PROCEDURE OF EFFICENT INTEGRAL INDEX GENERATION OF THE UKRAINIAN INDUSTRIAL PRODUCTION

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Abstract. The manuscript presents an algorithm for integral index generation of the Ukrainian industrial production efficiency. The author has proposed a method of the performance index of the industrial production calculating, taking into account all the advantages and disadvantages of an integrated parameter generation. The main emphasis is made on the factor analysis usage. Incoming information is presented in the form of three-dimensional data matrix. Its qualitative analysis includes data validation for the abnormally large or small values presence, filling in transmitted information, descriptive statistics analysis. Unification of the indicators is provided through standardization procedure. The author recommends classifying basic and advanced metrics for the efficiency evaluation of the Ukrainian industrial production by factor analysis. The formula for integral index calculating is based on convolution of factor loadings values and of input parameters normalized values with regard to their significance.

Keywords: economic activity, efficiency, integral factor, method, industrial production, factor analysis.

1. Introduction

Ukrainian industrial production (IP) is characterized by economic phenomena of complexity and diversity. It requires a significant amount of research indicators for its evaluation. Each index, which has proper interpretation, however, is a part of integral generalizing property. Large amounts of informational indicators make it impossible to form general conclusions about the industrial production effectiveness (IPE). Therefore, in economic analysis theory and practice there are different formal methods that minimize significant analytical data number, in order to use a smaller number of integrated indicators. Using these methods provides a compact calculations, visualization of researched results, quality evaluation improving.

2. Materials and methods

Scientific papers analysis shows that today in Ukraine there isn't agreement on the list of algorithms, parameters and their combinations for the complex IPE research in Ukraine on the basis of informational resources from the State Statistics Service of Ukraine.

Industrial development in Ukraine is largely influenced by the hidden patterns that depend on various factors. And it is very important to detect the hidden patterns of Ukrainian IPE. Therefore, it is advisable to develop appropriate methodological basis for integral index of IPE calculating, based on the multivariate statistical analysis procedure's use together with factor analysis and principal component method application.

Such approach to the complex socio-economic phenomena and processes calculation and evaluation is present in both native and foreign economic science. Based on the methodology approved by the Ukrainian State Statistics Department, the integral index calculation of regional economic development [1] is based on the current system of regional statistics indicators that reflects the main components and factors of socio-demographic and economic situation in each region and provides opportunities for inter-regional comparisons.

The ideology of the proposed methodology meets the methods of human development measuring approved by injunction of the Presidium of Ukrainian National Academy of Sciences and the Board of the State Statistics Service of Ukraine [2].

A similar algorithm is present in the economic security` integral index calculation, approved by the Ministry of Economic Development and Trade of Ukraine [3] and also in the calculation method of enterprises financial level rating proposed by the group of experts from Institute of Demography and Social Studies of Ukraine and the State Statistics Service of Ukraine [4].

Russian economists use the main component's method in the study of the political and legal factors influence on economic growth of Russian regions [5]; identifying macroeconomic development` patterns [6]; dependencies of regional macroeconomic indicators establishment [7]; macro analysis of industrial development [8] and certain activities [9].

3. Integral index of IPE calculating methods

Integral index of Ukrainian IPE is a generalized synthetic indicator that is based on an integrated approach to the Ukraine's industrial production assessment using special mathematical and expert methods.

The algorithm of its generation involves several stages: formation, informational management analysis and processing, correlation matrix construction, main components method's usage to determine a sufficient number of factors and their capacities, determining the weight coefficient of integral index of Ukrainian IPE calculation.

A precondition for integral index of IPE calculation is the presentation of a multidimensional input X matrix =

(xi1, xi2, xij), formed on the basis of State Statistics Service of Ukraine data. The matrix is three-dimensional and includes the following features: time, name of the object and sign-indicator. For the correct index calculation, the year is characterized by the time sign, industries are grouped by economic activity (EA) and represent the name of the object, and corresponding numeric valuesare the sign indicator. Number of numerical data in a matrix is determined by the number of year's studied, economic activities and indicators. Their reflection corresponds to the scale of X matrix.

$$X = \begin{pmatrix} x_{11}(t) & x_{12}(t) & \dots & x_{1n}(t) \\ x_{21}(t) & x_{22}(t) & \dots & x_{2n}(t) \\ \dots & \dots & \dots & \dots \\ x_{m1}(t) & x_{m2}(t) & \dots & x_{mn}(t) \end{pmatrix}, \quad (1)$$

where $t=1,2,...T$ and $x_{ij}(t)$, $(j=1,2,...n)$ are the value of *i*-index by the *j*-economic activity at the *t* – moment of time. Given to the specificity of industrial production data formation at the meso-level, the year must be used as time index.

Thus, according to the formula (1) spatio-temporal information is formed from sample data including indicators of Ukrainian enterprises economic activity from several periods (years).

The next iteration is a qualitative data analysis and descriptive statistics analysis. On the base on qualitative analysis completion of data sampling is carried out and replacement of abnormally large or small values, if any will be detected, by using robust statistics methods. Descriptive statistics is performed to better understand the structure of the survey data and to standardize indicators. During these procedures we calculate the maximum, minimum, average, and standard deviation values of each parameter that characterizes the variation of all traits.

In order to standardize the aggregate input characteristics of X = (xi1, xi2, ..., xij), with regard to their standard, minimum and maximum values we use the standardization procedure to ensure comparability. Zero dimensional indicators make it possible to obtain a summary description of the indicators importance that is measured in different units.

For further analysis the standardized values are centered with the help of next formula:

$$\widetilde{X}_{ij}^{c} = \widetilde{X}_{ij} - \overline{\widetilde{X}}_{i}, \quad (2)$$

where $\widetilde{X}_{ij}^{c}$ – is a standardized value of *i*-index in *j*-aggregate of industrial enterprises by their economic activities; $\overline{\widetilde{X}}_{i}$ – average normalized value of *i*-index by all industrial enterprises and their economic activities;

$$\overline{\widetilde{X}}_{i} = \frac{\sum_{i=1}^{J} \widetilde{X}_{ij}}{J}, \quad (3)$$

where *J* – is the total number of economic activities in aggregate.

The next step is to build a matrix of pair wise correlations. The dependence degree between the original x_{ij} indexes is based on the pair correlation coefficients usage. For $\widetilde{X}_{ij}^{c}$ matrix with standardized centered values of $m \times n$ dimension, paired coefficients form a symmetrical correlation relative to the main diagonal correlation matrix of $n \times n$ dimension, where items that are located on the main diagonal are equal to unity.

$$R_{[n]} = \left\| r_{ij} \right\|_{n}^{n}, \quad (4)$$

where r_{ij} – is correlation coefficient between *i*-index of *j*-economic activity;

$$r_{ij} = \frac{\widetilde{x}_{ij}^{c}}{\sigma i \sigma j}. \quad (5)$$

To determine the hidden patterns` quantitative impact on the Ukrainian IPE we must analyze the values of elements of correlation matrix. High values of estimated coefficients can characterize the multicollinearity` presence of input index-features. These values form the false regression dependence. We must use the main components method that eliminates large collinearity between transitional indicators to the new generalized factors that are linear combinations of input characteristics.

Correct models construction using main components method provides confirmation of pair correlations matrix significance [10, p. 64].

The test of correlation matrix significance should be done by using the Wilks criterion $\chi^2(Wilks)$ that is based on the Barlett formula [11, c. 142]:

$$\chi^2 = -(n - \frac{1}{6}(2m+5)) \ln|R|, \quad (6)$$

where R – matrix of correlation coefficients; m – value of variables; n – number of observations.

We make the comparison of the calculated index with the tabulated value χ^2, with the number of discretion ranges $\nu = \frac{1}{2} m(m-1)$. The significance of correlation coefficients matrix is confirmed at $\chi_P^2 > \chi_T^2$, where χ_P^2 – is a calculated value of Wilks criterion, χ_T^2 – is theoretical value of Wilks criterion.

4. Basic and additional indicators` definition and classification

The next step is the definition and classification of basic and additional indicators that should be used to evaluate Ukrainian IPE and its significance. To ensure the evaluation of these indicators we use the method of factor analysis.

The factor analysis method is based on the assumption that the studied parameters are only accounting for certain components of existing properties phenomena that are not directly measured. These root causes are called components (factors). Identification of components and providing them with a certain socio-economic content is based on parameters

that have the greatest load factor. Load factor reflects the density of communication between the studied parameters and components. It also shows the effect of initial rate on the latent factor.

The direct use of factor analysis leads to primary factorial matrix *(A)* obtaining. Columns of this matrix describe the hidden patterns of IPE Ukraine and rows show the closeness and character of the input parameters of the identified patterns. The elements of the matrix *(A)* are the factor capacities a_{js} *(j,s=1,2,...n)*, where a_{js} characterizes the weight of *j*-partial indicator for the formation of *s*- principal component (factor), which reflects some hidden pattern of IPE.

Factor capacitates of a_{js} are partial correlation coefficients that reflect the relationship of input multitude $X = (x_{i1}, x_{i2}, ..., x_{ij})$ and principal components of F_s. As the correlation coefficient, a_{js} varies within range [-1, 1]. In the main component model the remains are absent, so that all components of the total variance explain the main dispersion of the multitude. For each of the *s*-column of *A* matrix is a fair condition $a_{1s}^2 + a_{2s}^2 + ... + a_{ns}^2 = \lambda_s$, where λ_s is the dispersion of F_s main component. Columns of *A* matrix of a_{ij} factor capacities are the basis for the main components interpretation.

Initially, the number of input parameters equals the number of main components. Clearly, not all main components should be used in the analysis of Ukrainian IPE. Therefore, we selected such main components, which total share of dispersions explains most of the input data variations (usually 75%).

In practice, scientists use such methods for the number of factors determination [12, p. 53 - 54]:

- Kaiser criterion is the most common method. It suggests to retain those factors with eigenvalues equal or higher than 1. The choice is made according to the (k = 1,2, ..., K; (K> s), for which equality $\lambda_s \geq 1$ is true;

- A graphical method is the *scree* test first proposed by Cattell. Cattell suggests to find the place where the smooth decrease of eigenvalues appears to level off to the right of the plot.

The complex factorial structure in the application of the main components method complicates its identification. The simplification of the factorial structure is that the value of factor loadings a_{ij} close to 1 or 0 (so most of them adjacent to the coordinate axes) and it is made through out orthogonally (varymax, quartimax, equamax, biquartimax) or oblique rotation (quartimin, oblimin, oblimax, etc.). In orthogonal rotation the angle between the factors is direct and there is an assumption about uncorrelated factors. The most common method is varymax at which the number of indicators that have a high factor capacity is minimized. Due to this around the factor are grouped indexes $\tilde{z} = (\tilde{z}_1(X), \tilde{z}_2(X), ..., \tilde{z}_s(X))$, which have stronger influence than others.

After determining the required number of factors and parameters that influence the most, there is an interpretation factors procedure. It depends on the awareness of the researcher and is based on economic explaining the main components F_k and their factor capacities a_{ij}.

General indicator of individual influence on IPE is calculated with the help of the convolution of following compositional scheme:

$$I = IIIE = \sum_{k=1}^{K} \varphi_k F_k , \quad (7)$$

where φ_k are variable coefficients of compositional valuation (to determine the importance of factors in IPE); F_k – factors (main components); *k* – number of factors.

Factors are determined by regression equation:

$$F_{nk} = \sum_{i=1}^{m} a_{ij} \tilde{Z}_{ij}^{c}, \quad (8)$$

where a_{ij} – factor capacities of *i*-index; $\tilde{Z}_{ij}^{c}$ – normalized centered values of the input *i*-index of *j*-economic activity.

Based on formulas 7 and 8, the formula for calculating integral index of IPE is transformed into the form:

$$\text{IPE index} = \sum_{i=1}^{m} [\varphi_1 a_{ij} + \varphi_2 a_{ij} + ... + \varphi_k a_{ij}] \tilde{Z}_{ij}^{c} . \quad (9)$$

The weighting coefficients of w_k indexes are determined by the formula:

$$w_k = \varphi_1 a_{ij} + \varphi_2 a_{ij} + ... + \varphi_k a_{ij} . \quad (10)$$

The weighting coefficients of compositional estimation φ_k are determined through the proportion of explained variance λ_k:

$$\varphi_k = \frac{\lambda_k}{\sum_{k=1}^{K} \lambda_k} . \quad (11)$$

It is important to perform the operation of w_k indexes weights normalization by the formula

$$\tilde{w}_k = \frac{w_k}{\sum_{k=1}^{K} w_k} . \quad (12)$$

Integral index of IPE is calculated on the basis of general indicators influence of individual factors by the formula:

$$IIIE = \sum_{k=1}^{K} I w_k , \quad (13)$$

where w_k is weight, with the help of which generalized index of I phase taken into account when calculating IPE; I is integral indicator of specific direct evaluation of the effectiveness.

5. Conclusions

Thus, the integral index of IPE of Ukraine construction is based on the additive reduction parameters

that characterize such efficiency, using the technique of factor analysis to determine the weight of each. This method of integral index calculating simplifies the analysis of PE, provides the possibility of comparisons dynamic efficiency over time. In addition, the determination of indicators weighting coefficients is a source of additional analysis of interdependencies between factors impact and economic activities efficiency. Significant calculations of estimates IPE of Ukraine at the macro level is the basis for industrial policy's correction and improvement. In terms of European integration processes, quality improvement of the industrial production will promote stability and balance of the entire country's economy; strengthen its competitive position internationally.

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