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Composite Ranking Using Multiple Indicators

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Introduction

The increasing availability of large integrated databases and access to the information ("big data") created a data-rich environment. New measures/indicators regularly emerge, making room for innovative solutions, such as combining these measures/indicators to represent concepts not yet quantified - composite indicators (CIs).

In addition, prioritizing the available information helps business and governments make more targeted data-driven decisions using rule-based and statistical methods. Ranking is one way to summarize the data to attain an initial decision on where to focus resources and time - CIs are often used in such cases. It is worth emphasizing, however, that *"All things considered, composite indicators should be identified for what they are - simplistic presentations and comparisons of performance in given areas to be used as starting points for further analysis and discussion."*[1]

Some examples of ranking include:

- Ranking of K-12 students in a school by their height;
- Ranking institutions of higher education by their overall performance;
- Ranking countries by their Human Development Index;
- Ranking countries by the opacity of their financial institutions - the Financial Secrecy Index.

Ranking is straightforward when it is done based on a single indicator, such as ranking K-12 students by their height. However, if two indicators are available such as height and weight, then the two measures can be summarized by a single indicator called body mass index (BMI).

The BMI and the latter three examples represent complex phenomena. Complex phenomena are not directly measurable and require the construction of a composite indicator (CI) to summarize all the information available in the multiple individual indicators. CIs are widely used tools for ranking countries, institutions, entities, products and services; in particular, CIs are very useful in representing phenomena such as business confidence, e-business readiness, environmental performance, sustainability, corruption perceptions, and fraud patterns.

The construction of CIs follows a series of well-established methodological procedures described in the following sections.

The librarian Rutherford D. Rogers famously stated that *"We are drowning in information and starving for knowledge."*

The Construction of Composite Indicators: The Foundation

The two fundamental steps required for the construction of CI are:

Theoretical Framework: According to the Organization for Economic Co-operation and Development (OECD) Handbook on Constructing Composite Indicators, *"the theoretical framework should clearly define the phenomenon to be measured and its sub-components, giving the reader a clear sense of what is being measured by the composite indicator."*[2] A well-grounded theoretical framework is necessary to justify the choice of indicators that best represent the not-directly-observable phenomenon that will be the basis of the ranking. For example, the Growth Competitiveness Index (GCI) developed by the World Economic Forum uses a theoretical framework based on economic theory and political science, which includes indicators reflecting the macroeconomic environment, the quality of public institutions, and technology. Also, the theoretical framework draws knowledge from subject matter experts (SMEs) and institutions.

Data Selection: The choice of indicators in the data selection process may include two limitations:

- It can be somewhat subjective due to the lack of just one definitive set of indicators;
- It may not have pertinent information to construct sound CIs.

If there is a scarcity of comparable quantitative (hard) data to construct sound CIs, the construction may include qualitative (soft) data from surveys or policy reviews. Proxy measures are also used when the desired data are unavailable or when cross-unit comparability is limited.

THE CONSTRUCTION OF COMPOSITE INDICATORS: THE COMPLEMENTARY STEPS

The following steps complete the list of tasks required for the construction of CIs. Some of these steps are often done concurrently - Data Treatment and Multivariate Analysis; Normalization, Aggregation, and Weighting.

Data Treatment: Data treatment addresses issues such as incomplete data and outliers. Missing data is handled using a standard method of imputation while outliers are dealt with to mitigate a possible unplanned impact on the benchmarks during the normalization step.

Multivariate Analysis: Multivariate analysis (MA) is essential in the identification of the interrelationships between the selected indicators - for example, the exclusion of redundant information. MA determines whether the selected indicators are appropriate and sufficient to describe the phenomena summarized by the composite indicator. The data selection decision must combine expert opinion with the statistical structure of the dataset. MA tools such as principal components analysis and factor analysis - as well as the reliability coefficient Cronbach-Alpha (C-alpha) - can be used to validate the structure of the selected data. The C-alpha is based on the correlation between individual indicators.

Normalization: Normalization is crucial to the cross-comparison of the data when individual indicators have different measurement units. Two common types of normalization are:

- The conversion of individual indicators into z-scores, with a mean of zero and a standard deviation of one;
- The standardization of the indicators within a [0, 1] range by subtracting the minimum value and dividing by the range of the indicator values - the Min-Max method.

Aggregation and Weighting: Aggregation and weighting create a single composite indicator based on multiple individual indicators. Different aggregation rules are applicable leading individual indicators to be summed, multiplied, or aggregated using non-linear techniques. For instance, if there are four normalized individual indicators with equal weights, an additive aggregation method will summarize the data by taking the simple arithmetic mean, whereas a geometric aggregation method will summarize by computing the simple geometric mean.

Regarding weighting schemes, variables used in the construction of CIs are often given equal weights. However, an important counterexample to the norm is the consumer credit score, which is a number between 300 and 850 assigned by the major three credit bureaus (Equifax, Experian, and TransUnion) to every individual in the system. The scoring algorithm uses data held by the three bureaus to rank how good the credit stand of consumers is - higher scores indicate a better credit rating. The algorithm considers five main pieces of financial information and assigns to each a different weight. The Economist magazine estimates that the credit score is comprised of payment history (35%), total already owed (30%), length of credit history (15%), two scores for the mix of credit (10%), and applications for new credit (10%)[3].

Uncertainty and Sensitivity Analysis[4]: Uncertainty and sensitivity analysis validates the construction of CIs. Uncertainty analysis studies the way sources of uncertainty; data errors, for example, affect the structure of the CI. Sensitivity analysis examines how much each indicator contributes to the variance of a CI as a source of uncertainty.

AN EXAMPLE: RANKING THE SOCIAL WELFARE OF 130 COUNTRIES

To illustrate the application of proper ranking methods, we used data of 130 countries as of July 2019 to assess the social welfare of their populations. A well-established theoretical framework recognized by international institutions and health practitioners supported our inclusion of the two following sub-groups in the ranking analysis - economic achievement and health status of the population. The four indicators utilized in the construction of the social welfare composite indicator were:

- Gross Domestic Product (GDP) per capita - 2017, The World Bank
- Income inequality index (GINI) - average value 2003-2017, The World Bank; transformed into Income Equality Index
- Infant Mortality per 1,000 births - 2017, The World Health Organization; transformed into Infant Survivability per 1,000 births
- Life Expectancy - 2016, The World Health Organization

The data were normalized using the Min-Max approach. We used two different methods to rank the 130 countries according to the population levels of their social welfare - the geometric aggregation method and the additive aggregation method. The goal was to identify the top 20 countries using the two methods.

An essential feature of aggregation methods is the compensability effect when the high performance of some indictors can compensate for the poor performance of other indicators. The results below illustrate the relevance of the compensability effect and its relationship with the choice of aggregation rule. Some of the results worth emphasizing are:

- The 21 countries in Table 1 include the top 20 countries ranked by the two ranking methods separately. Tables 2 and 3 display the top-ranked 20 countries as classified by the geometric aggregation and the additive aggregation methods, respectively.
- Nineteen countries are ranked at the top 20 (out of the 130 analyzed) under both the geometric and additive aggregation methods. Israel is in the top 20 in the geometric method and Spain is in the top 20 in the additive aggregation method.
- The compensability effect is illustrated in the reverse ranking position of Slovenia and the United States. The lower variability across individual indicators of the United States (performance indicators at more consistent levels) is rewarded by the geometric method by being ranked ahead of Slovenia (16 against 19). The lower variability is also reflected in the fact that the United States has a lower standard deviation across indicators (0.15) than Slovenia (0.34). In contrast, the United States ranks behind Slovenia in the additive aggregation method classification (17 against 16).

The analysis demonstrates an advantage of the geometric aggregation method over the additive aggregation method; it mitigates the undesirable compensability effect.

Table 1: Top 20 Countries According to Either Ranking Method (Sorted by 2017 GDP per Capita)

Country	GDP Per Capita ($), 2017	Income Equality Average (%), 2003-2017	Infant Survivability Rate per 1,000 Births, 2017	Life Expectancy (Years), 2016
Switzerland	$80,342.85	67.19%	996.30	83.3
Norway	$75,704.25	72.78%	997.90	82.5
Iceland	$71,311.79	71.92%	998.40	82.4
Ireland	$68,885.45	67.38%	997.00	81.5
United States	$59,927.93	59.10%	994.30	78.5
Denmark	$57,218.85	73.30%	996.30	81.2
Australia	$53,793.54	65.50%	997.00	82.9
Sweden	$53,253.48	72.58%	997.70	82.4
Netherlands	$48,482.77	71.37%	996.70	81.6
Austria	$47,380.83	69.73%	997.10	81.9
Finland	$45,804.65	72.44%	998.10	81.4
Canada	$44,870.78	66.23%	995.50	82.8
Germany	$44,665.51	69.02%	996.90	81.0
Belgium	$43,467.45	71.57%	996.90	81.2
Israel	$40,543.58	59.10%	997.10	82.3
France	$38,484.19	67.91%	996.50	82.9
Japan	$38,430.29	67.90%	998.10	84.2
Italy	$32,110.03	65.60%	997.10	82.8
Spain	$28,208.30	65.46%	997.40	83.1
Malta	$26,748.21	70.89%	994.40	81.5
Slovenia	$23,601.40	75.05%	998.30	80.9

Table 2: Top 20 Countries (Out of 130) - Ranked by the Geometric Aggregation Method (Normalized Indicators)

Position	Country	GDP Per Capita, 2017	Income Equality Average, 2003-2017	Infant Survivability, 2017	Life Expectancy, 2016	CI Values
1	Norway	0.9421	0.9411	0.9942	0.9457	0.9555
2	Iceland	0.8872	0.9188	1.0000	0.9425	0.9362
3	Switzerland	1.0000	0.7964	0.9756	0.9712	0.9320
4	Ireland	0.8569	0.8014	0.9837	0.9137	0.8864
5	Denmark	0.7111	0.9547	0.9756	0.9042	0.8797
6	Sweden	0.6616	0.9361	0.9919	0.9425	0.8723
7	Netherlands	0.6020	0.9046	0.9802	0.9169	0.8364
8	Finland	0.5685	0.9323	0.9965	0.9105	0.8328
9	Australia	0.6683	0.7526	0.9837	0.9585	0.8299
10	Austria	0.5882	0.8622	0.9849	0.9265	0.8248
11	Belgium	0.5394	0.9098	0.9826	0.9042	0.8126
12	Germany	0.5543	0.8437	0.9826	0.8978	0.8014
13	Canada	0.5569	0.7714	0.9663	0.9553	0.7935
14	Japan	0.4764	0.8148	0.9965	1.0000	0.7886
15	France	0.4771	0.8150	0.9779	0.9585	0.7770
16	United States	0.7450	0.5868	0.9523	0.8179	0.7639
17	Italy	0.3975	0.7552	0.9849	0.9553	0.7290
18	Israel	0.5028	0.5868	0.9849	0.9393	0.7228
19	Slovenia	0.2912	1.0000	0.9988	0.8946	0.7142
20	Malta	0.3305	0.8922	0.9535	0.9137	0.7119

Table 3: Top 20 Countries (out of 130) – Ranked by the Additive Aggregation Method (Normalized Indicators)

Position	Country	GDP Per Capita, 2017	Income Equality Average, 2003-2017	Infant Survivability, 2017	Life Expectancy, 2016	CI Values
1	Norway	0.94	0.94	0.99	0.95	0.9558
2	Iceland	0.89	0.92	1.00	0.94	0.9371
3	Switzerland	1.00	0.80	0.98	0.97	0.9358
4	Ireland	0.86	0.80	0.98	0.91	0.8889
5	Denmark	0.71	0.95	0.98	0.90	0.8864
6	Sweden	0.66	0.94	0.99	0.94	0.8830
7	Finland	0.57	0.93	1.00	0.91	0.8520
8	Netherlands	0.60	0.90	0.98	0.92	0.8509
9	Australia	0.67	0.75	0.98	0.96	0.8408
10	Austria	0.59	0.86	0.98	0.93	0.8405
11	Belgium	0.54	0.91	0.98	0.90	0.8340
12	Japan	0.48	0.81	1.00	1.00	0.8219
13	Germany	0.55	0.84	0.98	0.90	0.8196
14	Canada	0.56	0.77	0.97	0.96	0.8125
15	France	0.48	0.81	0.98	0.96	0.8071
16	Slovenia	0.29	1.00	1.00	0.89	0.7961
17	United States	0.74	0.59	0.95	0.82	0.7755
18	Italy	0.40	0.76	0.98	0.96	0.7732
19	Malta	0.33	0.89	0.95	0.91	0.7725
20	Spain	0.35	0.75	0.99	0.96	0.7634

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