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Methodology of Optimal Classification of Regional Manufacturing Industry Outlook Development

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Abstract

The article describes the methodology of classification of multidimensional observations, according to which, in theory, development indices of regional industrial production were developed. Conditional regions according to this index are divided into lower, middle and upper classes. In the study, the development tendencies of the regions classified by the development index into stratified groups were also determined. At the end of the article, the theoretical and empirical conclusions obtained as a result of the research are presented.

Keywords: *cluster, set, metric, multivariate tracking, Euclidean distance.*

JEL classification*: C02, C38, F0, L60, O14*

1. Introduction

Classification of multivariate observations is a complex process that directly requires a lot of work and complex calculations. In turn, the issue of classification is carried out using cluster analysis methods. The main purpose of clustering is to form similar groups between objects and to analyze the interactions between them.

The importance of clustering is determined by the nature and economic relevance of the practical problems it can solve. In our study, the issue of classification of multidimensional observations was highlighted, according to which conditional regions were divided into lower, middle and upper classes according to the "level of development of industrial production". It is an important issue to sort these regions according to a certain level of development and to determine the laws in this regard, in which each region is characterized by its own set of indicators. Therefore, they cannot be sorted at the same level. This puts new scientific problems before the issue of classification of objects, and the research focuses on the theoretical aspects of this issue.

The existence of a scientific need for the proposed methodology is that it considers not only the issue of classification of objects (areas), but also the issue of determining the development tendencies of objects into classified groups.

In the study, the parallel clustering method was used in the classification of objects. The essence of parallel operations is that at each step of the algorithm, all indicators are compared and calculated at the same time. Because it is more difficult to make a selection even when dividing into small number of classes. Therefore, the main essence of the development of various parallel classification algorithms is to determine a method that can provide a quick solution to the set goals and reduce the selection options.

2. Literature review

№	Paper title	Abstract summary	Region	Main findings
1	Regional classification of China's regional manufacturing industrial competitiveness Chen Ying-biao 2006	The highest level and steady-going are the types of RMIC from the provincial macroscopic point of view.	China	• The evaluation system of RMIC comprises 11 indexes. • Five types of RMIC are classified from the provincial macroscopic point of view. • Four different types of RMIC are diagnosed based on competitive manufacturing performance and the change of national ranking of provincial RMIC from 1985 to 2003[1]

2	Industry classification considering spatial distribution of manufacturing activities Jungyul Sohn 2014 12 Citations	The analysis identifies five major industry groups in terms of their spatial distribution patterns.	Korea	• Analysis of 162 administrative units in mainland Korea revealed 180 manufacturing sectors with distinct spatial distribution patterns. • Concentration and agglomeration measures were used to examine the spatial distribution and association of individual sectors. • Factor analysis was used to classify the 180 sectors into five major industry groups based on their spatial distribution patterns.[2]
3	Regional industrial growth: evidence from Chinese industries Ting Gao 2004 100 Citations	Local competition is positively related to regional industrial growth.	China	• Local competition is positively related to regional industrial growth. • Provinces with a smaller state sector grow faster. • A better transport system helps growth. • Exports and foreign direct investment have strong positive effects on regional industrial growth[3].
4	The Economic Performance of Regions M. Porter 2003 1849 Citations	The relative wage level in the overregional clusters in a region has a dominant influence on the regional wage level.	United States	• Regional economic performance varies significantly in terms of wages, wage growth, employment growth, and patenting rate. • Traded industries account for only one-third of employment but have higher wages, higher rates of innovation, and influence local wages. • Regional wage differences are largely determined by the performance of the region in the clusters in which it has positions[4].
5	Research on the development approach of regional manufacturing industry in Internet+era* Zhengxuan Jia, Yingying Xiao, Guoqiang Shi, Mei Wang, Tingyu Lin, Z. Shen Automation Science and Engineering (CASE) 2019 1 Citations	Individual manufacturing enterprises should actively conduct technological, business model, and management innovation to accomplish the upgrading of both individual enterprises and regional manufacturing industry.	China	• Internet+ era has a dramatic influence on the development approach of regional manufacturing industry. • Smart Cloud Manufacturing (CMfg) platform is a driving force for the transformation and upgrading of regional manufacturing industry. • Individual manufacturing enterprises should actively conduct technological, business model, and management innovation to accomplish the upgrading of both individual enterprises and regional manufacturing industry[5].
6	An Evaluation of Competitive Industrial Structure and Regional Manufacturing Employment Change J. Drucker 2015 21 Citations	The importance of industrial competitive structure for understanding regional employment change, economic performance and industrial development is suggested.	United States	• Regional industrial structure is associated with employment change in the manufacturing sector. • Economic diversity, industrial specialization and competitive structure are important factors in understanding regional economic performance. • Detailed metrics across broad geographic and industrial ranges can be used to evaluate the relative associations of industrial structure with economic performance[6].
7	Evaluation Study on Comprehensive Developing Ability of Regional Manufacturing Industry in China Based on the Empirical Analysis of Manufacturing Industry in East, Middle and West China Li Lian-shu 2014 5 Citations	The comprehensive development abilities of manufacturing industry in the central and western regions are significantly lower than the eastern region.	China	• The comprehensive development ability of regional manufacturing industry in China has increased from 2003 to 2011, but there is a significant regional difference, with the eastern region having a higher level of development than the central and western regions. • To promote the comprehensive development of regional manufacturing industry, policies should be implemented to encourage industries to relocate, promote coordinated development of regional manufacturing industry, and give overall consideration to the development of the industry[7].

8	Manufacturing industries in the Asian part of Russia: strategies and development opportunities A. Sokolov, V. A. Bazhanov Economics Profession Business 2021 0 Citations	The manufacturing industries are presented in the article by twelve groups.	Russian Federation	• Manufacturing industries in the Asian part of Russia are presented in twelve groups. • Analysis of regional strategies revealed a commonality of intentions and opportunities for the development of processing in the Asian part of Russia. • There is a different level of development of manufacturing industries in the constituent entities of the Federation[8].
9	The evaluation and analysis of competitiveness in regional equipment manufacturing based on factor analysis Rongping Li, Huidong Cui, Zheng Cui	The competitiveness of regional equipment manufacturing is related to economic strength.	China	• An evaluation system was proposed from three key elements and twelve indexes to measure and evaluate the competitiveness of regional equipment manufacturing. • There is a strong correlation between the competitiveness of regional equipment manufacturing and economic strength. • Regions should adjust measures to local conditions and take effective measures to improve competitiveness of equipment manufacturing[9].
10	Research on Comprehensive Evaluation of High-quality Development of China's Regional Manufacturing Industry Wenrui Xiao, Zi-fu Fan BCP Business & Management 2022	The high-quality development of the manufacturing industry in China is unbalanced among regions.	China	• The high-quality development of the manufacturing industry in China is unbalanced among regions, with strength in the east and weakness in the west. • An evaluation index system for the high-quality development of the manufacturing industry was built from four dimensions: high-end, innovative, service-oriented, and green. manufacturing industry in 30 provinces and cities from 2010 to 2020[10].
11	An analysis model of the developable value of shipments of a regional manufacturing industry Hitoshi Sakai 1978 0 Citations	The model is useful for the harmonious development of the manufacturing industry between regional economics and natural environment.	Japan	• The proposed model is composed of seven sectors for analytical purposes: population, industry, labor, government funding of transportation, power resources, environmental pollution, and land use. • The model is useful for the harmonious development of the manufacturing industry between regional economics and natural environment[11].
12	A supply-side interregional model of the u.s. manufacturing industry: 1960-781 Makoto Nobukuni, F. Adams 1990 5 Citations	Regional investment sensitively responds to the marginal productivity of capital in the respective region relative to the national average.	United States	• The regional investment in the U.S. manufacturing industry is sensitive to the marginal productivity of capital in the respective region relative to the national average. • The net interregional migration follows the relative regional wages. • The model can be used to evaluate the economic value of migration and analyze the relationship between the overall national growth[12].
13	An analysis model of the developable value of shipments of a regional manufacturing industry Hitoshi Sakai, Takayoshi Mutoh, Chikashi Watanabe 1977	The model is useful for the harmonious development of the manufacturing industry between regional economics and natural environment.	Japan	• The proposed model is composed of seven sectors for analytical purposes: population, industry, labor, government funding of transportation, power resources, environmental pollution, and land use. • The model is useful for the harmonious development of the manufacturing industry between regional economics and natural environment, as well as for regional planning[13].
14	Regional industrial structure and agglomeration economies: An analysis	A more concentrated regional industrial structure limits	-	• Regional industrial structure concentration has a consistently negative and substantial direct effect on firm productivity. • Agglomeration economies are not a mediating

	of productivity in three manufacturing industries Joshua Drucker, Edward Feser 2012 106 Citations	agglomeration economies and ultimately diminishes the economic performance of firms in that industry.		factor in this effect. • Small firms are particularly affected by regional industrial structure concentration[14].

2. Materials And Methods

When classifying regions according to the level of development of industrial production, we first select 6 economic indicators that are most important, and then create individual indicators from them. These indicators not only characterize the level of development of industrial production in the regions, but they also directly determine the place of economic development of countries in the world in this sector.

3.1 Options for the formation of private indicators representing the level of development of industrial production and the calculation of a generalized indicator

To classify regions according to the level of development of industrial production, we initially introduce the following designations:

q_i^t - t - added value of industrial production of the i region during the period;

gdp_i^t - gross territorial product of the i region during the period;

qe_i^t - t export of industrial products of the i region during the period;

te_i^t - t total export volume of the i region during the period;

wq^t - t the added value of the country's industrial production during the period;

wqe^t - t volume of export of industrial products in the country during the period.

Based on the given initial indicators, we create private indicators as follows:

$z_{i,1}^t = \frac{q_i^t}{gdp_i^t}$ - share of added value of industrial production in gross regional product of the i region during the t period;

$z_{i,2}^t = \frac{qe_i^t}{te_i^t}$ - the share of the export of industrial products in the total export of the i region during the t period;

$z_{i,3}^t = \frac{q_i^t}{wq^t}$ - the i region's share in the country's industrial production during the t period;

$z_{i,4}^t = \frac{qe_i^t}{wqe^t}$ - the i region's share in the export of industrial products of the country during the t period, $i = 1,2,...,n$.

From the initial private indicators presented above, the following vector representing the development of regional industrial production in period t is created:

$$Z_i^t = \left(Z_{i,\rho}^t\right)_{\rho=1,2,3,4.}, \ i = 1,2,...n. \quad (1)$$

(1) from which the following matrix can be created, which represents the development of regional industrial production and is called "Object-property".

$$Z_i^t = \begin{pmatrix} z_{1,1}^t & z_{1,2}^t & z_{1,3}^t & z_{1,4}^t \\ z_{2,1}^t & z_{2,2}^t & z_{2,3}^t & z_{2,4}^t \\ z_{3,1}^t & z_{3,2}^t & z_{3,3}^t & z_{3,4}^t \\ . & . & . & . \\ z_{n,1}^t & z_{n,2}^t & z_{n,3}^t & z_{n,4}^t \end{pmatrix}, \quad (2)$$

thus, $z_{i,\rho}^t$ - indicator ρ representing the development of industrial production in region i in the t period, $\rho = 1,2,3,4$.

If Z_i^t matrix $t = 1,2,.....T$ if viewed in moments, then regional spatial indicators are formed, which include the development of industrial production.

So, in t period i characterizing the development of industrial production in the region $Z_i^t = \left(Z_{i,\rho}^t\right)_{\rho=1,2,3,4.}$, $i = 1,2,..n$ through a vector of periodic spatial indices $O = \{O_i, i = 1,2,...,n\}$ a set of regions $S^u = \left\{S_1^u, S_2^u, S_3^u\right\}$ divided into 3 classes. In this, S_1^u, S_2^u and S_3^u are a set of classes that include a group of regions with "low", "medium" and "high" industrial production, respectively.

Hera S_1^u the regions belonging to the class are characterized by the low impact of industrial production on the development of the country's economy. The regions belonging to the second (S_2^u)and third (S_3^u)classes are characterized by medium and high impact on the economy of the whole country, respectively.

Also,

$$S_i \cap S_j = \varnothing \text{ учун } i \neq j,$$
$$\bigcup_{i=1}^{k} S_i = \{i, i = 1,2,...,n\}, \quad (3)$$

Here k - number of classes.

The integrated indicator of the development of regional industrial production should have an aggregate character and be the sum of vector private indicators for all $i = 1,2,...,n$.

All private indicators are close or similar to each other in terms of their economic essence and construction. Since the possible values for all i and ρ within a single interval, then separate measurements of $0 < Z_{i,\rho}^t < 1$ specific indicators can be used to construct a generalized indicator.

So, when dividing into initial classes, we accept the generalized indicator ( ) representing the development of the country's industrial production i for the period t, and we consider (ω_i^t) the procedure and options for its calculation.

Procedures and options for calculating the generalized indicator representing the development of regional industrial production:

1.All private indicators are of equal value, with the the same shares. In this case, the generalized indicator representing the development of industrial production in the region i for period t will be equal to the following:

$$\omega_i^t = \frac{1}{4}\sum_{i=1}^{4} z_{i,j}^t, \quad i = 1,2,..n. \quad (4)$$

2. The percentage of importance for all $Z_{i,j}^t$ private indicators has different values λ_i, then the generalized indicator will be equal to:

$$\omega_i^t = \sum_{j=1}^{4} \lambda_i z_{i,j}^t, \quad i = 1,2,...n. \tag{5}$$

3.If the share of importance of private indicators characterizing the development of industrial production of the region is the share of λ_i, importance of private indicators $1-\lambda_i$ characterizing the place of this region in the country in this sector, then the cumulative indicator is calculated as follows:

$$\omega_i^t = \lambda_i \frac{1}{2}\left(z_{i,1}^t + z_{i,2}^t\right) + \left(1-\lambda_i\right)\frac{1}{2}\left(z_{i,3}^t + z_{i,4}^t\right), \quad i = 1,2,...n. \tag{6}$$

here the selection of λ_i is made using the expert evaluation method.

3.2 Methods of dividing regions into classes according to the level of development of industrial production and criteria for choosing appropriate metrics

Given $O = \{O_i, i = 1,2,...,n\}$ regions there are many ways to classify a set of regions $O = \{O_i, i = 1,2,...,n\}$, and we introduce size as a criterion to choose the best one. size i, and regions j are determined by finding Z_i^t and Z_j^t the distance $d\left(Z_i^t, Z_j^t\right)$ between vector indicators characterizing the development of industrial production $O_i \in O - d\left(O_i, O_j\right)$.

There are various measures that characterize the distance between features, including the Euclidean distance, the Mahalonobis metric, the Hamming distance, and the Canberra metric.

As of studing $Z_{i,\rho}^t$, $i = 1,2,...,n$ since the indicator of the vectors is the same according to its economic content and calculation method, it is appropriate to use the simple Euclidean distance when measuring the specified distance:

$$d_e\left(Z_i^t, Z_j^t\right) = \sqrt{\sum_{\rho=1}^{4}\left(z_{i,\rho}^t - z_{j,\rho}^t\right)^2} \tag{7}$$

If the development of industrial production is carried out with specific goals in mind, and its location is formed by an expert, then it is appropriate to use the weighted Euclidean distance:

$$d_{be}\left(Z_i^t, Z_j^t\right) = \sqrt{\sum_{\rho=1}^{4}\lambda_\rho\left(z_{i,\rho}^t - z_{j,\rho}^t\right)^2} \tag{8}$$

here $0 \le \lambda_\rho \le 1$, $\rho = 1,2,3,4.$

After choosing a suitable metric, we perform clustering using a parallel clustering operation. The essence of this cluster operation is that it compares and calculates all indicators simultaneously at each step of the algorithm.

We use an algorithm that sequentially performs "transfer of objects from class to class" when dividing regions into classes according to the level of development of industrial production. Because, particular region $z_{i,\rho}^t$ a development indicator can move from one development state to another development state after a certain period of time.

Research shows that cluster analysis algorithms typically implement one of two common ideas when classifying a set into classes:

1. Optimization of the classification using the previously selected classification quality function.

2. Creating clusters according to the principle of determining the most concentrated areas of the indicators in the 4-dimensional space of the considered indicators.

So, period t set of regions $O = \{O_i, i = 1,2,...,n\}$ $S^u = \{S_1^u, S_2^u, S_3^u\}$ in dividing into three classes generalized indicator built above $\{\omega_i^t, i = 1,2,...,n\}$ initial separation S^0 can be carried out in 2 ways (collective indicators in cases of symmetric and asymmetric distribution).

3.3 Algorithm for dividing regions into initial classes according to the level of development of industrial production when collective indicators are symmetrically distributed

First, let's break down the generalized indicators:

$$\omega_{i_1}^t \le \omega_{i_2}^t \le \omega_{i_3}^t \le \ldots \le \omega_{i_n}^t . \tag{9}$$

After that, we divide the range of all possible changes of cumulative indicators into 3 intervals:

$$\left[\omega_{i_1}^t, \omega_{i_1}^t + \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3}\right), \left[\omega_{i_1}^t + \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3}, \omega_{i_1}^t + \frac{2}{3}\left(\omega_{i_n}^t - \omega_{i_1}^t\right)\right), \left[\omega_{i_1}^t + \frac{2}{3}\left(\omega_{i_n}^t - \omega_{i_1}^t\right), \omega_{i_n}^t\right] \tag{10}$$

If, $i_l = \max_i \arg \omega_i^t$ then:

$$\omega_{i_l}^t \in \left[\omega_{i_1}^t, \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3} + \omega_{i_1}^t\right), \quad \omega_{i_{l+1}}^t \notin \left[\omega_{i_1}^t, \omega_{i_1}^t + \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3}\right) \tag{11}$$

Here, it can be found as $S_1^0 = \{i_1, i_2, ..., i_l\}$.

If, $i_q = \max_i \arg \omega_i^t$ so:

$$\omega_{i_q}^t \in \left[\omega_{i_1}^t + \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3}, \omega_{i_1}^t + \frac{2}{3}\left(\omega_{i_n}^t - \omega_{i_1}^t\right)\right) \text{ so } \omega_{i_{q+1}}^t \notin \left[\omega_{i_1}^t + \frac{\omega_{i_n}^t - \omega_{i_1}^t}{3}, \omega_{i_1}^t + \frac{2}{3}\left(\omega_{i_n}^t - \omega_{i_1}^t\right)\right) \tag{12}$$

Here we can be demonstrated $S_2^0 = \{i_{l+1}, ..., i_q\}$. From above equation can be simple S_3^0 classification can be deternined: $S_3^0 = \{i_{q+1}, ..., i_n\}$.

3.4 Algorithm for dividing regions into initial classes according to the level of development of industrial production when collective indicators are symmetrically distributed

This algorithm is based on mode detection in discrete series, $\{\omega_i^t, i = 1,2,...,n\} - \omega_{\text{mod}}^t$. Then, i_l can be found from follwing equation:

$$\omega_{i_l}^t \le \omega_{\text{mod}}^t, \text{ аммо } \omega_{i_{l+1}}^t > \omega_{\text{mod}}^t \tag{13}$$

Then, it is come to $S_1^0 = \{i_1, i_2, ..., i_l\}$ equation, with i_q following conditions can be:

$$\omega_{i_q}^t \le \overline{\omega}^t, \text{ but } \omega_{i_{q+1}}^t > \overline{\omega}^t \tag{14}$$

Here avarage value is $\overline{\omega}^t$, ω_i^t, $i = 1,2,...,n$.

As known, ω_{mod}^t - is the most frequently occurring character value in the set in the given variant $\{\omega_i^t, i = 1,2,...,n\}$ represents the most frequent variant. Also, if we consider a discrete series with equal intervals, then ω_{mod}^t in the internal modal interval is defined by the following:

$$\omega^t_{\text{mod}} = \omega^t_{\text{modmin}} + k\frac{\omega^t_{\text{mod}} - \omega^t_{\text{mod}-1}}{\left(\omega^t_{\text{mod}} - \omega^t_{\text{mod}-1}\right) + \left(\omega^t_{\text{mod}} - \omega^t_{\text{mod}+1}\right)}, \quad (15)$$

then: ω^t_{modmin} - the lower limit of the modal interval, k - interval size, ω^t_{mod} - frequency of the modal interval, $\omega^t_{\text{mod}-1}$ - frequency of the modal interval that belongs to the previous modal interval, $\omega^t_{\text{mod}+1}$ - modal interval frequency that belongs to the next modal interval.

So, accordingly $S_2^0 = \{i_{p+1}, i_{p+2}, \ldots, i_q\}$ and $S_3^0 = \{i_{q+1}, i_{q+2}, \ldots, i_n\}$. For symmetric distribution types $f(\omega^t)$ the empirical density of the distribution will have the following form (Fig. 1).

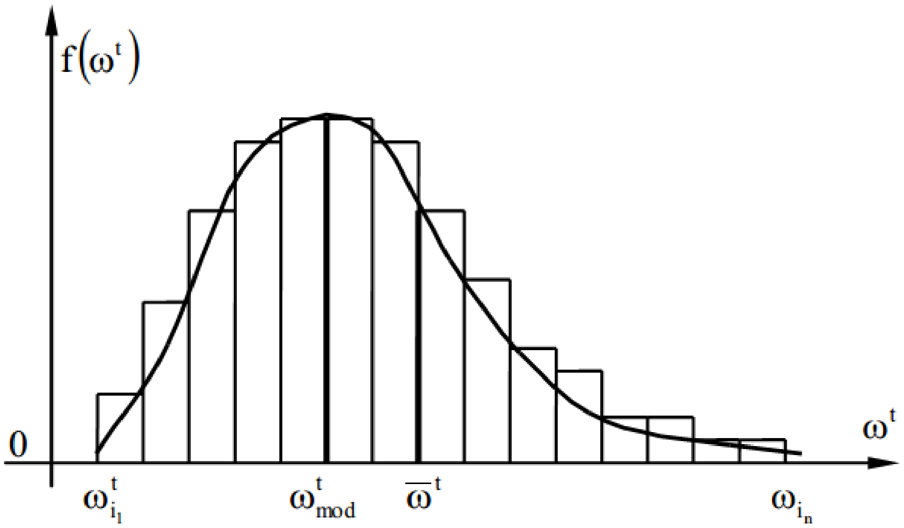

Figure 1. An approximate theoretical view of the empirical distribution of the cumulative indicator of industrial production development

As can be seen from the empirical distribution function, S_1^0 - cumulative indicators $\left[\omega^t_{i_1}, \omega^t_{\text{mod}}\right)$ area numbers located in the interval, S_2^0 - pooled indicator $\left[\omega^t_{\text{mod}}, \varpi^t\right)$ and the numbers of the regions located in the interval S_3^0 - and class are aggregate indicators $\left[\varpi^t, \omega^t_{i_n}\right]$ represents the numbers of regions located in the interval.

3.5 Completion of work on quality criterion and algorithm for dividing areas into classes

S^0 after the initial separation option is selected, $Q(S^0)$ after the initial separation option is selected:

$$Q(S) = \sum_{k=1}^{3} \sum_{i \in S_k^0} d^2\left(Z_i^t, \overline{Z}_k^t\right), \quad (16)$$

бунда, $d^2\left(Z_i^t, \overline{Z}_k^t\right)$ - after the initial separation option is selected, S_k^0 - k division into classes, the number of classes is fixed by $(k = 1,2,3)$.

$\overline{Z}_k^t$ - k for avarage vectors: $\overline{Z}_k^t = \left(\overline{z}_{k,1}^t, \overline{z}_{k,2}^t, \overline{z}_{k,3}^t, \overline{z}_{k,4}^t\right)$,

$$\overline{z}_{k,\rho}^t = \frac{\sum_{i \in S_k} z_{i,\rho}^t}{\dim S_k^0}, \quad \rho = 1,2,3,4., \quad k = 1,2,3. \quad (17)$$

$z_{i,l}^t$ - Z_i^t vector components, $\dim S_k^0$ - S_k^0 measures of the set.

$Q(S)$ inner summation in respectively S_1^0, S_2^0 or S_3^0 suitable for classes i taken by area points. After that, each Z_i^t the points move through all the clusters in turn and $Q(S)$ remains at the best (minimum) value of the function. When, Z_i^t the algorithm is complete if the migration does not lead to an improvement in the quality of grouping (when the sum of intraclass variance values is minimized).

The following condition can be obtained as a condition for the completion of the algorithm: if $Q(S^m)$ and $Q(S^{m+1})$, m and $m+1$ if the value of functions in successive steps, $S^m = \{S_1^m, S_2^m, S_3^m\}$, $S^{m+1} = \{S_1^{m+1}, S_2^{m+1}, S_3^{m+1}\}$ classes obtained in these steps. If small $\varepsilon > 0$ (ε calculation accuracy) If the following condition is met for , then the classification process stops:

$$\left|Q(S^m) - Q(S^{m+1})\right| < \varepsilon \tag{18}$$

As a result of the conducted classification S^{m+1} we get the separation and it S^t we define through. It should be noted, $Q(S)$ the sequence is monotonically decreasing: $Q(S^0) < Q(S^1) < \ldots < Q(S^{m+1})$ the built-in algorithm is applied multiple times to exactly the same set, $\{Z_i^t, i = 1,2,\ldots,n\}$ and S^0 after various initial allocations, the best variant of $Q(S)$ is finally generated.

3.6 Formation of stable localization zones according to the level of development of industrial production

According to the above algorithm, each t for period $i = 1,2,\ldots,n$ 3 sets of regions according to the level of development of industrial production $S^t = \{S_1^t, S_2^t, S_3^t\}$ can be divided into classes.

If the level and length of development of industrial production in the cross-section of regions N lengh (N - retrospective length) if we have the statistics of monitoring the economy of the regions ($t_0 - N + 1,\ t_0 - N + 2, \ldots, t_0$ period, here t_0 basis year) then the proposed algorithm is each from the retrospective period t and $O = \{O_i, i = 1,2,\ldots,n\}$ allows you to build a family of classifications $\{S^t, t \in [t_0 - N + 1, t_0]\}$.

Using the theoretical operations of the calculation of sets, it is possible to form the following:

$$S_k = \bigcap_{t=t_0-N+1}^{t_0} S_k^t,\quad k = 1,2,3 \tag{19}$$

here, S_1 - a set of regions characterized by stable low rates of industrial production development and maintaining such dynamics throughout the retrospective period.

S_2, S_3 - respectively, a set of regions characterized by medium and high development of industrial production and maintaining such dynamics during the analyzed period. Then S_k ($k = 1,2,3$), худудлар кесимида саноат ишлаб чиқариши турлича ривожланишининг барқарор зоналари деб аташ мумкин.

It should be noted, $\tilde{S} = \left\{ i, i \in S / \bigcup_{k=1}^{3} S_k \right\}$ the development of industrial production in a set of regions has changing and unstable dynamics. Therefore, the collection can be called an area of unstable development of industrial production in the region. These regions "move" from class to class during the retrospective period.. Each i moving region $k(i^t)=\arg S_k^t$, $i^t \in S_k^t$ can be determined from the condition. Here,

$$K_i^t = \{k(i^t), [t \in t_0 - N + 1, t_0]\}. \quad (20)$$

K_i - during the retrospective period of the ordered collection i determines the sequence of "migrations" of the territory. Note that if all $[t \in t_0 - N + 1, t_0]$ region will be

$$K_i^t = \{k(i) = const = k\} \quad (21)$$

then, elements of the sequence store a constant value, that is, (19) then $i \in S_k$ it follows that.

3.7 Algorithm for determining the propensity of regions to classes classified by the level of development of industrial production

During the retrospective period i we use relation (20) to analyze the movements of inter-class "migrations" of the territory. Set $K_i^t(l)$ through as follows::

$$K_i^t(l) = \{k(i^t) = l, t \in [t_0 - N + 1, t_0]\}, \ l = 1,2,3. \quad (22)$$

So region i moving class number l region industry manufactoring i type l serves as a characteristic that expresses the tendency of the species to develop:

$$N_l(i) = \dim K_i^t(l), \ l = 1,2,3, \ i = 1,2,\ldots,n. \quad (23)$$

i region l average time spent in class i area of industrial production l serves as a characteristic that expresses the tendency of the species to develop:

$$T_l(i) = \frac{N_l(i)}{N}, \ l = 1,2,3, \ i = 1,2,\ldots,n. \quad (24)$$

It should be noted,

$$\sum_{l=1}^{3} T_l(i) = \frac{1}{N} \sum_{l=1}^{3} N_t(i) = 1 \quad (25)$$

A set of regions one or the other $G \subset S$ it is very important to monitor the progress of the class and the development of their industrial production. For example, G - industrial production is a set of steadily developing regions. For these regions, group membership is taken into account by entering separate shares. Then, during the retrospective period, the set "moves" between classes can be observed using the following theoretical set operations:

$$G_1 = G \cap S_1, \ G_2 = G \cap S_2, \ G_3 = G \cap S_3,$$

here, G_1, G_2, G_3 - the development stability of industrial production is maintained G subsets of a set:

$$G_4 = G \setminus \bigcup_{k=1}^{3} G_k = G \setminus \bigcup_{k=1}^{3} (G \cap S_k)$$

Unsustainable development of industrial production is observed in collections. $i \in G_4$ class-to-class migrations in individual regions can be observed according to relations similar to (20) $i \in G_4$ the dynamics and character of regional migrations can be analyzed according to relations (22) - (25).

4. Implementation of the methodology

In order to test the proposed methodology, conditional economic indicators for conditional areas presented in Annexes 1-4 were used. The obtained empirical results are recorded in Table 1. According to the analysis, of time T_1 - T_4 to the first group during which industrial production was developed at a low level (S_1^u) №13 if the conditional area is entered (№13 region T_1 - T_4 the average value of the development index in years 8.63), T_1 to this group in 13.41 and T_3 period 7.25 with values entered area №1.

T_1 - T_4 to the second group, where industrial production is moderately developed (S_2^u) №8 and №3 T_1 , T_2 period entered area №12. Including, №12 this index in the area T_1 year 23.17 value, T_2 and in 21.26 constituted the value.

Table 1. Indexes of development of industrial production in conditional regions (in percent)

Conditional Regions	Period			
	(T_1)	(T_2)	(T_3)	(T_4)
№1	13,41	26,83	7,25	27,25
№2	26,83	25,41	26,35	25,90
№3	22,27	21,90	21,24	21,78
№4	29,52	29,88	30,36	30,99
№5	28,91	28,66	27,94	26,83
№6	27,16	24,80	26,25	26,02
№7	32,68	26,97	31,13	31,51
№8	21,13	21,38	21,75	22,23
№9	27,32	26,68	27,53	27,76
№10	28,38	27,10	30,22	27,25
№11	29,37	27,00	28,08	28,24
№12	23,17	21,26	25,74	24,54
№13	8,54	8,33	8,85	8,78
№14	26,50	26,63	27,84	27,67
№15	25,07	24,45	25,95	26,63
№16	28,95	26,43	28,29	25,54
№17	28,67	29,60	28,66	29,03
№18	26,01	24,36	24,65	24,36
№19	27,50	26,61	27,03	26,65
№20	28,54	27,28	28,09	27,79

Source: authoring

The analysis shows that most conditional regions belong to the third group with highly developed industrial production belongs to (S_3^u).

According to the level of development of industrial production, the tendency of conditional regions to develop into stratified groups is noted in Table 2 below..

Table 2. Development propensities of conditional regions into stratified groups according to the level of development of industrial production (in the coefficient)

Conditional Regions	Groups		
	S_1^u - group	S_2^u - group	S_3^u - group
№1	0.5	0	0.5
№2	0	0	1.0
№3	0	1.0	0
№4	0	0	1.0
№5	0	0	1.0
№6	0	0	1.0
№7	0	0	1.0
№8	0	1.0	0
№9	0	0	1.0
№10	0	0	1.0
№11	0	0	1.0
№12	0	0.5	0.5
№13	1.0	0	0
№14	0	0	1.0
№15	0	0	1.0
№16	0	0	1.0
№17	0	0	1.0
№18	0	0	1.0
№19	0	0	1.0
№20	0	0	1.0

Source: authoring

According to the analysis, T_1 - T_4 during period of №13 area industrial production tends to develop in the first group with a 100 percent probability, and area No. 1 industrial production has a 50 percent probability. №3 and №8 indicators of development of industrial production of regions tend to develop in the second group with 100 percent probability and the industry of region No. 12 with 50 percent probability. Industrial production development indicators of all other conditional regions tend to develop in the third group with 100 percent probability.

Appendix 1.

Indicators of conditional economic development by conditional regions in the T_1 period of time

Conditional regions	Share of industrial production in gross regional product (percentage)	The share of the region in the country's industrial production (percentage)	Share of exports of industrial products in total exports (percentage)	Share of the region in the export of industrial products of the country (percentage)
№1	18,44	0,73	34,45	0,02
№2	15,28	0,75	87,66	3,64
№3	13,99	0,05	74,89	0,13
№4	24,22	0,42	92,44	0,99
№5	21,95	0,56	92,32	0,80
№6	11,58	3,19	89,07	4,80
№7	21,31	7,69	90,33	11,39

№8	7,90	0,25	76,18	0,18
№9	19,58	0,28	88,69	0,74
№10	20,02	0,54	91,84	1,12
№11	16,82	3,84	92,47	4,34
№12	12,69	1,05	75,52	3,40
№13	8,77	0,34	24,72	0,34
№14	17,84	0,72	86,37	1,06
№15	12,48	0,30	87,06	0,42
№16	21,19	0,29	93,99	0,34
№17	22,93	0,15	91,16	0,43
№18	13,87	2,05	86,04	2,07
№19	17,87	0,87	89,76	1,49
№20	18,74	0,91	92,95	1,55

Appendix 2.

Indicators of conditional economic development by conditional regions in the T_2 period of time

Conditional regions	Share of industrial production in gross regional product (percentage)	The share of the region in the country's industrial production (percentage)	Share of exports of industrial products in total exports (percentage)	Share of the region in the export of industrial products of the country (percentage)
№1	19,00	0,01	88,30	0,01
№2	14,00	0,01	87,60	0,04
№3	15,00	0,00	72,60	0,00
№4	28,00	0,01	91,50	0,01
№5	21,00	0,01	93,60	0,01
№6	11,00	0,03	88,10	0,05
№7	20,00	0,07	87,70	0,11
№8	7,00	0,00	78,50	0,00
№9	21,00	0,00	85,70	0,01
№10	16,00	0,00	92,40	0,01
№11	16,00	0,04	91,90	0,04
№12	12,00	0,01	73,00	0,03
№13	8,00	0,00	25,30	0,00
№14	19,00	0,01	87,50	0,01
№15	12,00	0,00	85,80	0,00
№16	15,00	0,00	90,70	0,00
№17	25,00	0,00	93,40	0,01
№18	12,00	0,02	85,40	0,02
№19	17,00	0,01	89,40	0,01
№20	19,00	0,01	90,10	0,02

Appendix 3.

Indicators of conditional economic development by conditional regions in the T_3 period of time

Conditional regions	Share of industrial production in gross regional product (percentage)	The share of the region in the country's industrial production (percentage)	Share of exports of industrial products in total exports (percentage)	Share of the region in the export of industrial products of the country (percentage)
№1	18,43	0,71	9,83	0,02
№2	14,16	0,66	87,25	3,34
№3	14,98	0,06	69,76	0,16
№4	26,58	0,46	93,17	1,21
№5	20,52	0,50	90,15	0,57
№6	11,01	2,84	87,11	4,05
№7	19,23	6,70	88,14	10,45
№8	8,14	0,21	78,45	0,20
№9	21,14	0,27	87,92	0,78
№10	25,44	0,60	93,89	0,95
№11	14,66	2,94	90,92	3,81
№12	12,26	0,97	86,08	3,65
№13	8,67	0,32	26,06	0,33
№14	21,59	0,99	87,44	1,32
№15	11,42	0,25	91,70	0,43
№16	22,54	0,30	89,86	0,45
№17	20,55	0,15	93,35	0,59
№18	11,66	1,59	83,37	1,99
№19	16,97	0,80	89,01	1,33
№20	18,56	0,89	91,18	1,71

Appendix 4

Indicators of conditional economic development by conditional regions in the T_4 period of time

Conditional regions	Share of industrial production in gross regional product (percentage)	The share of the region in the country's industrial production (percentage)	Share of exports of industrial products in total exports (percentage)	Share of the region in the export of industrial products of the country (percentage)
№1	19,00	0,72	88,10	1,16
№2	12,00	0,56	87,50	3,53
№3	16,00	0,06	70,90	0,17
№4	29,00	0,48	93,30	1,19
№5	16,00	0,37	90,40	0,53
№6	10,00	2,54	87,60	3,92
№7	21,00	7,02	87,90	10,11
№8	8,00	0,17	80,50	0,23

№9	21,00	0,26	89,00	0,76
№10	15,00	0,35	92,80	0,84
№11	15,00	2,81	91,50	3,63
№12	12,00	0,89	81,60	3,68
№13	8,00	0,29	26,50	0,32
№14	21,00	0,98	87,30	1,40
№15	13,00	0,27	92,80	0,46
№16	15,00	0,21	86,50	0,45
№17	21,00	0,19	94,30	0,63
№18	12,00	1,54	81,90	2,01
№19	16,00	0,73	88,70	1,17
№20	18,00	0,91	90,60	1,64

4. Conclusion

1. The empirical results obtained during the research provide the opportunity to develop a specific strategy for the long-term economic development of industrial production in regions with different development trends, to identify regions with active and slow development of the processing industry, and to clarify its reasons.

2. On the basis of the research, development indexes (RI) of industrial production of conditional regions were developed, according to which this index $0 \leq RI \leq 100$ varies within the range. Which means that the index value approaching 100 indicates the stable development of the industrial production of the region.

3. According to the obtained empirical results, the industrial production of region №13 has a 100 percent probability, and the industry of region №1 has a lower level with a 50 percent probability, the industries of regions №3 and №8 have a 100 percent probability, and the industry of region №13 has a 50 percent probability. to develop at a medium level, the industrial production of all other conditional regions tends to develop at a high level with 100 percent probability.

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