

## Composite measure of industrial performance for cross-country analysis<sup>1</sup>

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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)<sup>2</sup> 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.

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<sup>1</sup> A longer version of this paper with statistical annexes and references is available upon request.

<sup>2</sup> For further information, visit: <http://www.unido.org/resources/statistics/statistical-databases.html>

Recently, UNIDO decided to publish the CIP as a stand-alone report and detached it from the *Industrial Development Report*. 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 report<sup>3</sup>.

## 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 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

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<sup>3</sup> 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)

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).

### 3. Scope and dimensions of CIP index

An abundance of composite indicators compiled and disseminated by several agencies may be quite limited in scope as well as in terms of relevance for any newcomers. 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). 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.

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 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 relates to the intensity of industrialization and the quality of manufactures exports. As industrialization progresses, a gradual shift from low-technology and resource-based to high-technology products may occur. 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 is explained by the fact that the required data are available in UNIDO’s statistical database, which undergo a strict transformation process as defined in UNIDO’ quality assurance framework (Upadhyaya et al, 2009).

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

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

Where

- $CIP_{jt}$  is the index for j-th country and t-year, which lies between 0 to 1
- $S_{ijt}$  depicts the normalized score of i-th indicator for j-th country and t-year
- $w_i$  refers to the 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 i) benchmarking, ii) ranking and grouping, iii) industrial diagnostics and iv) comparison with other composite measures.

The most important use of CIP index is the possibility it offers for cross-country analysis of industrial performance. The index is presented with the statistical information for a set of eight key economic indicators for a large number of countries. CIP database contains the input data and normalized values for the period of 1990 to 2010. The users can observe the movement of countries in CIP ranks by different indicators and analyze their performance at regional and global level.

#### 5. Latest CIP publication

Although UNIDO has been compiling CIP index since 2003 in connection with its flagship publication of *the Industrial Development Report*, the latest CIP index is released in a stand-alone publication of UNIDO Statistics with a title of *the Industrial Competitiveness of Nations*. The index is compiled from the data up to 2010. The publication presents the original and normalized values of sub-indicators together with the CIP ranks of 135 countries. The ranking reveals some familiar patterns as high income industrialized countries are industrially the best performing nations in the world. Top five positions of CIP ranks in 2010 went to Japan, Germany, the United States, the Republic of Korea and Taiwan (China). Among the emerging industrial economies China is placed with industrialized countries at the seventh position. Other emerging industrial economies stand in the upper middle quintile. The lower middle range as well as the bottom of the ranking primarily includes low income or relatively small economies. These countries have combined contribution of less than 1.0 percent to the world manufactured value added and world manufactures trade.

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

#### 6. Sensitivity analysis

Construction of a composite index goes through a number of stages such as selection of indicators, normalization and aggregation. In each stage there are different choices to make. The purpose of 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.

CIP index is made of the non-linear combination of eight indicators focusing three dimensions of competitive performance. On one hand, lack of any strong correlation between the variables of the different dimension is an essential condition to ensure that they measure different aspects of the competitive performance, on the other hand, overall index may appear sensitive to the change of individual indicators if the country ranks by one indicator are quite different from another. Sensitivity analysis for CIP index was carried with respect to the impact made by the number of indicators and underlying weights, normalization method, imputation method of missing data and arithmetic versus geometric weighting. The analysis was made for the impact of change of one assumption while other remains the same and for the impact of joint changes. For a single assumption, Spearman rank correlation was applied to estimate the correlation coefficient between the original CIP values and those with changed assumption. Additionally, average absolute rank shift of CIP values due to the change in assumption was estimated. For the second scenario,

The joint effect was analyzed using Monte Carlo approach, which led to a so-called *Monte Carlo CIP*: a complete distribution of the CIP per country as 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 ranks and those that could have been obtained with different methods is relatively high. It indicates that ranking of countries would not be much different if a different choice was made at any level of the construction of CIP. Thus CIP values are robust and fit for ranking of countries for their competitive performance.

## 7. Conclusion

Historical evidences show that the manufacturing has been the engine of overall economic growth of nations. Thanks to their increasing share in the world industrial production, the global MVA growth has been consistently higher than GDP growth in recent decades. At the same time, a significant number of developing countries still lag far behind in industrialization process. Such imbalance poses serious concerns for international development partners. While the world industrial development is a multi-dimensional phenomenon, the policy makers demand a consolidated measure for a cross-country analysis of industrial performance.

CIP index is a simple yet powerful and transparent measure of 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 that a composite measure is attributed to, but it serves the purpose of policy makers to benchmark the performance and carry out industrial diagnostics for required policy interventions. CIP as a statistical product has gone through all statistical processes and passed the quality test. Its results are ready for use. While CIP depicts an overall picture of competitive industrial performance of the country, its sub-indicators provides more precise measures of the key aspects of industrial development. Therefore, CIP gives the choice of the large set of statistical information together with the analysis based on a single composite indicator.