}$ and

$\omega_{i5} = \frac{f_{i\,max}}{n}$. Let intermediate weight $W_{i1} = \omega_{i1}$

The common difference α can be found as $\alpha = \frac{5f_{imax} - f_{i\,min}}{4n}$ since $W_{i1} + 4\alpha = 5W_{i5}$

Define other intermediate weights as:

$W_{i2} = \frac{1}{2}(\omega_{i1} + \alpha);\ W_{i3} = \frac{1}{3}(\omega_{i1} + 2\alpha); W_{i4} = \frac{1}{4}(\omega_{i1} + 3\alpha)$ and $W_{i5} = \frac{1}{5}(\omega_{i1} + 4\alpha)$.

Get final weights $W_{ij(Final)} = \frac{W_{ij}}{\sum_{j=1}^{5} W_j}$ enabling $\sum W_{ij(Final)} = 1$ and

$kW_{ik(Final)} - (k-1)W_{i(k-1)(Final)}$= Constant, value of which may be different for different items.

3.1 Observations:

i) Finally selected weights ($W_{j(Final)}$) are based on data (empirical probabilities).

ii) The zero value of the transformed scores is obtained when $f_{ij} = 0$.

iii) *E*-scores as weighted sum are continuous and equidistant.

iv) The method is applicable for items with different number of response-categories including binary items.

Standardize *E*-scores by $Z_{ij} = \frac{X_{ij} - \overline{X_i}}{SD(X_i)} \sim N(0,1)$.

Take linear transformation of *Z*-scores to normally distributed *N*--scores by:

$$N = \left[\frac{99(Z_{ij} - Min(Z_{ij})}{Max\,(Z_{ij}) - Min(Z_{ij})}\right] + 1 \qquad (3)$$

For the *i*-th item, $N_i \sim N\ (\mu_i, \sigma_i^2)$ and $1 \leq N_i \leq 100$ where estimates of μ_i and σ_i^2 are obtained from the data. Item-wise *N*-scores as per (3) are applicable irrespective of length of scale and width of items. Thus, all items have same score range.

Dimension score of a country is taken as sum of normally distributed *N*-score of relevant items which follows normal with mean $\sum_i \mu_i$ and SD

$= \sqrt{\sum \sigma_i^2 + 2\sum_{i \neq j} Cov(N_i, N_j)}$. Similarly, $CEPI$ is sum of dimension scores following normal.

For items seeking variables in ratio scales like sub-indices of HCI, TII, etc. transformation to *E*-scores are not required and can be standardized and transformed to follow normal distribution in the score range [1, 100].

3.2 Properties:

1. No weights were assigned in the aggregation method since there does not exist an weighting scheme which is beyond criticism (Greco, et al. 2019).
2. Normally distributed dimension scores (D_i) and scale scores ($CEPI_i$) of the i-th country are continuous, monotonically increasing. Normality ensures meaningful computation of AM, SD, correlation, etc. and estimation of population parameters like mean (μ), variance (σ^2), testing of statistical hypothesis like $H_0: \mu_1 = \mu_2$ or $H_0: \sigma_1^2 = \sigma_2^2$ etc. over time and space.
3. Progress registered by the *i*-th country in time-period (*t*) over the previous period (*t-1*) can be quantified by $\frac{CEPI_{i(t)} - CEPI_{i(t-1)}}{CEPI_{i(t-1)}} \times 100$. Decline is indicated if $CEPI_{i(t)} - CEPI_{i(t-1)} < 0$

   Similarly, for a group of countries, $\overline{CEPI_{\iota(t)}} > \overline{CEPI_{\iota(t-1)}}$ indicates progress. Normally distributed $CEPI_i$helps to test H_0: $\mu_{CEPI_t} = \mu_{CEPI_{(t-1)}}$ and also H_0 : $Progress_{(t+1)over\ t} = 0$. Decline if any, may be probed to find dimension(s) where $D_{i(t)} - D_{i(t-1)} < 0$ and initiate corrective actions.
4. Graph depicting progress and/or decline of $CEPI$ of a country or a sample of countries at various time points can be used to compare them from the start.

5. Normally distributed scores satisfy the assumptions of PCA, FA and enable to find factor structure of e-participation and also factorial validity of $CEPI$ as ratio of the first eigenvalue to the sum of all eigenvalues i.e. Factorial Validity = $\frac{\lambda_1}{\sum \lambda_i}$, where λ_1 is the first principal component with highest eigenvalue reflecting the main factor being

measured by the questionnaire. Such factorial validity avoids the shortcomings of construct validity and selection of criterion scale.

6. Normality helps to estimate variance of each item, dimension and questionnaire, enabling Cronbach alpha for a dimension at population level as

$$\hat{\alpha} = (\frac{n}{n-1})\ (1- \frac{Sum\ of\ estimates\ of\ variance\ of\ items\ in\ the\ dimension)}{Estimate\ of\ variance\ of\ the\ dimension}) \quad (4)$$

Reliability of $CEPI(r_{tt})$ consisting of *K*-number of dimensions can be obtained as a function of dimension reliabilities by $r_{tt} = \frac{\sum_{i=1}^{K} r_{tt(i)} S_{Xi} + \sum_{i=1, i\neq j}^{K} \sum_{j=1}^{K} 2COV(X_i, X_j)}{\sum_{i=1}^{K} S_{Xi} + \sum_{i=1, i\neq j}^{K} \sum_{j=1}^{K} 2COV(X_i, X_j)}$ (5)

where $r_{tt(i)}$ and S_{xi} denote respectively reliability and SD of the *i*-th dimension.

7. Discriminating value of a scale indicates ability of the scale to distinguish between individuals that have different degrees of the underlying construct (e.g. more or less user satisfaction). Chakrabartty (2020) defined discriminating value of K-point item ($Disc_i$) and test ($Disc_{Test}$) by Coefficient of variation (CV) where $Disc_i = \frac{SD_i}{mean_i}$ and $Disc_{Test} = \frac{SD_{Test}}{Mean_{Test}}$ and proved

$$\text{Cronbach}\,\alpha = (\frac{m}{m-1})(1 - \frac{\sum_{i=1}^{m} \overline{X_i}^2 . Disc_i^2}{\bar{X}^2 . {Disc_T}^2}) \quad (6)$$

where *m* denotes number of items in the test

and $(Disc_{Test})^2 = \frac{{CV\ True\ scores}^2}{r_{tt}}$ where $r_{tt} = \frac{S_T^2}{S_X^2}$ (7)

where r_{tt} denotes test reliability as per theoretical definition.

Thus, test reliability and $Disc_{Test}$ are related by a negative non-linear relationship.

8. Efficiency of classification may be assessed by Davies-Bouldin Index (DBI) which considers ratio of within-cluster and between-cluster distances (Davies and Bouldin, 1979). For *K*-number of classes DBI is computed by

$$DBI_K = \frac{1}{K} \sum_{i=1}^{K} \sum_{j=1\ (i\neq j)}^{K} Max[\frac{DiamC_i - DiamC_j}{\|C_i - C_j\|}] \quad (8)$$

where diameter of *i*-th class $DiamC_i = \sqrt{\frac{\sum_{x_i \in C_i} \|x_i - C_i\|^2}{n_i}}$

C_i: Centroid or mean of the *i*-th class; n_i: number of members in the *i*-th class.

Max. DBI = 1 and lower value ⟹ better efficiency.

The optimal number of clusters has the smallest DBI value, which can be obtained from the plot of DBI and number of clusters.

9. Possible to adopt Quartile clustering to classify the countries under survey in terms of *CEPI* scores. Let $f(x)$ be the normal probability density function (pdf) of total *CEPI* scores of all countries following *N(* μ, σ). Boundary points Q_1, Q_2, Q_3, Q_4 of quartile clustering of *CEPI* can be obtained by assigning equal probability to each quartile/class i.e.

$$\int_1^{Q_1} f(x)dx = \int_{Q_1}^{Q_2} f(x)dx = \int_{Q_2}^{Q_3} f(x)dx = \int_{Q_3}^{Q_4} f(x)dx \quad (9)$$

10. For normally distributed *CEPI* scores, a given score of X_0 in Survey-1 will be equivalent to a score of Y_0 in Survey-2 if $\int_{-\infty}^{X_0} f(x)dx = \int_{-\infty}^{Y_0} g(y)dy$ (10)

where $f(X)$ and $g(Y)$ denotes normal pdf of *CEPI*-scores of Survay-1 and Survey-2 respectively. The equation (10) can be solved using Standard Normal probability table. It helps to find all combinations of $\{X_0, Y_0\}$ such that correlation between equivalent scores is close to unity. The approach also helps to find equivalent scores of EGDI, METEP, LOSI, etc.

11. It is possible to calculate $CEPI$ separately for supply side variables $CEPI_S$ and demand side variables$CEPI_D$ and find empirical relationship between $CEPI_S$ and $CEPI_D$. This in turn may help to predict one with knowledge of the other.

4. Limitations:

The issues of missing data and multicolinearity were not considered since they will be beyond the scope of the paper. Frequency of raw score of a country in *j*-th response-category of *i*-th item of a questionnaire was taken as different from zero.

5. Discussions:

The paper describes a simple method of evaluation of comprehensive e-participation index ($CEPI$) covering both supply and demand sides. This involves transformation of each sub-indices and component indices to follow normal distribution, which enables meaningful arithmetic aggregation of scores of sub-indices, dimensions and *CEPI* as sum of dimension scores and computation of descriptive statistics. Calculation of *CEPI* avoids scaling and involves no weights in the aggregation method.

Contribution of each dimension to *CEPI* of a country is easy to calculate and sum of contributions of all the dimensions is equal to one. Similarly, contributions of all the countries to global *CEPI* are also equal to one.

Countries can be ranked with respect to *CEPI* scores. For longitudinal data, it is possible to rank the countries by growth of *CEPI* reflected by $\frac{CEPI_{i(t)}-CEPI_{i(t-1)}}{CEPI_{i(t-1)}} \times 100$

The proposed $CEPI$ following normal distribution satisfies desired properties for better comparisons, ranking and classification of set of countries, statistical inferences like estimation and testing hypothesis, assessing progress of$CEPI$ and statistical parametric analysis including testing of equality of means of $CEPI$ for a pair of countries by *t*-test, whether improvement of $CEPI$ by a country or by a group of countries from previous year is significant or not using the result that ratio of X and Y follows χ^2distribution where X$\sim N$ and Y$\sim N$.

Similarity of progress path i.e. plot of progress or decline of $CEPI$ over a span of time-periods for two countries can be tested by choosing appropriate similarity measure which takes care of autocorrelations like Modified Mann-Kendall trend test, which is robust in autocorrelation (Hamed and Rao, 1998).

It is possible to find effect of small change in *i*-th dimension to *CEPI* by elasticity as ratio of change in *CEPI* due to unit change in a dimension. Such elasticity can be used to rank the dimensions.

Normally distributed $CEPI$ scores of two surveys may be compared by finding equivalent scores even if there are small changes in the later survey.

Government priorities on online services provision have been developed on priority areas like health, education and social protection. The proposed *CEPI* helps to assess e-participation in expanded areas to cover broader political, administrative and other socio-economic contexts, to cover everybody in e-government with emphasis on inclusive design including e-inclusion. Thus, the proposed method satisfying the desired properties is an improvement over the existing methods.

6. Conclusion:

The paper contributes in improving assessment of *CEPI* avoiding major limitations of scaling, ordinal scores and enabling parametric analysis for meaningful comparisons. Policy makers and researchers can take advantages of the proposed method of arithmetic aggregation of normally distributed variables to find relationship between supply side and demand side of e-participation.

Empirical studies may be undertaken to investigate properties of CEPI and generalization of findings.

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