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METHODS OF STRUCTURAL CHANGES ANALYSIS IN THE NATIONAL ECONOMY

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Abstract. *One of the basic requirements for the economic growth and development are constant structural changes of the economic system, enabling the latter to adequately respond to its environment changes. The main task of the macroeconomic analysis is to define and analyze structural changes. The article deals with method of economy's structural changes analysis. The method envisions two-dimensional analysis – the structural changes process analysis and the structural changes analysis. The first dimension deals with characteristics of the changes process itself, whereas the second one allows to answer the question of how exactly the studied structure changes. The structural changes process analysis is based upon defining and further analysis of the three markers: changes intensity; changes speed; changes sustainability. The second analysis dimension envisions decomposition of structural changes to the level of structural elements, as well as the corresponding analysis of the change measures (element(s) size changes) and the structure shape changes (proportion changes between the elements and the aggregate).*
Keywords: *national economy, economy structure, structural changes, structural changes analysis, methods of structural changes analysis.*

Problem Statement. Sustainable economic growth and stable development of the country's economy depend on the state and efficiency of its structure. The structure of the economy evolves and changes in the process of its development, adapting to objective factors, it constantly adapts to external conditions and is subject to regulatory influence of the state. Therefore, identification and assessment of structural changes and development that

create conditions for sustainable economic growth become the main tasks of macroeconomic structural analysis.

Analysis of Recent Studies and Publications. The problem of measuring and analyzing of structural changes has not arisen in recent years. Economists have already had some experience with assessment of the effectiveness of structural changes in the economy. In particular, a significant contribution to the development of the indicators and indices system for the analysis of structural changes was made by foreign researchers - M. Valesiak, E. Vasylevska, K. Hatiev, L. Kazynets, O. Krasylnykov, K. Kukula, M. Markovska, A. Mrozinska, V. Riabtsev, A. Salai, O. Sukhariev, M. Tsyrek. Existing indicators are informative and easy to calculate, but there are some difficulties in interpreting them.

There are several interesting works in the domestic achievements, which offer the indicator system for the analysis of structural changes and development in application to a particular problem at the macro level, including works of T. Trubnik, T. Romanova, N. Skirka, V. Druzhynina, O. Kolomytseva.

Previous researches have covered only some aspects of change. The current study aims to present a methodology for analyzing the structural changes in the national economy, which covers a wider area: analysis of the state and dynamics of changes in the structure of the national economy. The methodology covers the minimum required set of indicators that ensures the achievement of these analysis tasks; appropriate level of comprehensiveness, completeness of analysis; simplicity and rapidity of obtaining results.

Presentation of the Basic Material. Today, there are a number of indicators used to assess structural changes and development. In particular, the United Nations Economic Commission for Europe has proposed an index of the intensity of structural change, which is the weighted mean of annual changes in the share of growing industries in production, employment and fixed capital. The index can be calculated for each factor of production separately, as well as it is possible to calculate the integrated indicator for the whole set of factors. However, it does not quite correctly describe minor structural changes. For taking into account the possible cumulative effect of such changes, it is necessary to recalculate it, taking into account the ratio of the share of fast-growing industries at the beginning and at the end of each period [1, p.98].

Forty years ago L. Kazynets [2] expressed the meaning of all calculations in one sentence: absolute and relative increases in the share of various elements of the economic system, linear and quadratic coefficients of absolute and relative structural changes are used in statistics and planning to quantify structural development.

O Krasylnykov [3] divides the indicators into the following groups by the content: the mass of structural changes; rapidity of structural changes; intensity; inertia; potential of structural changes; index of structural changes.

T. Kovaliova [4] provides a more detailed system of statistical indicators for qualitative analysis of changes: indicators of dynamics and variations of structural changes, indicators of uneven distribution and indicators of concentration, analysis of structural differences, analysis of the intensity of structural changes.

This system is often supplemented by a number of specific indicators that determine the nature of the problem under the study. O. Sukhariev writes about this: “If there is a conscious

transformation of the economic system, which becomes a target for society and government, then structural changes are not so much genetic as teleological, and a special economic policy is needed to manage such structural changes. In this regard, it is very important to assess the effectiveness of structural changes, as well as the relationship of changes with macroeconomic processes in the economy. It should be noted at once that the quality and efficiency of the economic structure or the structure of any economic organization is not the same as the quality or efficiency of structural changes. In addition, emphasis should be placed on the effectiveness of structural change management and the feasibility of applying certain economic policy measures. Then the effectiveness of structural changes can be defined as a change in the proportions of the economic system (with such rapidity) that allows to systematically increase the efficiency of the economy as a whole". [5]. The scientist complements the above indicators with a system of 7 groups of indicators: use of capital; use of labor resources; indicators that characterize the efficiency of production; indicators that characterize the technical support of the economy; number of staff by sectors and activities; financial results; investments.

Analyzing the structural dynamics, at the best case, most authors are limited to calculating the share of structural elements and analysis of their dynamics.

Developing our own methodology for structural changes analyzing, we have taken as a basis an approach that is embodied in the works of modern researchers and considers economic development as multidimensional and multilevel. The main thesis of this approach is formulated by J. Khomenko: "the category of" economic development "should be considered in three aspects: quantitative, structural and qualitative… Quantitative aspect means extensive development of productive forces, and structural and qualitative - intensive. At the same time, economic growth is only a component of development, in which quantitative and qualitative changes are synthesized" [6, p. 23–24].

There are two approaches to understanding the concept of structure in statistical analysis of structural changes [7, p. 26]. In the first approach, the structure is considered as a configuration of points in a multidimensional space formed by the characteristics of points. The configuration of points is their placement/grouping or ordering, i.e. a certain hierarchy formed by points. The methods of clustering, linear ordering of multidimensional objects, and so on are commonly used to determine configuration. The second approach assumes that a structure is a collection of one-dimensional objects that form some integrity. Each object represents a separate structural characteristic of the system, while taken together they describe the structure as a whole. Within the structure, these characteristics are interrelated: the change of some causes the change of the others, and this effect is different for different sets of characteristics.

Our proposed method of structural change analysis is based on the second approach, and it can be called by the content – *two-level quantitative analysis of the local structural matrix*. The method was based on the following provisions:

- the need to take into account the tasks and features of the structural-temporal approach to the analysis of structural changes in the process of economic development;
- decomposition of economic development should be based on the selection and study of local structures. To study each local structure, it is necessary to form an

appropriate structural matrix, which should take into account the structural and dynamic features of local structures;

– analysis should characterize structural changes in two perspectives: on the one hand, to study how changes occur and whether they occur; on the other hand, to investigate changes in the structure itself. To complete this, the minimum required set of indicators should be determined, which provide: achievement of the specified tasks of the analysis; achievement of the appropriate level of comprehensiveness and completeness of the analysis; simplicity of calculations and rapidity of obtaining results.

The economic system, being multidimensional and multilevel, is a set of aggregate subsystems, each of which describes a separate logical entity and has its own structure. Therefore, the study of the system in general can be based on the study of these local aggregate structures, and the study of the dynamics of structural changes in the system - on the analysis of structural changes in local structures.

A structural matrix is constructed to study each such local structure. The *structural matrix* acts as a kind of integration skeleton, which identifies structural changes within the system unit and integrates them. The matrix allows identifying those elements that were formed for the need of joint interaction, focuses on the integrity of the structure, emphasizes the fundamental impossibility of changing one element without changing the other elements of the system.

At the same time, the structural matrix lays down a general primary model of analysis. This is a kind of analysis scheme, built in some coordinate system. The structural matrix can be multidimensional, but we consider the simplest version – a two-dimensional table. The first axis (the first dimension – the rows of the table) is formed by elements of the structure. The analysis will study the properties of these elements, as well as the correlation/relationship between them. The second axis (the second dimension – the columns of the table) is for fixing structural dynamics. It can be temporal dynamics, spatial dynamics, or of any other nature. Regarding temporal dynamics, the values of the structural elements of the object under the study, taken in different time periods, are fixed on the axis. Spatial dynamics are used when we want to study different territorial objects – the values of the corresponding structural elements of different objects (territories, regions) are laid down along this axis. In the case when the purpose of the analysis is to study the set of objects that differ in features, and we want to find out the structural differences of the whole set of objects, the values of corresponding structural elements of the studied objects are laid down. The structural matrix constructed in this way is easily formalized.

Indicators of analysis of structural changes. We assume that the study deals with n objects or time periods ($j = 1,..., n$). Each object has the same structure, which is formed by m components ($i = 1, ..., m$). Then the formalized record of object j can be written as a vector

$$U_j = \begin{bmatrix} u_{1j} \\ u_{2j} \\ \vdots \\ u_{mj} \end{bmatrix},$$

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where u_{ij} is the value of the *i*-th element of the structure of the object *j*. Without diminishing the generality, we believe that the value of the element of the structure is numerical, cost or quantitative, which is characteristic of economic systems. This allows us to calculate different indicators based on the elements, compare them with each other, calculate the values of generalized indicators that characterize the set of objects on a particular side.

For the formalized record of the structural matrix, we use the dimensional matrix $m \times n$

$$U = \begin{bmatrix} u_{11} & u_{12} & \dots & u_{1n} \\ u_{21} & u_{22} & \dots & u_{2n} \\ \vdots & \vdots & & \vdots \\ u_{m1} & u_{m2} & \dots & u_{mn} \end{bmatrix}.$$

The row describes the dynamics of the *i* component of the structure within the whole set of objects (first axis), and the matrix column corresponds to a single object (second axis).

In addition to the vector U_k and the matrix *U*, which are composed of absolute values of the *elements,* their derivatives are used

Vector

$$W_k = \begin{bmatrix} w_{1k} \\ w_{2k} \\ \vdots \\ w_{mk} \end{bmatrix},$$

and *matrix*

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1n} \\ w_{21} & w_{22} & \dots & w_{2n} \\ \vdots & \vdots & & \vdots \\ w_{m1} & w_{m2} & \dots & w_{mn} \end{bmatrix},$$

where w_{ik} – is the part (share) of the *i*-th element in the structure as a whole for the *k*-th object. The value of w_{ik} is calculated as

$$w_{ik} = \frac{u_{ik}}{\sum_{i=1}^{m} u_{ik}}.$$

It follows that $0 \le w_{ik} \le 1$, and $\sum_{i=1}^{m} w_{ik} = 1$.

To compare two objects within a structural matrix, the indicators that characterize the degree of their similarity or difference are used. Investigating the structural changes, first of all, we focus on the differences between the vectors. The more the structure of one object differs from the structure of another, the greater the value of the indicator, which is calculated on the basis of the structural elements of the corresponding vectors, should be. And vice versa, if the objects differ little from each other (they are similar or close), the calculated values of the indicators differ little. This principle is the basis of indicators that measure the distance (difference) between objects (vectors) [8].

Mostly, methods of analyzing structural changes are reduced to three basic principles: 1) it is necessary to compare two structures – the previous and next to measure structural changes; 2) if the structures of objects (or the same object, but in different periods) differ, it is concluded that changes have taken place; 3) the greater the difference in indicators, the more intense the changes were.

Developing a *method of analysis* of structural changes, we focused on two levels of analysis: 1) analysis of the process of structural changes; 2) analysis of changes in structure. The first concerns the characteristics of the process of changes, the second allows us to answer the question of how the structure under the study changes.

At the first level – analysis of the process of structural changes – three types of assessments are calculated and analyzed: intensity (depth) of change, rate of change, stability (monotony) of change.

1) The intensity indicator describes how strong (deep) the changes were.

The two vectors *k* and *l*, which describe the state of objects at different points in time in *m*-dimensional space (the structure consists of *m* elements), form an angle *θ*. The vectors can be determined by the values of the coordinates *sin (θ)* or *cos (θ)*. Regarding the ease of interpretation, *cos (θ)* is usually used. This indicator has all the necessary properties to be an adequate measure for assessment of the intensity of structural changes. It gives a clear interpretation of the calculated values: a large difference between the vectors *(cos (θ)* approaches *0)* indicates significant changes, while a small angle of *θ* (function of *cos (θ)* close to 1) is a sign of minor changes. In special cases, when the compared structures are identical, the angle *θ* between the vectors is 0°, and cos *(θ)* = 1. The maximum angle *θ* that vectors can form (the most cardinal structural changes) is 90°, then *cos (θ)* = 0.

The cosine between the two vectors W_k and W_l is calculated by the formula

$$\cos(\theta) = \frac{\sum_{i=1}^{m} w_{ik} w_{il}}{\sqrt{\sum_{i=1}^{m} (w_{ik})^2} \sqrt{\sum_{i=1}^{m} (w_{il})^2}}$$

This method of estimating the intensity of changes is called the method of angle *θ* or the method of $\cos(\theta)$. In the literature, the indicator $\cos(\theta)$ is also called the indicator Q Moore, by author name [9].

However, as noted in [10, p. 80], as a rule, the changes are insignificant (up to 10°) in studies of structural changes. Therefore, for a clearer interpretation, it is better to operate with the concept of angle, rather than its cosine.

E. Vasilevska [11, p.71] determines three conditional intervals of the angle change of *θ*: [0; 30°], [30°; 60°], [60°; 90°], which correspond to small, moderate and significant differences between the vectors. Similarly, we can talk about small, medium and significant intensity of structural changes.

2) The intensity indicator of change is supplemented with the rate indicator of change. As a rule, this indicator is applied to temporal structural changes. The rate indicator was proposed by K. Kukula [12]. The rate of structural changes is determined by the dynamics of the transition from one step to the next (by the estimation of the degree of difference in structures over time *t* and *t*-1)

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$$\frac{\sum_{i=1}^{m}\left|w_{it}-w_{i(t-1)}\right|}{2}.$$

Note that this indicator can be used for the assessment of differences in structures between two arbitrary objects, if you use the corresponding indexes of objects in the formula instead of indexes *t* and *t*-1.

We use the average change rate to assess the average rate throughout the analyzed period

$$\gamma=\frac{\sum_{t=2}^{n}\sum_{i=1}^{m}\left|w_{it}-w_{i(t-1)}\right|}{2(n-1)},$$

where w_{it} and $w_{i(t-1)}$ – *i*- are the elements of two structures that follow each other (respectively, in the period of time *t* and *t*-1).

T. Romanova notes that the rate of structural change characterizes the dynamics of changes in the economic system. "The study of the rate of structural changes allows obtaining the analytical data to compare the dynamics of changes in various structural elements in order to identify patterns and contradictions of processes occurring in the economy… Low level of rate should indicate slow economic development, transformational decline or rising of trends of repressiveness of the economic system. The greatest rate is inherent in regressive structural developments in the conditions of strengthening of the crisis phenomena." [13, p.205].

The greater rate of transformation corresponds to the greater value of γ. This indicator actually shows the pace of the transformation process, while the intensity indicator shows the size (depth) of the transformation. Both of these indicators are closely correlated, so some researchers use only one of them in the analysis, for example, K. Kukula [12], [14] uses the indicator of rate of changes.

3) A separate methodological problem of structural dynamics is the measurement of the stability of the direction (monotony) of changes. The problem is to answer the question whether the evolution of the studied structure shows a trend of sustainable development in a constant direction, or whether it is the result of random multidirectional changes that do not lead to a given end result.

The idea of assessing the monotony of structural changes is that, ideally, the direction of change at each step should be exactly the same as the direction of the desired final changes (movement from initial to final structure) throughout the study period. Subject to monotony, the desired end result is easier and faster to achieve. Note that in practice, it is difficult to find consistent structural dynamics in the longer term.

As a rule, the initial structure captures the actual values of structural variables (components) at the beginning of the study period. The final structure can be defined in different ways. For example, these may be the values of structural variables at the end of the study period, then the assessment of monotony answers the question: how consistently we have moved from the starting point to the end. If we take as the final structure a set of desired or planned values of structural variables, then we get an answer to the question of how adequate the progress has been to the tasks throughout the period.

Adequate to the said degree of monotony is the construction proposed by K. Kukula, which consists of *n-1* indicator

$$\eta_p = \frac{\sum_{i=1}^{m}\left|w_{ip} - w_{i1}\right|}{\sum_{t=2}^{p}\sum_{i=1}^{m}\left|w_{it} - w_{i(t-1)}\right|} \quad (p = 2, 3, \ldots n).$$

Each individual indicator η_p measures the monotony of changes for the period from the initial stage to time p. If it is necessary to measure the monotony for the entire study period, then we look for the indicator η_n (here *n* is the last stage).

The sequence of values $\{\eta_2, \eta_3, \ldots, \eta_n\}$ provides information about the degree of preservation of a constant direction of changes throughout the whole period of change of structure.

The indicator η_p calculated in this way varies in the range [0, 1]. By construction (definition) η_2 is always 1. As for the other indicators $(p = 3, 4, \ldots n)$, the closer the value of η_p is to 1, the more structures evolve sequentially and are stable to avoid deviations from a given direction of change. These deviations are usually caused by the chaotic transformation of the components. If η_p is 0, it means that the structure at step *p* (the final structure of the stage) is identical to the initial structure. The proximity of $\eta_p$to zero indicates either a practical absence of change, or a chaotic change that does not lead to significant changes.

In conclusion, it should be noted that each of the three indicators considered adds its own details to the review, thus enriching the overall analysis of structural changes.

Turning to the second level of analysis – **the analysis of changes in the structure**, let's focus on some of its features.

Let's start with the basic concepts – change of the size and shape of the structure. The structure of each object is defined by a set of absolute and relative values of structural variables. According to M. Valesiak [15, p. 26], structures are similar in size if the absolute values of the corresponding structural variables are close. Structures are similar in shape if they have close relative values of structure variables. Therefore, the values of the elements of the structure determine the size of the structure, and the result of the share of elements in the total sum of the elements of the structure outlines its shape. From this point of view we say that changes in the size of the element/elements determine changes in the size of the structure, and changes in the proportions between the elements and the whole - changes in shape.

The next feature, which concerns possible variants of structure changes, is described in [16, p. 76]. In general, there may be three such possibilities: stabilization, growth and decline of the share of the element (set of elements) relative to the whole.

The described features prove the need to use two indicators to assess changes in structure – changes in size and changes in shape. In addition, they show that the role of any element in changing the structure can be either active (the value increases/decreases faster than others) or passive (the value of the element remains unchanged, but the share in the structure changes due to the changes in other elements).

M. Markovska and A. Sokolovskyi [17] propose a decomposition *indicator* that assesses *changes in the size of the structure*. To assess the change in the size of the *i*-th element, the formula is used in the structure

$$UR_i = \frac{u_{ik} - u_{il}}{\sum_{i=1}^{m} |u_{ik} - u_{il}|},$$

where *k* and *l* – are time periods (or dynamics objects) being compared.

The sum of the modules UR_i of all components is equal to one, and the sign indicates whether the value of the structure element has increased (positive value) or decreased (negative value). The module UR_i shows the share of changes in the *i*-th indicator in the structure changes.

Similar to UR_i, the decomposition *indicator* is calculated, which assess the *changes in the shape of the structure*. For the *i*-th element, the estimation is calculated as

$$UK_i = \frac{w_{ik} - w_{il}}{\sum_{i=1}^{m} |w_{ik} - w_{il}|}.$$

Here, the values of the matrix are taken for calculations.

The sum of the modules of the values of UK_i, as in the case of UR_i, is equal to one, but the sum of the values of UK_i is zero. This can be interpreted as follows: the 'magnitude" of the structure (the sum of the shares of all components of the whole) is always equal to 1, but the relative increase in the share of some components of the structure is always offset by a decrease in the share of other components. For example: 1) the structure consists of two elements, then if $UK_1 = -0{,}5$, then $UK_2 = 0{,}5$ (decrease in the share of the first element in the structure occurred due to the same increase in the share of the second); 2) the structure consists of three elements, then if $UK_1 = 0{,}5$, then UK_2 and UK_3 will be both negative and in the sum equal to -0.5 (increase in the share of the first element in the structure occurred due to the reduction of the shares of the second and third).

The method is presented in detail in [18].

Conclusion. The development of the national economy is based on effective structural changes. The studies of these transformations of the structure of the economy in the framework of macroeconomic analysis, namely their identification and analysis, are of particular importance. In the framework of the structural-temporal approach, a method of quantitative analysis of structural changes is proposed, which provides for two stages of analysis: analysis of the process of structural changes and analysis of structure changes. The first concerns the study of the dynamic characteristics of the process of changes, while the second answers the question of how the studied structure changes. Analysis of the process of structural changes is based on the definition and analysis of three estimates: intensity (depth) of change; rate of changes; constancy (monotony) of changes. The second aspect of the analysis – changes in the structure – involves the decomposition of structural changes at the level of structural elements and analysis of changes in the size and shape of the structure on this basis.

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ЗМІСТ

ДО ЮВІЛЕЙНИХ ДАТ ЛЬВІВСЬКОГО УНІВЕРСИТЕТУ

(360 років від часу заснування Львівського університету, 55 років – економічного факультету)

ЕКОНОМІКА ЯК НАУКА. ТЕОРІЯ, ПОЛІТИКА І ПРАКТИКА

КІЛЬКІСНІ МЕТОДИ В ЕКОНОМІЦІ. ЦИФРОВА ЕКОНОМІКА

СУЧАСНІ МЕТОДИ ОБЛІКУ, АУДИТУ ТА ОПОДАТКУВАННЯ

ПІДПРИЄМНИЦТВО. МЕНЕДЖМЕНТ І МАРКЕТИНГ

СОЦІАЛЬНА ЕКОНОМІКА І ПОЛІТИКА. МІЖДИСЦИПЛІНАРНІ ДОСЛІДЖЕННЯ В ЕКОНОМІЦІ

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