

Composite measure of industrial performance for cross-country analysis

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A country's industrial performance can be assessed using a number of statistical indicators reflecting the level, growth and structure of industrial activities. However, policymakers prefer a single composite measure over a set of indicators to obtain an overall picture of their country's relative performance compared to that of other countries. The paper describes UNIDO's experience of constructing such a measure, namely the *Competitive Industrial Performance (CIP) index*, which considers countries' productive capacity, intensity of industrialization and impact on the world market as major components of industrial performance. The compilation of the CIP index, however, poses two major challenges. First, the composite measure for a broad international comparison can only be constructed when data are available for all indicators and if the computation methodology is uniform across the countries. Second, as the final result is a normalized index used for country ranking, any uncertainty in one of the indicators may result in a shift of a given country in the overall ranking. The primary data source for the compilation of the CIP index is UNIDO's database based on an underlying quality assurance framework for international comparability. To address the second problem, a sensitivity analysis is performed. The analysis reveals a substantially high correlation between the default CIP rankings and the alternatives, indicating that the composite measures are robust in a comparative assessment of countries' industrial performance.

Keywords: statistical indicators, comparability, sensitivity analysis

1. Introduction

UNIDO promotes industrialization around the world. It facilitates global debates on emerging issues, advises on development strategies and monitors the progress achieved by its Member States in industrial development. The task of statistics in this process is to support the research programme and policy advisory services of the Organization with empirical evidence and meaningful indicators and assist the policymakers of Member States in understanding the key drivers of industrial performance.

The international industrial statistics database (INDSTAT)¹ maintained by UNIDO contains historical series of principal indicators of industrial statistics for about 180 economies of the world. These data offer tremendous opportunities for research and analysis on different aspects of industrial development at country, regional and global level. A set of indicators for performance analysis has been recommended in a UNIDO Statistics publication – *Industrial Statistics; Guidelines and Methodology* (UNIDO, 2010). Prior to this publication, UNIDO used the *System of Industrial Development Indicators (SIDI)* and *Measures for Measure* for the analysis of industrial performance. These indicators gradually evolved into a scoreboard of industrial performance and production capabilities. While these indicators

¹ For further information, visit: <http://www.unido.org/resources/statistics/statistical-databases.html>

covered different aspects of global industrial development, the Organization deemed that using a single measure for determining the position of countries with respect to industrial performance and its structural features would be more practical (UNIDO, 2003). The *Competitive Industrial Performance (CIP) index* was first introduced in the *Industrial Development Report 2003*, which focused on a country's ability to produce manufactured goods competitively. Results and analyses based on the CIP index became part of the *Industrial Development Report* in following years.

Recently, UNIDO decided to publish the CIP as a stand-alone report and detached it from the *Industrial Development Report*. The Statistics Unit is in charge of compiling the CIP index and for analysing its findings. This transfer of responsibility was not a purely organizational change. UNIDO Statistics organized an expert group meeting with the participation of representatives of key international agencies and experts involved in composite indicators. The set of indicators was revised, a quality assurance scheme was applied to the source data and a sensitivity analysis was carried out to assess the robustness of the index. This paper was prepared upon completion of the first CIP report².

2. The composite index in international practice

The composite index has been widely applied around the world. A survey of composite indicators conducted by UNDP lists 178 composite indices which are currently compiled in different frequencies. The list shows a quite diverse coverage of indices including *Ethno-linguistic and Religious Fractionalization and Political Instability Index*, *Global Climate Risk Index*, *Happiness Index*, *Technology Achievement Index*, *Welfare Index*, etc. The composite index is quite popular among international development agencies, especially since the successful launch of the *Human Development Index*. It is considered a useful tool for policymakers to depict the broader picture of the development agenda and to attract wider public attention.

The use of the composite index for performance analysis has not been free from controversy. Many statisticians argue that a composite index, while attempting to capture many things at the same time, essentially does not provide a precise measure of anything, and thus sends a simplistic and misleading message to policymakers about the complexity of the issue at hand. Moreover, it undermines the significance of comprehensive statistical surveys and their results with the large variety of estimates behind a dubious single measure (Saisana *et al* 2005). The composite index is based on a set of indicators, and failure to obtain data for any one of the individual indicators in a pre-defined set makes it impossible to construct the entire index. Any efforts by statisticians to produce several statistical measures are thus go to waste. Even when all underlying statistics are available to construct a single composite index, there is no way of capturing the entire wealth of knowledge embedded in a set of numbers in one real number (Sen *et al.* 1994).

Despite this drawback, policymakers and development practitioners value a composite measure which summarizes complex processes in a single measure that can be used to benchmark their country's performance. The option of ranking countries based on their performance—which a composite measure can provide—is particularly attractive for

² This paper is extensively based on the economic analysis of Antonio Andreoni and the sensitivity analysis of Kris Boudt, which is included in the CIP report (UNIDO, 2013)

international development agencies. Shifts in the ranking generate public debate, attract media attention and advise the political leadership to adopt appropriate policy measures.

The construction of a composite index is largely a statistical exercise. Statistical analysis generally entails deriving major factors or components from a dataset with a large number of variables. A number of multivariate analysis methods are applied for this purpose. Typically, a principle component analysis can indicate a few uncorrelated statistical dimensions that measure different aspects of the dataset. This analysis still carries a lot of importance in terms of selecting indicators for a composite measure. The method and compilation procedure of a composite measure involves prior selection of relevant statistical indicators, data preparation including imputation of missing data, a multivariate analysis, normalization and weighting and aggregation. The step-by-step guidelines to this end are provided in the OECD Handbook on Constructing Composite Indicators (OECD, 2008).

The reliability of the composite measure depends on the quality of data used to compile the underlying indicators. The data preparation for the composite measure undergoes the same process of data editing scrutiny and validation. That is, the appeal of using a composite measure does not relieve statisticians from their responsibility of quality assurance of the source data.

3. Scope and dimensions of CIP index

An abundance of composite indicators compiled and disseminated by several agencies may suggest very limited scope and relevance for any new comers. There are other composite measures directly related to the performance of countries in competitiveness and business activities. Examples include *The Global Competitiveness Index (GCI)* by the World Economic Forum (WEF), *The World Competitiveness Scoreboard (WCS)* by the Institute for Management Development (IMD) and *The Doing Business Index (DBI)* by the World Bank.

The CIP's major distinction relates to its sector perspective. Industrial competitiveness is defined as the capacity of countries to increase their presence in international and domestic markets whilst developing industrial sectors and activities with higher value added and technological content (UNIDO, 2012). Industrial competitiveness necessitates innovation, technological sophistication, developed infrastructure and effective industrial policy directed at exploiting comparative advantage. GCI and DBI focus on the potentials of economic growth and the prevailing business climate. CIP is based on output measures and thus captures a country's production performance. Another important feature is that the CIP is fully based on statistical measures. Indices published by WEF and IMD are a mixture of quantitative and perception indicators. While the uniformity of the computation methods and classification standards ensures the international comparability of statistical data, respondents' business perceptions are difficult to harmonize. Perception indicators are based on the respondent's individual understanding and are influenced by the time and context of the interview.

As a performance indicator, CIP reflects a country's productivity, structural change and competitiveness. These concepts are taken as a departure point for the selection of indicators under the three major dimensions of the CIP illustrated in Figure 1. The first dimension includes manufacturing value added (MVA) per capita, which is the ratio of output to the country's population. This indicator represents the level of overall productivity and

quantifies the country's capacity to produce. Another indicator of the same dimension shows the extent of the realization of domestic manufacturing products in external markets.

Figure 1: Dimensions and indicators of CIP

Dimensions	Indicators
Capacity to produce and export	1. Manufacturing value added per capita 2. Manufacturing export per capita
Technological upgrading and deepening	3. Share of MHT activities in total MVA 4. Share of MVA in GDP 5. Share of MHT manufactures exports 6. Share of manufactures export in total exports
Impact on world production and trade	7. Share of the country in world MVA 8. Share of the country in world manufactures exports

The second dimension of the CIP consists of indicators relating to the intensity of industrialization and the quality of manufactures exports. As industrialization progresses, two forms of major structural change may occur. First, the manufacturing sector's position in the overall economy may strengthen (increased share of MVA in GDP) and second, a gradual shift from low-technology and resource-based to high-technology products may occur. Increasing levels of industrialization trigger the export of high-technology and high quality products. The third dimension comprises indicators on the country's share in the world market and thus introduces exogenous factors into the analytical framework of the CIP.

The "home-grown" nature of the CIP can be explained by the fact that the required data for all selected indicators are available in UNIDO's statistical database. These data regularly undergo a strict transformation process as defined in UNIDO' quality assurance framework (Upadhyaya et al, 2009). Subsequently, the major part of the consistency check and imputation process is completed before the construction of the CIP. Nevertheless, the CIP as a composite measure requires figures to be available for all indicators in the given timeframe for target countries. To avoid the exclusion of a country due to missing data, additional imputation may also be necessary.

4. Construction and use of CIP index

After defining the indicators, the CIP index is constructed based on a standard data transformation process for the composite measure which involves the imputation of missing data, outlier cleaning and normalization. The purpose of normalization is to obtain a common measure from indicators with a value in varying scales. The CIP index follows the *Min-Max normalization* process, which is particularly useful for obtaining harmonized scores between 0 to 1. The score for individual indicators included in the CIP is computed as;

$$S_{i,j}^k = \frac{X_{i,j}^k - \min(X_{i,j}^k)}{\max(X_{i,j}^k) - \min(X_{i,j}^k)} \quad S_{i,j}^k = \overline{0,1} \quad (1)$$

where:

$S_{i,j}^k$ - score obtained from k-th variable of i-indicator and j-th country

$X_{i,j}^k$ - value of k -th variable for i -th indicator and j -th country
 min and max - smallest and largest value in the sample.

One of the main drawbacks of the *Min-Max normalization* process is that outliers and extreme values can distort the transformed indicator. This problem is checked in a sensitivity analysis, applying the z-score transformation as an alternate approach.

Following normalization of each indicator, the best performing country is assigned a value of 1 and the weakest performing country is assigned a value of 0. The composite measure is subsequently calculated from the individual scores. At this stage, two methodological options are available – weighting and aggregation. The general idea is to distribute equal weights to all indicators and to maintain the balance of the three dimensions. As the second dimension has four indicators, the weights are equally distributed within the dimension. With respect to aggregation, the choice is based on the assumption that indicators are substitutable, i.e. poor performance of one indicator can be compensated for by higher values of other indicators. Aggregation using geometric means limits such compensation to some extent, and thus higher values for all indicators are necessary to achieve an improved CIP.

Figure 2 Distribution of weights by indicators

Indicators	Weight
1. Manufacturing value added per capita	1/6
2. Manufacturing export per capita	1/6
3. Share of MHT activities in total MVA	0.5 × 1/6
4. Share of MVA in GDP	0.5 × 1/6
5. Share of MHT manufactures exports	0.5 × 1/6
6. Share of manufactures exports in total exports	0.5 × 1/6
7. Share of the country in world MVA	1/6
8. Share of the country in world manufactures exports	1/6

The composite index as a weighted geometric mean of the normalized scores of indicators can be expressed as:

$$CIP_{jt} = \prod_{i=1}^q S_{ijt}^{w_i} \quad (2)$$

Where

- CIP_{jt} - index for j -th country and t -year, which lies between 0 to 1
- S_{ijt} - normalized score of i -th indicator for j -th country and t -year
- w_i - weight of i -th indicator, which must be a positive value and the sum of all weights equal to 1.

CIP index values obtained thereby represent a composite measure of a country's competitive industrial performance. The CIP index can be interpreted in time-series and

across countries. A positive change in the CIP value of a given country over time indicates increased productive capacity and improved quality of products with a better chance of realization in international markets. A comparison of the CIP across countries indicates the comparative advantage of one economy over others.

The compilation of the composite measure requires the transformation of a large amount of statistical information at several stages. This process raises many questions concerning the quality of statistical measures. One of the main advantages of the composite index in terms of quality is its fitness for purpose (Saltelli *et al*, 2004), which is essential for its use in performance analysis. The CIP index is primarily used for the following purposes.

Benchmarking – The CIP index is an important tool for benchmarking a country's industrial performance. Countries vary considerably by stage of industrial development, technological endowment and degree of production capabilities. The composite measure captures different dimensions of industrial performance and clusters countries with similar production and technological structures. Hence, the CIP index serves as a suitable country comparator. Despite some known limitations, a normalized measure rescales the indicators of different values and produces a common index which is quite useful for cross-country performance analysis.

Ranking and grouping – The benchmarking exercise allows identification of the relative industrial competitiveness of nations and their corresponding rank. Rankings are the most important outcome of the compilation of composite measures, and indicate a country's relative position in comparison to others. Rankings are also used to group the countries by quintiles – top, upper middle, middle, lower middle and bottom quintile. The CIP ranking reveals a general pattern that is consistent with global economic reality: industrialized economies congregate near the top, emerging industrial economies are found in the middle of the ranking, other developing and least developed countries are at the lower middle and lower end of the world ranking. Upward movement of countries in the CIP ranking indicates industrial development.

Industrial diagnostics - The index provides countries with a package of industrial diagnostics. The CIP is constructed from a number of sub-indicators which cover the different dimensions of competitive performance. Statistical information presented in the CIP indicates the capacity of countries to produce and export competitively, their industrial structure and level of technological deepening and upgrading and, finally, their impact on global manufacturing production and export. By comparing countries' relative performance, governments can identify the strengths and weaknesses of their economy and introduce corrective policy measures.

Comparison with other composite measures - Country rankings produced by the CIP can be compared with other indices relating to country performance in economic or human development. Similarities between indices are measured using the Spearman rank correlation. For example, despite the fact that both the CIP and GCI measure economic competitiveness, these two indices were found to be relatively diverse. The CIP is more similar to the HDI, with a correlation coefficient of 0.79. Generally, countries with a higher level of industrial development also have a higher expenditure on health and education. However, not all countries have the same results in both composite measures. The largest divergence between the CIP and HDI was found among emerging industrial economies such as China, India and Indonesia.

The CIP index's most important feature is the possibility it offers to conduct cross-country analyses of industrial performance. The index comprises statistical information for a set of eight key economic indicators for a large number of countries. The CIP database consists of input data and normalized values for the period 1990 to 2010. Users can observe shifts of countries in the CIP ranking by different indicators and analyse their performance at regional and global level. A recently introduced new country classification in UNIDO statistics adds yet another dimension for cross-country analysis. Analyses of the CIP index in the past, in particular recommendations made in UNIDO's *Industrial Development Report*, has prompted countries to review their industrial performance and adopt new policy measures. Countries' relative position in the CIP ranking has also contributed to the launch of policy debates between the government and business community.

There is one notable advantage of the CIP for the development of national industrial statistics. Governments of countries excluded from the CIP ranking have initiated internal inquiries on how the quality of their industrial statistics could be improved and how to produce the necessary data for performance analyses. Thus, the CIP index has attracted the attention of the political level regarding the current condition of national statistics.

5. Latest CIP publication

Although UNIDO has been compiling the CIP index since 2003 in connection with its flagship publication *The Industrial Development Report*, the most recent CIP index is being released as a stand-alone publication of UNIDO Statistics and is entitled *The Industrial Competitiveness of Nations*. The index is compiled from data up to 2010. The publication presents the original and normalized values of sub-indicators together with the CIP ranking of 135 countries. Analysis of the world ranking has been performed by quintiles of the world ranking with 27 countries in each quintile. Descriptive statistics presented for each quintile denote the inequalities of the CIP value within and across quintiles. The ranking reveals some familiar patterns, with high income industrialized countries showing the highest levels of industrial performance worldwide. The top five positions of the CIP ranking in 2010 were held by Japan, Germany, the United States, Republic of Korea and China, Taiwan Province. Among the emerging industrial economies, China ranks seventh among industrialized nations. Other emerging industrial economies are found in the upper middle quintile.

The lower middle range as well as the bottom of the ranking mainly includes low income or relatively small economies. Nearly all African economies congregate in the bottom quintile of the ranking, with the exception of South Africa, Egypt, Tunisia, Morocco and Mauritius. The lower middle and low quintile also include least developed countries. These countries have a combined contribution of less than 1.0 percent to world manufactured value added and world manufactures trade. As shown in Table 1, eight of the bottom ten countries are from sub-Saharan Africa. The biggest country in the lower middle quintile in terms of population size is Nigeria with a population of more than 160 million.

TABLE 1: (ABOUT HERE)

Results obtained from the compilation of the CIP index confirms the development trend statistical data disseminated by UNIDO through other publications indicates, especially the *International Yearbook of Industrial Statistics*. However, the CIP publication consolidates the different aspects of industrial development with the vast amount of analytical material.

Like any other composite measure, it will be debated and questioned. But the methodology of the CIP is sound and transparent, and its indicators provide quantitative measures. The primary data source for the compilation of the CIP index is UNIDO's database based on an underlying quality assurance framework for international comparability. To address the uncertainty of the various levels of composite measures, UNIDO statistics performed a sensitivity analysis of the CIP.

6. Sensitivity analysis

The construction of a composite index entails a number of stages such as the selection of indicators, normalization and aggregation. In each stage, different choices need to be made. The purpose of a sensitivity analysis is to check the extent of uncertainty created by the choice of each method *vis-à-vis* another in relation to the total uncertainty of the index.

The CIP index consists of the non-linear combination of eight indicators that focus on three dimensions of competitive performance. On the one hand, the lack of any strong correlation between the variables of the different dimensions is an essential condition for ensuring that they measure different aspects of a country's competitive performance. On the other hand, the overall index may appear sensitive to changes in the individual indicators if the country ranking by one indicator is quite different from that of another indicator. By performing a sensitivity analysis, we can determine the robustness of the composite index. For this purpose, the impact of changing an indicator or applying another methodological approach on the ranking of countries is examined. If the impact from such a change is significant, then the ranking of the countries based on the CIP value is not unambiguous or robust.

A sensitivity analysis of the CIP index was conducted regarding the impact of the number of indicators and underlying weights, normalization method, imputation method of missing data and arithmetic versus geometric weighting. The impact of changing one assumption was analysed while others remained the same, and the impact of joint changes was examined. For a single assumption, the Spearman rank correlation was applied to estimate the correlation coefficient between the original CIP values and those with changed assumptions. In addition, the average absolute rank shift of the CIP values due to the change in assumption was estimated.

TABLE 2: (ABOUT HERE)

The joint effect was also analysed using the Monte Carlo approach, resulting in the so-called *Monte Carlo CIP*: a complete distribution of the CIP per country generated by the random draws from the distribution of the uncertainty factors in the calculation of the CIP index. The main conclusion of the analysis was that the correlation between the original CIP rankings and those that could have been obtained using different methods is relatively high. The analysis indicates that the ranking of countries would not differ much if a different choice had been made at any level of the CIP's construction. Thus, the CIP values are robust and suitable for ranking countries' competitive performance.

7. Conclusion

Historical evidence shows that manufacturing has been an engine of overall economic growth of nations. This is also true for a large part of today's emerging industrial and developing economies. Thanks to their increasing share in world industrial production, global MVA growth has been consistently higher in recent decades than GDP growth. At the same time, a significant number of developing countries still lag far behind in the industrialization process. In some African countries, for example, not only has industrialization progressed at marginal levels, it has actually regressed. Such an imbalance poses serious concerns for international development partners. While global industrial development is a multi-dimensional phenomenon, policymakers demand a consolidated measure for cross-country analyses of industrial performance.

The CIP index is a simple yet powerful and transparent measure of the competitive industrial performance of nations. It highlights the relative achievements of countries in industrial development and indicates their weakest links. It is not free from all deficiencies attributed to a composite measure, but it serves the purpose of benchmarking countries' performance and conducting industrial diagnostics for policy interventions.

The CIP as a statistical product has undergone all statistical processes and passed the quality test. Its results are ready for use. While the CIP depicts a country's overall picture of competitive industrial performance, its sub-indicators provide more precise measures of the key aspects of industrial development. Therefore, the CIP offers both a large set of statistical information and an analysis based on a single composite indicator.

Annexes

Table 1. Top and bottom 10 countries in the CIP index, 2012

Top 10 countries		Bottom 10 countries	
1	Japan	126	Sudan
2	Germany	127	Haiti
3	United States	128	Niger
4	Republic of Korea	129	Rwanda
5	China, Taiwan	130	Ethiopia
6	Singapore	131	Central African Republic
7	China	132	Burundi
8	Switzerland	133	Eritrea
9	Belgium	134	Gambia
10	France	135	Iraq

Source: UNIDO Statistics

Table 2: Impact on ranking when modifying one assumption

Change	Absolute difference*	Spearman correlation**
Four vs. eight indicators	13.71	0.901
Arithmetic vs. geometric mean	13.21	0.914
z-score vs. Min-Max normalization	12.81	0.923
Linear interpolation vs. last price interpolation	9.932	0.972
Product-based technology classification ³ vs. activity-based	5.732	0.975

*Year-average of average absolute difference in ranking between the modified and default method

** Year-average of correlation between the ranking of new method and default method

³ UNIDO, Industrial Development Report 2003.

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