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Measurement of Sustainability: Statistical Model

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Abstract- Till now, the question remains the same whether organizations are moving towards a sustainable future or not. The impact of policies on the sustainable growth of the organization. The main assumption in this model is that for calculating growth or development, GDP per capita alone cannot be considered as only criteria, a multi –criteria model must be used to calculate it. If GDP increases, by destruction of natural vegetation and by depletion of natural resources it cannot be considered development. In this paper I present a statistical model, such that by using that model any number of organizations can be compared or ordered in increasing or decreasing sustainability. These organizations can be as large as countries or can be as small as local companies. The model is prepared in such a way that it is not biased towards any organization or sector. It considers all the factors necessary for a sustainable growth or sustainable future.

Index Terms- Aggregation, Sub-Indicators, Normalization, Weighing.

I. INTRODUCTION

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs WECD (1987)" as stated by the Brudtland report of 1987. Concept of sustainability came into existence when we realize that GDP per capita alone cannot be considered as an indicator of development. As GDP per capita can be increased by destruction of natural resources, it cannot be considered as the development of the country or organization. Sustainability is a very important term for me and for every man present on the earth. As it is important for each and every person on this earth there is need to properly define and measure it, so that we can see the impact of each and every action on the sustainability. Sustainability measure has to be defined first so that a model can be created to calculate it. So, sustainability measure is defined as a pyramidal structure which is divided into three parts from top to base. On the bottom there are sub-indicators. These sub-indicators are the base of this model as the base of any structure. Sub-Indicators have concepts or ideas which we can measure in term of numbers or preference order. These sub-indicators are inter-related and belong to a group which comes at second level of this pyramid structure. Sub-indicators highly related are put under the same group. Then these groups are combined using several combination techniques for measuring sustainability

II. SUB-INDICATORS

First step involved in measuring sustainability is the selection of sub indicators. It is considered as the main part of the sustainability measurement because this decides on which grounds sustainability is going to be calculated. These should be selected on the basis of availability of data for the entire organization, source of the information, advice of experts & must be related to development of the organization.

It is possible that data may not be available for some organizations. To get that data a lot of techniques are present. Mean of those whose values are already present in place of missing values, after removing outliers. There are also frameworks ``missing completely at random" (MCAR) Rubin (1976), can be used to fill missing data but applicable for large populations only.

Multiple Imputation technique (Little and Rubin (1987) and Schafer (1997)) can also be used for imputation of missing values. Using such techniques and methods we have complete set of data of all the sub-indicators and of all the organizations available for analysis. There are also other techniques like Regression and Expectation Maximization (EM) imputation by Nardo (2005) can also be used for multivariate analysis.

III. NORMALIZATION

The data obtained from the sub-indicators give information of different kinds and units. For example: The profit of an organization is measured in money value, while the import and exports are measured as number of goods. So, to make all the sub-indicators of same standard, there is a need to normalize the data so that they can be used for comparison. Different normalization techniques that can be used for normalize the data Nardo (2005).

DISTANCE FROM A REFRENCE

I= delta(R)/R (reference)

R (reference) = the reference value from which we are calculating the distance

Delta(R) = the difference in values of sub-indicator and the reference

MINIMUM-MAXIMUM

I= (x-Min) / (Max-Min)

Min= Minimum value of the data from sub indicator, Max= Maximum Value of the data from sub-indicator, x= value of the sub indicator. All the normalized will be between 0 and 1.

STANDARDISATION

For each indicator we will calculate the mean and standard deviation (sigma). The normalization is

I= (x-mean) / (sigma)

It is the most common used method for normalization, it converts the values in such way that the mean of the normalized data would be 0 and the standard deviation is equal to one. By this method all the sub indicators will have same mean and standard deviation, so all the sub indicators are scaled properly.

IV. WEIGHING

Different sub indicators are not equally important, so a method is required, that provides a tradeoff between the sub-indicators. Meaning how much increase in one can be compensated by decrease in other sub-indicator. Different weights can be given to different sub-indicators on the basis of their relevance, effectiveness of the source of data, availability etc. Weighing method should be selected in such a way that it is not inclined to any specific organization, giving high weight to that sub-indicator in which a particular organization is best or worst can led to wrong application. Therefore weighing method should be transparent and must not be biased (Michela Nardo, Michaela Saisana, Andrea Saltelli & Stefano Tarantola).Moreover, the reader should bear in mind that, no matter which method is used, weights are essentially value judgments and have the property to make explicit the objectives underlying the construction of a composite (Rowena et al., 2004)

In many composite indicators all the indicators are given the same weight when there is no statistical base or method (like in the case of Environmental Sustainability Index - World economic forum, 2002). This does not mean equal weighing because when sub-indicators are clustered into a group, group having number of sub-indicators will have high weightage.

Weighing can also be done on the basis of reliability of source of data; if data is taken from organizations then it could be given high weight while if data is taken from random surveys than low weight can be provided to it. There is one problem with equal weighing that if equal weight is given to two sub-indicators with high correlation than two times weight is given to that indicator. So, we need a statistical model which can give us the information on the correlations and provide weights according to that. There would always be some positive correlation between two sub-indicators of same group. Principal component analysis and Factor analysis are techniques which can provide weights according to their correlation.

V. PRINCIPAL COMPONENT & FACTOR ANALYSIS

In this method first step is to find the co-variance of each sub indicator with other indicator if no co-variance is there in between sub indicators than weight cannot be given with this method. If there is co-variance between the sub-indicators than second step is to find correlation matrix, in which each row contains correlation of one sub indicator to all other sub indicators. In third step eigenvectors and eigenvalues are calculated of correlation matrix. Eigenvector shows how dataset of sub-indicators are related along the lines of these vectors (Manly, 1994). Eigenvectors are arranged according to their eigenvalues and subsets of these eigenvectors are selected according to number of groups required. As not selecting all the eigenvectors will led to some uncertainty but if its eigenvalue is not comparable than it can be neglected. After selecting these eigenvectors, these vectors are rotated in such a way that for those sub-indicators who have less correlation with some eigenvector, finally after rotation it becomes negligible and get correlated with its own eigenvector (group). So, it is basically the process in which sub-indicators are clubbed to their respective group. After rotation weights are provided to sub-indicators according to the group in which they are clubbed. The groups get their weights by finding correlation with all the sub-indicators. Then sub-indicators in that group get their weight by multiplying the weight of group to the ratio of correlation of that sub-indicator to the sum of correlations of all sub-indicators in that group.

$$W_{ij} = W_j * (corr_{ij} / (\sum corr_j))$$

W_{ij} weight of ith indicator in jth group
W_j weight associated with jth group
$\sum corr_j$ Sum of correlation of all the sub-indicators in jth group
$corr_{ij}$ Correlation of ith indicator to jth group
Note that the correlation must be found with the rotated values.

VI. AGGREGATION

A lot of methods or techniques are already present there for aggregation. It can be divided into two types. In one calculations are done in a way that will give a numerical value and using that value, different organizations can be compared. Other approach is called discrete multi-criteria approach (Munda, 1995; Roy, 1996; Vincke, 1992). In which organizations are arranged in decreasing order of sustainability.

VII. LINEAR AGGREGATION

It comes under first type. It is used when all sub-indicators have same measurement units and ambiguities due to scale have been neutralized (Nardo, 2005).

$$S_j = \Sigma W_i * X_{ij} \qquad 1<= i \& i <= N$$

S_j represents the sustainability value of the jth organization
W_i represents the weight associated with ith sub-indicator
X_{ij} represents the value of ith indicator for jth organization.

VIII. GEOMETRIC AGGREGATION

It also comes under the first type. It is used when all the organizations are comparable to each other. Indicators are multiplied with weights appear as exponents.

$$S_j = \prod X_{ij} \wedge (W_i) \qquad 1<= i \& i <= N$$

S_j represents the susutainability value of jth organization

W_i represents the weight associated with ith sub-indicator
X_{ij} represents the value of ith indicator for jth organization.

Countries with low score should prefer a linear rather than geometric because if value of one of the sub-indicator is very low for an organization than it will take a very high value to compensate that low value. Organizations will improve those sub-indicators in which their score is low, if geometric aggregation is used, while in linear aggregation to improve their sustainability organizations can continue to improve in which they are good.

IX. MULTI CRITERIA APPROACH

This technique comes under second category. It tries to resolve the conflict arising in comparison of organizations as some are in favor of one method of aggregation or some are in favor of the other one. So, in this method approach this dilemma is solved by pairwise comparison.

A set of sub-indicators are there for every organizations and their respective weights. For some indicators high values are preferred while for others low value is preferred. Example for pollution low value is preferred, but for profit high value is preferred. Therefore for those sub-indicators in which low value in preferred, subtract their standardized value from 1 so that they will change into high value preference Munda (1995, 2007).

Second step is to do pairwise comparison of one organization with all other organizations in an N×N matrix (N represents number of organizations) named comparison matrix. S_{jk} represents the comparison of jth organization with kth organization. Comparison is done by taking sum of the weights of sub-indicators, in which jth organization has more value than kth organization. Therefore

$S_{jk} + S_{kj} = 1$ for all j,k j<=N, k<=N

After calculation of comparison matrix, all the permutation of organizations are taken. These permutation are the arrangement of organizations in decreasing sustainability. Score of each permutation is calculated by summation of comparison values of organization at first position to all other organizations plus values of comparison values of second organization to rest, on the left of it this process continues till we reach to the end (Munda and Nardo 2003).

Example: If ABCD is the order of permutation of A, B, C & D organizations than score is equal to,

$$C_{AB} + C_{AC} + C_{AD} + C_{BC} + C_{BD} + C_{CD}$$

Permutation with highest score is considered best order. It is possible that one or two arrangements have same score.

X. CONCLUSION

Some organizations will be placed high and some will be placed low. The impact of each and every decision can be seen by changing the values of sub-indicators according to that value. Which decisions can led too sustainable development can be known after calculation. Whether someone likes or not, composite indicators are not the only way to calculate the development of the organizations. There will always be controversies on this topic, as everyone wants to be on the top. These models will never be seen as the goal of any organization, these are just numbers. These should be seen as a starting of topics and discussions.

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