DOI: https://doi.org/10.30525/2256-0742/2022-8-5-198-208

REGULATION OF DYNAMIC PROCESSES IN THE INDICATORS OF DISPROPORTIONS OF UKRAINIAN REGIONS: OPERATIONAL AND LOGISTIC APPROACH

Olga Shevchenko[1], Oleg Shevchuk[2], Bohdan Polovynko[3]

Abstract. Indicators of socio-economic development of the regions of Ukraine demonstrate a tendency to increase disproportions, which are significantly intensified in the conditions of military operations. In addition to the deterioration of performance indicators, this trend leads to the fragmentation of the country's economic space. Regulation of regional development does not contribute to the reduction of disparities, in particular, due to shortcomings in the assessment, interpretation of indicators of disparities and modeling of their dynamics, which leads to the definition of unrealistic goals of regulation. Taking into account the need to ensure the connection between short-term and long-term planning of regional development, *the purpose of the article* is to develop theoretical and empirical foundations aimed at regulating dynamic processes in the indicators of regional development disproportions. To achieve the goal, the following *tasks* were chosen: to analyze the models of convergent-divergent processes of regional development imbalances, to build models of long-term interaction of indicators of imbalances in the spheres of life, to determine the basis for assessing the crisis dynamics of regional indicators. *Methodology*. To regulate the development of regions, a model of long-term interaction of indicators of disproportions in various spheres has been developed. The process component of the study of dynamic processes in the indicators of regional disproportions and forecasting of crisis situations in the spheres of regional activity, which covers the tasks, tools and main results of the study, has been formed. The paper investigates the long-run interaction of inequality indicators in different areas using econometric dynamic vector autoregressive and error correction models (VAR&ECM). This makes it possible to identify and predict non-stationary impulse processes in general, to identify trends relevant to individual phases of activity, to identify the relationship and interdependence of the trajectory of imbalances. The research tools are designed to solve a set of tasks on the regulation of imbalances. The *originality* of the article lies in the application of the modeling results in the form of interrelationships of disproportions for different time intervals in the formation of a set of programs and preventive measures to manage regional development disproportions. This also enhances the practical significance of the study. *Practical implication*. The data obtained as a result of the study of the dynamic processes of disproportion indicators can be taken into account in solving a set of tasks to regulate the disproportions of regional development, developing a set of measures for the implementation of regional strategies, financial and budgetary regulation of regional development, determining budget expenditures for solving problems arising from disproportions.

Key words: regional economy, regional economy disparities, econometric modeling, operational-logistics approach, regional development regulation, financial and budgetary relations.

JEl Classification: R12, R58, G28, C51, C36, C13

[1] Kyiv National Economic University named after Vadym Hetman, Ukraine *(corresponding author)*
E-mail: olvalshev@gmail.com
ORCID: https://orcid.org/0000-0003-0386-7550
ResearcherID: HGC-5262-2022
[2] Kyiv National Economic University named after Vadym Hetman, Ukraine
E-mail: Ol.Shevchuk@ukr.net
ORCID: https://orcid.org/0000-0002-3206-6966
ResearcherID: HGC-7172-2022
[3] V. N. Karazin Kharkiv National University, Ukraine
E-mail: polovynko96@gmail.com
ORCID: https://orcid.org/0000-0003-0592-941X
ResearcherID: HGB-5903-2022

1. Introduction

At the present stage, the development of the regions of Ukraine is characterized by unevenness, which is a long-term feature of regional economic indicators. At the same time, during the current year it has deepened due to military operations on the territory of Ukraine. The analysis of the socio-economic indicators of the regions of Ukraine shows a clear tendency to increase disproportions and fragmentation of the economic space. Strategic and tactical regulation of regional development insufficiently addresses a number of problems that are actually caused by shortcomings in approaches to assessing the socio-economic situation in the regions. Such approaches do not take into account the dynamic processes of disproportion indicators in the long term, which further leads to incorrect definition of the goals of regulating structural changes in the regional economy, causing an increase in disproportions. Taking into account the need to ensure the connection between current and strategic goals of regional development, the purpose of the article is to determine the principles of regulation of dynamic processes in the indicators of regional disparities. To fulfill these tasks, the models of convergent-divergent processes of uneven regional development were analyzed, models of long-term interaction of disproportion indicators in different spheres were built, and the principles of assessing the crisis dynamics of regional development indicators were determined.

The authors consider it necessary to assess the regulatory impact of government and local self-government bodies on the indicators of regional disparities, as disparities are among the problems that cannot be solved by market self-regulation alone. Another aspect of the approach to the regulation of disparities is the use of logistical principles of planning and regulation of material, information and financial resources and flows, taking into account that the unevenness of regional potential is the root cause of the disparity of regional development. Thus, by combining operational and logistical approaches, the tools for regulating dynamic processes in terms of disproportions in the regions of Ukraine were built. This will allow solving the problems that arise in business entities at the regional level.

2. Literature review

Researches on the regulation of disparities in regional socio-economic development, including use of various models, are widely highlighted. Growth of regional development disparities and need to regulate it are proven in the work of Gonta (2018). Socio-economic problems of the regions are analyzed in the papers by Kyzym et al. (2021) and Kondratenko et al. (2022). Assessment of region disparities and examples of its regulation in Spain, Great Britain, and European countries in general, are presented in papers by Martinez-Galarraga (2015), McCann (2020), and De Dominic (2014). Some papers are devoted to regional and spatial aspects of Ukraine economy, spatial dimension of macroeconomic phenomena – Cherniuk et al. (2011), Dorosh et al. (2015). Evaluation of dynamics of regional development disparities is the subject of works by Gur'yanova (2013) and Bril (2020). Paper by Melnikova (2015) examines structural shifts in regional economy that lead to disparities. The dynamics of regional development is predicted and modeled in a number of works, among which it is worth noting Manoilenko et al. (2020), which considers the modeling of hierarchical systems, including the regional level, and the works of Klebanova et al. (2012), Gur'yanova (2012), Brumnik et al. (2014), Klebanova (2014), devoted to the forecasting of economic processes at the regional level. Considerable attention is paid to the latest tools regulating development of regions and communities, in particular, in the work by Shebanin et al. (2021). The analysis of theoretical and methodological approaches to the assessment, analysis and research of dynamic processes of socio-economic regional development is set out in a number of other thorough articles devoted to the dynamics of disproportionality and the development of tools for its regulation. Thus, Amosha et al. (2011), and Gur'yanova (2013) allowed conclude that methods of quantitative research of the dynamic processes of disparity and prediction of crisis situations by spheres of life in the region need further investigation. All this actualized the development of a structured scientific and methodological system that regulates dynamic processes in the indicators of regional development imbalances. It is based on the activity-logistic approach, which allows to form a strategy of balanced development of regions and the country as a whole.

3. Research methodology

According to Gur'yanova (2013) and Gur'yanova et al. (2012), regional economy should be considered not as a mono-object, but as a complex multi-regional system functioning through the basis of vertical and horizontal interactions, which affect indicators of disparities in different ways. Thus, the regulation of regional development in Ukraine requires the improvement of the methodology of a comprehensive mechanism for assessing, analyzing and forecasting socio-dynamic processes by indicators of disproportions. Estimates of relationships between disparity indicators obtained in the

previous paper by Shevchenko (2021) made it possible to designate three classes of regions: regions with balanced disparities in the development of a certain sphere, with controlled disparities, and with unrestrained (uncontrolled) disparities. Seven spheres of regional development were studied: general economic, socio-demographic, structural, socio-economic, foreign economic, natural and environmental, industrial. In most areas of development, most regions belong to the second class (with controlled disproportions). Classes of regions with higher territorial economic density demonstrate greater stress resistance to various types of external influences.

For the purposes of this study, a dynamic series of indicators of disproportions in the socio-economic development of regions in 2007–2021 was analyzed using data from the State Statistics Service of Ukraine. Among the limitations is the lack of statistical data on direct investment in certain regions, which distorted the results. To solve the problems of regional socio-economic development due to the crisis and global instability, it is necessary to apply new approaches to the study of relationships in various spheres of socio-economic development of regions, including financial and budgetary. The importance of research in this area is an indicator of stability, living standards, social benefits, business profitability and public welfare.

The model of long-term interaction of indicators of imbalances in different spheres of development is developed, which allows to regulate dynamic processes in the indicators of imbalances. Models of long-term interaction of indicators of disparities in different areas (based on the use of econometric dynamic models of vector autoregression and error correction – VAR&ECM):
– analysis of cause-and-effect relationships of dynamic rows of disparities indicators;
– assessment of stability and level of interrelationship of the components in different spheres of region;
– analysis of interdependence of indicators and forecasting the key indicators of unevenness.

The choice of such a tool for the study of non-stationary processes of the dynamics of disproportion indicators is due to the following features: it is a convenient tool for studying short- and medium-term trends in the dynamics of indicators; allows to reveal the dynamic relationship between the current and lagged values of the relevant indicator; the apparatus of one-time modeling of several hourly series of indicators by means of a system of dynamic equations is presented, which allows to take into account and study the feedbacks between indicators and their lag values, as well as to describe and analyze the relationships between economic variables (Klebanova et al., 2012).

The results of the study can be used to forecast further trends taking into account shocks and impulses. The proposed models can also be considered as a decision support tool for the formation of strategic priorities in the regulation of imbalances, taking into account short-term effects and fluctuations.

4. Process component of the study of dynamic processes in regional disparities

The assessment of the relationships between the indicators of disparities (Shevchenko, 2021) shows that clusters of regions with higher territorial economic density show greater stress resistance to various kinds of "shocks". Thus, disproportionality forms an additional factor that destroys the sustainable potential of regions in the interregional dimension. Thus, an urgent socio-economic issue for the country is the strengthening of regional policy measures aimed at reducing interregional disparities in various spheres, as well as improving approaches to assessing the dynamics and interrelationships of disparity indicators.

The level of disproportions of regional development in certain spheres of activity, as the main sign of structural disproportions, as well as disproportions in the financial and credit sphere, can be reduced by implementing a scientifically balanced state policy of structural transformations of the regional economy and forecasting crisis situations, based on the principles of an integrated, proportional approach to strategic planning of regional development (Scenario models, 2013, Otenko et al, 2019). A comparative analysis of the models of regional development regulation in different countries has led to the conclusion that, despite the different types of state structure, similar development priorities can be identified: ensuring a common standard of living and quality of life and reducing disparities between regions. The regulation of regional development in Ukraine emphasizes the priority of territorial development, which is a balanced economic territorial development that ensures the integrity of the economic space of the country as a whole (Amosha et al, 2011, Gur'yanova, 2013). Thus, the model of regional regulation in Ukraine requires improvement of the methodology of comprehensive assessment, analysis and forecasting of regional socio-economic development, as well as the study of the processes of disproportionality of indicators and forecasting of crisis situations in different areas of the region.

Figure 1 presents the procedural component of the study of the dynamics of indicators of regional development disproportions and forecasting of crisis situations. This component contains a description of the tasks set, the research tools with an indication of the software packages used, as well as the presentation

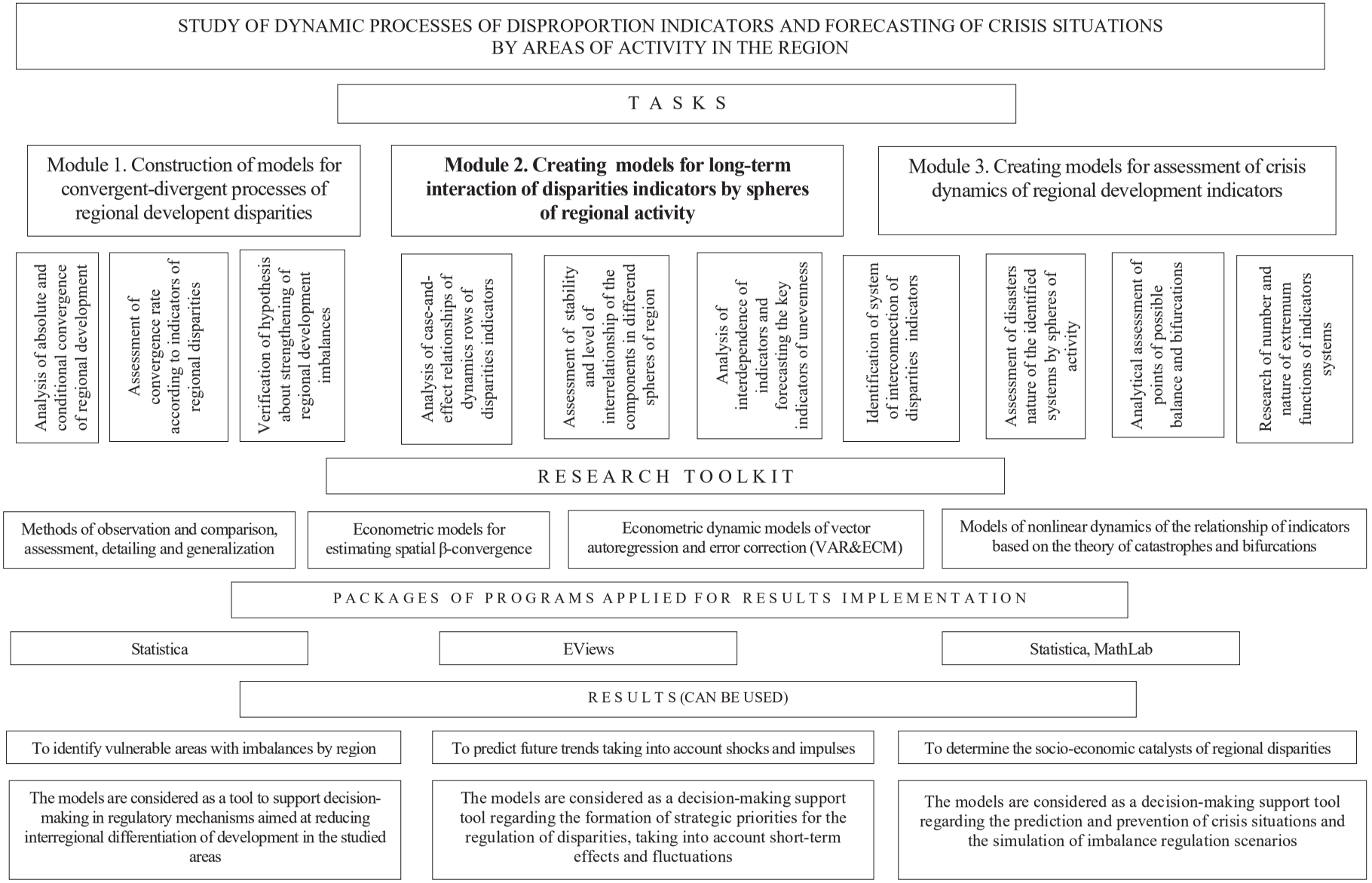

Figure 1. Algorithm (process component) for investigation of dynamic processes in indicators of regional development disparities

Source: authors' analysis

of the main results. The toolkit for studying the dynamic processes of disproportion indicators and forecasting crisis situations by spheres of regional activity is designed to solve a set of tasks for managing regional development disproportions through the following:
– building models of convergent-divergent processes of regional development disproportions (module 1);
– creation of models of long-term interaction of disproportion indicators by areas of regional activity (module 2);
– creation of models for assessing the crisis dynamics of regional development indicators (module 3).

Convergent-divergent processes were analyzed for the following groups of indicators: socio-demographic disparities (ratio in the migration movement of the population (arrived/left, per 10,000 people, sign X1)), production disparities (ratio of the amount of innovative products to the costs of innovation, X2), natural and ecological disparities (ratio between emissions of harmful substances and costs for environmental protection, X3), foreign economic disparities (coverage of imports by exports, X4), structural disparities (structure of gross value added (ratio of amount of extractive and processing industry, X5)), socio-economic disparities (ratio between regional and national average incomes of the population (X6)), total economic disparities (ratio of savings to gross regional product – GRP, X7).

The analysis of convergent-divergent processes (Module 1) has shown that divergent trends in the uneven development of Ukraine's regions are currently increasing. At the same time, there is interregional convergence within groups of homogeneous clusters, the so-called "convergent clubs". In the current period, the process of convergence of the uneven regional socio-economic development has slowed down; its activation requires adoption of appropriate measures of public administration, related primarily to raising the educational and professional level of the workforce, accelerating the development of R&D sphere, stimulating innovative activity, and creating the necessary infrastructure production. Given the decisive role of convergence of uneven regional development, it is necessary to use comprehensive approaches to accelerate this process. They should be implemented within the framework of innovation, scientific and technical, industrial, entrepreneurial and other types of state regulation policy. The results of the study can be used to identify vulnerable areas with regional disparities.

5. Model of long-term interaction of disparities indicators according to different shperes of regional development

In the modeling of long-term interaction of disparity indicators by different spheres based on econometric dynamic models of vector autoregression and error correction (VAR & ECM) (module 2) following processes were involved:
– analysis of cause-and-effect relationships of dynamic rows of disparities indicators;
– assessment of stability and level of interrelationship of the components in different spheres of region;
– analysis of interdependence of indicators and forecasting the key indicators of unevenness.

The structural form of VAR for k variables and the number of lags p has the form (1):

$$\begin{cases} x_{t1} = \alpha_{10} - \alpha_1 x_{t2} - \ldots - \alpha_k x_{t,k} + \beta_{11}^1 x_{t-1,1} + \beta_{12}^1 x_{t-1,2} + \cdots + \\ + \beta_{1k}^1 x_{t-1,k} + \beta_{11}^2 x_{t-2,1} + \beta_{12}^2 x_{t-2,2} + \cdots \beta_{1k}^2 x_{t-2,k} + \ldots + \beta_{1k}^p x_{t-p,k} + u_{t1} \\ x_{t2} = \alpha_{20} - \alpha_2 x_{t1} - \ldots - \alpha_k x_{t,k} + \beta_{21}^1 x_{t-1,1} + \beta_{22}^1 x_{t-1,2} + \cdots + \\ + \beta_{2k}^1 x_{t-1,k} + \beta_{21}^2 x_{t-2,1} + \beta_{22}^2 x_{t-2,2} + \cdots \beta_{2k}^2 x_{t-2,k} + \ldots + \beta_{2k}^p x_{t-p,k} + u_{t2} \\ \ldots \\ x_{tk} = \alpha_{k0} - \alpha_k x_{t1} - \cdots \alpha_{k-1} x_{t,k-1} + \beta_{k1}^1 x_{t-1,1} + \beta_{k2}^1 x_{t-1,2} + \cdots + \\ + \beta_{kk}^1 x_{t-1,k} + \beta_{k1}^2 x_{t-2,1} + \beta_{k2}^2 x_{t-2,2} + \cdots \beta_{kk}^2 x_{t-2,k} + \ldots + \beta_{kk}^p x_{t-p,k} + u_{tk} \end{cases} \quad (1)$$

The authors develop models of long-term interaction of disparity indicators in different areas on the example of disparity indicators in the Eviews software package.

To check the rows for cointegration, and, in particular, at the initial stage, when checking stationarity, extended Dickey-Fuller test (Engle, 1987) is used. It tests each separate row of the dynamic indicator and determines the integration of the first order.

The results of the test for the ratio of savings to GRP – general economic imbalances – are shown in Table 1.

In this case, the Dickey-Fuller test shows that the time row of the total savings-to-GRP ratio is non-stationary because its values less than the crutial values for the 10 %, 5 %, and 1 % significance levels. Aggregated results of tests for time rows are presented in Table 2.

Table 2 also shows the determination index and the Durbin-Watson criterion, which reflect the

Table 1

Dickey-Fuller criterion based on the ratio of savings to GRP (X7)

ADF Test Statistic	-1.447254	1% Critical Value*		-3.5889
		5% Critical Value		-2.9303
		10% Critical Value		-2.6030
*MacKinnon critical values for rejection of hypothesis of a unit root				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(X7)				
Method: Least Squares				
Sample(adjusted): 2007: 2021				
Included observations: 43 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
X13(-1)	-0.058256	0.040253	-1.447254	0.1556
D(X13(-1))	0.446455	0.138695	3.218960	0.0026
C	41.50782	30.49906	1.360954	0.1811
R-squared	0.221231	Mean dependent var		3.104143
Adjusted R-squared	0.182293	S.D. dependent var		82.14515
S.E. of regression	74.28153	Akaike info criterion		11.52082
Sum squared resid	220709.8	Schwarz criterion		11.64369
Log likelihood	-244.6975	F-statistic		5.681569
Durbin-Watson stat	2.039712	Prob(F-statistic)		0.006732

Source: authors' estimates

Table 2

The value of the test according to the Dickey-Fuller criterion for disaprities indicators

Indicators of regional development disparities	ADF Test Statistic	R^2 Determination coefficient	Durbin-Watson stat
X7	-1.447254	0.221231	2.039712
X1	-1.350981	0.077162	1.930197
X5	-1.312578	0.088450	1.932868
X6	-1.549853	0.075400	1.989725
X4	-1.515196	0.068891	1.909290
X3	-1.787479	0.145609	2.047677
X2	-1.812963	0.277812	2.072573

Source: authors' estimates

adequacy of the model and the absence of auto-correlation.

The Dickey-Fuller methodology involves finding the differences of a series in order to transform the series from non-stationary to stationary. Since cointegration involves the analysis of stationary time series, it is necessary for further analysis that the analyzed variables are stationary based on differences of the same order.

Since all the original time series are non-stationary, it is necessary to find the first differences and determine the order of integration. Table 3 shows the Dickey-Fuller first difference test for the time series.

Table 3 shows that all series of first differences are stationary as they exceed the critical values, which allows us to conduct further research and test the series for cointegration.

Cointegration is tested using the Engle-Granger test. Cointegration requires the same order of integration of non-stationary time series. Therefore,

Table 3

Values of the Dickey-Fuller criterion of disparities for first differences

Regional disaprities indicator	ADF Test Statistic d(1)
X7	-3.505409
X1	-4.501949
X5	-4.364007
X6	-4.042056
X4	-5.078195
X3	-6.081148
X2	-3.099277

Source: authors' estimates

the original time series should be, firstly, non-stationary, and secondly, have the same order of integration. In this case, all the studied disproportion coefficients are of the first order. Only compliance with this requirement allows to talk about the possibility of cointegration. In addition, the test for the presence of cointegration between two

variables was conducted if their linear combination is stationary.

Based on the errors of the model, the Dickey-Fuller test was conducted and the rows that are cointegrated with the corresponding defined indicator (in our case – the ratio of savings to GRP) were identified (Table 4).

Table 4

Results of the Dickey-Fuller test for cointegration by the ratio of savings to GRP (X7)

Residuals	ADF Test Statistic	Durbin-Watson stat
X7_X1	-2.678424	1.967278
X7_X5	-2.455174	1.987139
X7_X6	-2.035982	2.007451
X7_X4	-2.880047	1.980032
X7_X3	-2.937704	1.986673
X7_X2	-2.699071	2.140176

Source: authors' estimates

The obtained results allow us to conclude that the indicators X4, X1, X3, X2 cointegrate with the ratio of savings to GRP (X7) at the significance level of 10%, indicators X5, X6 cointegrate at the significance level of 5%. At the same time, the lag is taken equal to one, since cointegration is most clearly manifested at this lag. Therefore, the only hypothesis is accepted, which states that such series have the first level of integration and are cointegrated with each other. The original series of these indicators are non-stationary and have the order of integration I (1). In this case, cointegration means that a linear combination of variables (or an error term that measures deviations from long-run equilibrium) is a stationary time series.

Based on the results of determining the cointegration relationships of the differentiation indicator of the ratio of savings to GRP (X7), an error correction model (ECM) was built to study both the short-term and long-term impact of the indicators on each other, as well as their aggregate impact. The model is built for lags of 1 and 2 periods, which is not the maximum value, but, as it was determined earlier, this lag period is the most effective. The results of the ECM model are shown in Table 5.

After evaluation, the ECM model should be tested for adequacy. In order for the ECM model to be dynamically stable, it is necessary to adjust speed coefficients to be within the given limits of $0 \le \lambda_1 < 1{,}0 \le \lambda_2 < 1$. This condition ensures that λ_1 and λ_2 converge to a long-term balanced link. If the variables cointegrate, then at least, one of the coefficients λ_1 and λ_2 must be statistically significantly different from zero.

As a result of the construction of the ECM-model, it is possible to obtain the cointegration equation, short-term effects and speed coefficients with which the system can return to equilibrium. According to the cointegration equation, it can be established that the system of indicators of regional disparities is generally stable, which is reflected by the coefficient of deviation from the long-run equilibrium.

According to Akaike's information criterion, it can be stated that the greatest degree of relationship is observed between the indicator of savings ratio to GRP (X7) and the ratio of the innovative products amount to the costs of innovation (X2).

The system of equations of the cointegration model is presented below (2):

$$X7=1{,}46*X1-2{,}7*X4-1{,}3*X3+1{,}59*X2$$

$$D(X7) = - 0.07*(X7(-1) + 1.46*X1(-1) - 2.7*X4(-1) - 1.3*X3(-1) + 1.59*X2(-1) + 5275.91) + 0.12*D(X7(-1)) + 0.05*D(X7(-2)) + 0.1*D(X1(-1)) + 0.06*D(X1(-2)) - 0.05*D(X4(-1)) - 0.128*D(X4(-2)) - 0.24*D(X3(-1)) - 0.22*D(X3(-2)) + 0.15*D(X2(-1)) + 0.15*D(X2(-2)) - 0.44$$

$$D(X1) = - 0.28*(X7(-1) + 1.46*X1(-1) - 2.7*X4(-1) - 1.3*X62(-1) + 1.59*X2(-1) + 5275.9) + 0.45*D(X7(-1)) + 0.082*D(X7(-2)) + 0.15*D(X1(-1)) - 0.2*D(X1(-2)) - 0.32*D(X4(-1)) - 0.64*D(X4(-2)) - 0.42*D(X3(-1)) - 0.28*D(X3(-2)) + 0.48*D(X2(-1)) + 1.56*D(X2(-2)) - 21.5$$

$$D(X4) = - 0.11*(X7(-1) + 1.46*X1(-1) - 2.7*X4(-1) - 1.3*X3(-1) + 1.59*X2(-1) + 5275.9) + 0.62*D(X7(-1)) + 0.02*D(X7(-2)) + 0.05*D(X1(-1)) - 0.28*D(X1(-2)) + 0.004*D(X4(-1)) - 0.24*D(X4(-2)) - 0.48*D(X3(-1)) - 0.38*D(X3(-2)) + 0.17*D(X2(-1)) + 1.06*D(X2(-2)) - 20.4 \quad (2)$$

$$D(X3) = 0.04*(X7(-1) + 1.46*X1(-1) - 2.7*X4(-1) - 1.3*X3(-1) + 1.59*X2(-1) + 5275.9) + 0.759*D(X7(-1)) + 0.86*D(X7(-2)) + 0.28*D(X1(-1)) - 0.48*D(X1(-2)) + 0.01*D(X4(-1)) + 0.39*D(X4(-2)) - 0.73*D(X3(-1)) - 0.45*D(X3(-2)) - 0.19*D(X2(-1)) + 0.52*D(X2(-2)) - 5.59$$

$$D(X2) = - 0.11*(X7(-1) + 1.46*X1(-1) - 2.7*X4(-1) - 1.3*X3(-1) + 1.59*X2(-1) + 5275.91) + 0.23*D(X7(-1)) - 0.069*D(X7(-2)) - 0.1*D(X1(-1)) - 0.08*D(X1(-2)) + 0.08*D(X4(-1)) - 0.06*D(X4(-2)) - 0.24*D(X3(-1)) - 0.22*D(X3(-2)) + 0.5*D(X2(-1)) + 0.4*D(X2(-2)) - 2.55$$

Table 5

ECM model for indicators of regional disparities

Sample(adjusted): 2007: 2021					
Included observations: 42 after adjusting endpoints					
Standard errors & t-statistics in parentheses					
Cointegrating Eq:	CointEq1				
X7(-1)	1.000000				
X1(-1)	1.464173				
X4(-1)	-2.704880				
X3(-1)	-1.307671				
X2(-1)	1.594756				
C	5275.907				
Error Correction:	D(X13)	D(X21)	D(X53)	D(X62)	D(X71)
CointEq1	-0.071438	-0.284515	-0.111130	0.044521	-0.108876
D(X7 (-1))	0.119144	0.449451	0.620530	0.759315	0.228526
D(X7(-2))	0.050899	0.082444	0.021677	0.855744	-0.069310
D(X1(-1))	0.101953	0.153624	0.050952	0.282257	-0.099999
D(X1(-2))	0.060863	-0.200051	-0.280422	-0.484990	-0.078249
D(X4(-1))	-0.050892	-0.317470	0.004141	0.014461	0.080529
D(X4(-2))	-0.128443	-0.643112	-0.237922	0.396888	-0.060413
D(X3(-1))	-0.235645	-0.422209	-0.477814	-0.734139	-0.237673
D(X3(-2))	-0.214995	-0.282948	-0.383320	-0.454404	-0.219752
D(X2(-1))	0.154481	0.476719	0.174826	-0.194328	0.502068
D(X2(-2))	0.154115	1.556723	1.060919	0.515523	0.423054
C	-0.443958	-21.49478	-20.39716	-5.592783	-2.548685
R-squared	0.625087	0.415047	0.392995	0.443344	0.465612
Adj. R-squared	0.487619	0.200565	0.170426	0.239237	0.269670
Sum sq. resids	104762.7	3093232.	1929860.	646716.3	1473847.
S.E. equation	59.09392	321.1039	253.6310	146.8237	221.6489
F-statistic	4.547150	1.935109	1.765723	2.172112	2.376272
Log likelihood	-223.8529	-294.9436	-285.0365	-262.0773	-279.3755
Akaike AIC	11.23109	14.61636	14.14459	13.05130	13.87502
Schwarz SC	11.72757	15.11284	14.64107	13.54778	14.37150
Determinant Residual Covariance		1.57E+20			
Log Likelihood		-1274.570			
Akaike Information Criteria		63.78906			
Schwarz Criteria		66.47832			

Source: authors' estimates

The toolkit for analysis and decomposition of shocks caused by the disproportionality of regional development is based on the impulse response function and variance decomposition. The decomposition of forecast error variances allows to analyze the impact of different shocks on the forecast error variance for different lead times. T hus, the decomposition of variances makes it possible to estimate the shares of variance caused by shocks to different variables and, accordingly, to assess the degree of influence of the relationships between indicators.

For the studied series, which are cointegrated with the indicator of the ratio of savings to GRP (X7), the stability of the response is checked. On the basis of impulse analysis, the impulse response of the variable of the ratio of savings to GRP in relation to all cointegrating factors is investigated. In Figure 2 shows the impulse response function:

The above graph demonstrates the general possibility of system stability, i.e., return to equilibrium, but only in the long run over 10 years. Thus, based on the construction of the ECM-model and impulse analysis, it can be concluded that cointegration indicators, that is, inequality indices X1, X4, X3 and X2, have a long-term relationship with the ratio of savings to GRP (X7) and a change in the level of one indicator will lead to an adjustment in the level of the other. The presence of such

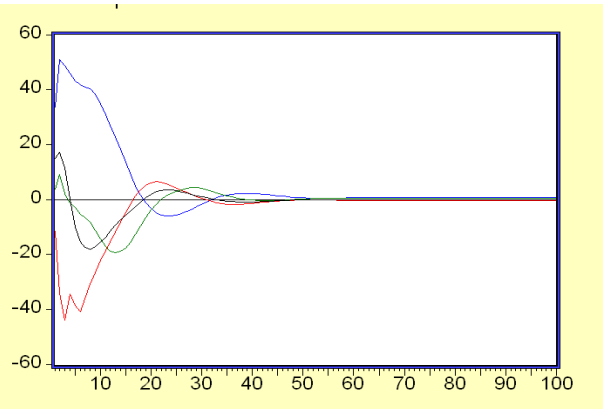

Figure 2. Impulse response function of the savings to GDP ratio (X7) relative to other indicators

Source: authors' estimates

a relationship indicates that their stochastic trends are interrelated. Thus, there is a common long-term balanced trajectory of change of such variables, from which they may deviate in short-term periods.

6. Economic interpretation of stability and interdependence of indicators

It is expedient to consider the economic interpretation of the stability and interdependence between the ratio of savings to GRP (X7) and the ratio of innovative products to innovation expenditures (X2), which have the highest degree of interconnection according to the variance decomposition graph and impulse response function (Figure 3).

Thus, the decomposition of variances makes it possible to estimate the shares of these variances caused by difference shocks and, accordingly, to assess the degree of influence of the relationships between inequality indicators. Dispersion analysis characterizes the relative importance of factors that affect the dynamics of change (dispersion) of a particular system process. The analysis of the above graphs allows to draw the following conclusions:

– dynamics of changes in the ratio of savings to GRP (X7) is practically explained by the dynamics in

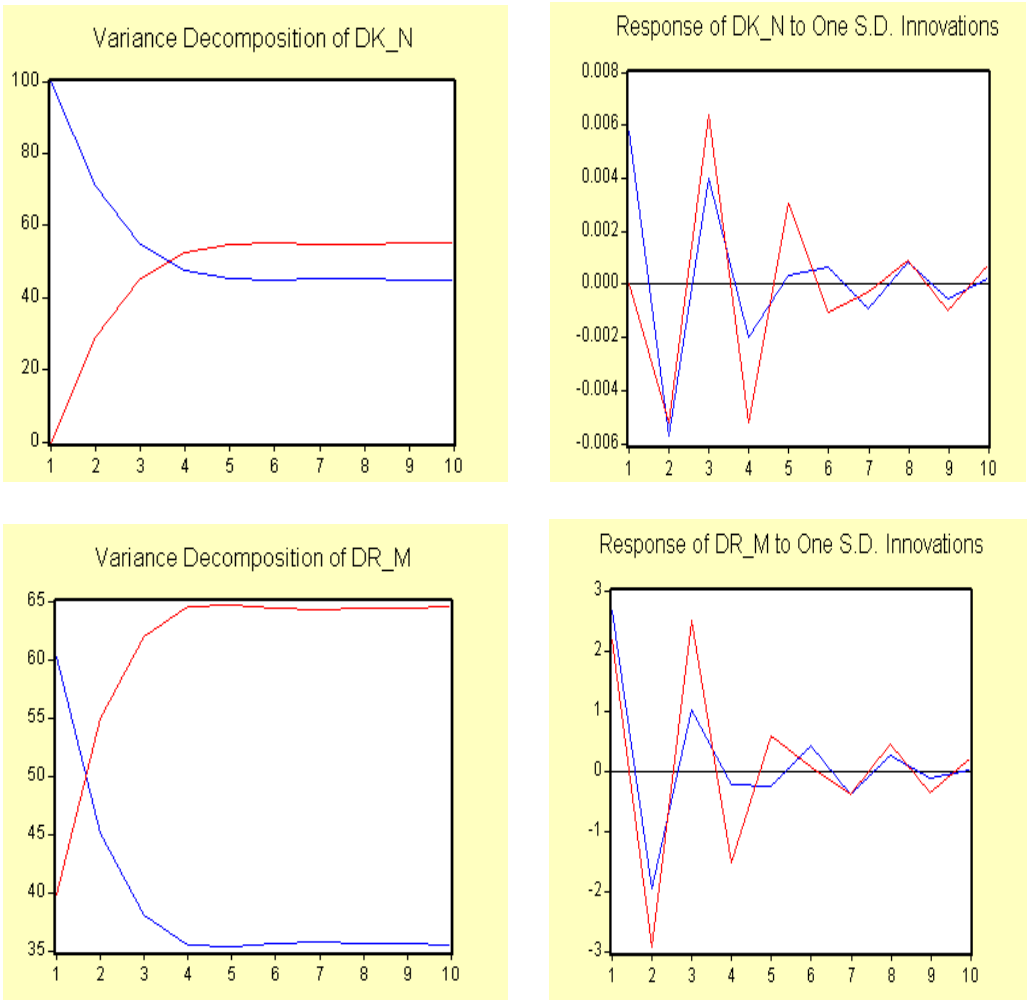

Figure 3. Variance decomposition plot and impulse response function for the ratio of savings to GRP (X7) and the ratio of innovative output to innovation expenditure (X2)

Source: authors' estimates

previous periods of time (up to 60%) and almost 50% is due to the influence of the ratio of innovative products to innovation expenditures (X2), the impact of which becomes less significant over time;
– the dynamics of changes in the ratio of innovative products to innovation expenditures (X2) largely depends on the dynamics of the ratio of savings to GRP (X7) (from 40% to 65% in a fairly short time and a stable level of influence of which remains for a long time) and is conditioned by fluctuations of the same indicator and its previous dynamics, which rapidly changes from 60% to 35% in a fairly short time and remains stable in the long term.

The impulse function analysis for the studied indicators proves that shocks in the dynamics of inequality indicators cause more negative than positive consequences in the dynamics of other aspects of the region's activity. The study of the dynamics of a longer period shows that fluctuations decrease and approach zero, which confirms the long-term stability of the regional system. Fluctuations go down and the system reaches a certain steady state, and in a rather long period – more than 10 years, which coincides with general trends.

The proposed complex of models of long-term interaction of indicators of disparities in the spheres of activity of different regions based on the use of econometric dynamic models of vector autoregression and error correction is an effective tool for a comprehensive study of general short-term and long-term trends in regional differences. This makes it possible to identify and predict non-stationary impulsive processes in the sphere and in general, to determine their typical trends, interconnection and interdependence of the trajectories of inequality. This is essential for the formation of programs and preventive measures to manage the imbalances of regional development for different time intervals.

7. Conclusions

The study of the dynamic processes of indicators of regional development imbalances involves the construction of the following models: analysis of convergent-divergent processes of regional development imbalances; long-term interaction of indicators of imbalances in the spheres of regional life; assessment of the crisis dynamics of regional development indicators. The analysis of convergent-divergent processes showed that currently there is an increase in divergent trends in the uneven development of the regions of Ukraine. The proposed set of models of long-term interaction of disparity indicators based on the use of econometric dynamic models of vector autoregression and error correction is an effective tool for a comprehensive study of general short-term and long-term trends in regional disparities. This allows to identify and predict non-stationary impulse processes in general and for individual spheres of regional activity, to determine the corresponding trends, interconnection and inter-dependence of the dynamics of disproportionality.

The analysis of the interrelationships of disproportions showed that most regions belong to the class with restrained (controlled) disproportions in most of the studied areas, so the situation with disproportions is regulated within the framework of improving the instruments of the state regional policy. At the same time, given the external and internal challenges to regional development, further research should focus on forecasting crises and disasters in various areas of regional socio-economic development (Module 3).

Taking into account theoretical and empirical studies on regional development disparities allows to develop an effective methodology for reducing interregional disparities, which will help to manage potential negative consequences for the regions of Ukraine. The tools for the study of dynamic processes in the indicators of imbalances can be used to solve a set of problems of regulating the imbalances of regional development, the formation of measures to prevent excessive growth of imbalances at different time intervals. This is the basis for the formation of current and strategic financial and budgetary regulation of regional development, development of budget programs to overcome the negative consequences of imbalances, as well as for determining the amount of budget expenditures for such purposes.

Objectively, there is an urgent need to analyze the interrelationships of regional development imbalances using a new operational and logistics approach. Its application to the analysis of regional development involves planning, organization, management, control and regulation of the activities of all participants in the process of resource allocation and redistribution. In the future, the implementation of the operational and logistics approach will involve analytical processing of information to assess the effectiveness of expenditures in certain areas to ensure a sufficient level of socio-economic development of the region. In the future, the implementation of the operational and logistics approach will involve analytical processing of information to assess the effectiveness of expenditures in certain areas to ensure a sufficient level of socio-economic development of the region.

References:

Amosha, O. I., Aptekar, S. S., Bilopol'skyi, M. G., Iuriy, S. U. et al. (2011). Structural economic reforms: international experience, institutions, strategies for Ukraine. Ternopil: Economichna dumka, TNEU.

Bril', M. S. (2020). Methodology of formation of a balanced system of indicators of regional differentiation. *Biznes Inform*, 4, 133–142. DOI: https://doi.org/10.32983/2222-4459-2020-4-133-142

Brumnik, T., Klebanova, L., Gur'yanova, L., Sergienko, O., Kavun, S., & Nepomnyaschiy V. (2014). Synthesis of systems modeling for early crisis forecasting and prevention. *European journal of scientific research*, 118 (1), Jan, 7–22.

Cherniuk, L. H. et al. (2011). Regional-spatial economic systems of Ukraine: methodology and modern practice of their formation. Kyiv, Cherkasy.

De Dominic, L. (2014). Inequality and Growth in European Regions: towards a place-based approach. *Spatial Economic Analysis*, 9 (2), 120–141. DOI: https://doi.org/10.1080/17421772.2014.891157

Dorosh, V. Yu., & Pushkarchuk, I. M. (2015). Evolutionary and conceptual approach to the identification of spatial aspects of the spread of economic phenomena. *Ekonomichnyy forum*, 4, 6–11.

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica*, 55 (2), 251–276. DOI: https://doi.org:10.2307/1913236.

Gonta, O. (2018). Problems of disproportionality of the economic growth of the national economy of Ukraine and its regions. *Problemy i perspektyvy ekonomiky ta upravlinnya*, 2, 57–63. DOI: https://doi.org/10.25140/2411-5215-2018-2(14)-57-63

Gur'yanova, L. S., Klebanova, T. S., Sergiyenko, O. A., & Goncharenko, G. S. (2012). Model of regional development asymmetry analysis. *Problemy ekonomiky*, 2, 27–33.

Gur'yanova, L. S. (2013). Modeling of balanced socio-economic development of regions. Berdyans'k: FOP Tkachuk O. V.

Klebanova, T. S., Gur'yanova, L. S., & Sergiyenko, E. A. (2012). Modern problems of forecasting socio-economic processes: concepts, models, applied aspects. Berdyansk: FOP Tkachuk O. V., pp. 58–73.

Klebanova, T. S., Gur'yanova, L. S., & Shevchenko I. K. (2014). Model basis of the early warning and localization of crises in economic systems of territories. *Actual problems of economics*, 3 (153), 201–211.

Kondratenko, N. O., Krasnonosova, O. M., & Papp, V. V. (2022). Problems and prospects of socio-economic development of the regions of Ukraine. *Biznes Inform*, 1, 198–204. DOI: https://doi.org/10.32983/2222-4459-2022-1-198-204

Kyzym, M. O., Belikova, N. V., & Bekker, M. L. (2021). Scientific and methodological support for solving problem situations in the regions of Ukraine. *Problemy ekonomiky*, 2, 70–85. DOI: https://doi.org/10.32983/2222-0712-2021-2-70-85

Manoilenko, O. V., Sergienko, O. A., & Gaponenko, O. Ye. (2020). Modeling of innovative activity of hierarchical systems: assessment of diffusion and economic effect of the existing potential and results. *Problemy ekonomiky,* 1 (43), 312–324. DOI: https://doi.org/10.32983/2222-0712-2020-1-312-324

Martinez-Galarraga, J., Roses, J. R., and Tirado, D. A. (2015). The Long-Term Patterns of Regional Economic Inequality in Spain. *Regional Studies*, 49 (4), 502–517. DOI: https://doi.org/10.1080/00343404.2013.783692

McCann, Ph. (2020). Perceptions of regional inequality and the geography of discontent: insights from the UK. *Regional Studies*, 54, (2), 256–267. DOI: https://doi.org/10.1080/00343404.2019.1619928

Melnikova, M. V. (2015). Matrix models in planning structural changes in the economy of the old industrial region. *Aktual'ni problemy rozvytku zovnishn'oekonomichnoyi ta innovatsiynoyi diyal'nosti:* coll. of science works of DonSUU. "Economy"; vol. XVI, issue 295. Mariupol: DonDUU.

Otenko, I., & Parkhomenko, N. (2019). Strategies of business systems development in global environment. *Scientific Annals of Economics and Business*, 66 (2), 153–166.

Scenario models of balanced socio-economic regional development (2013). Eds. T. S. Klebanova, & O. V. Mosenkov. Berdyans'k: FOP Tkachuk O. V.

Shebanin, V. S., Umanskaia, V. V., & Reshetilov, G. O. (2021). Development of territories in the system of state regional policy. *Rehional'na ekonomika*, 3, 28–35. DOI: https://doi.org/10.36818/1562-0905-2021-3-3

Shevchenko, O. (2021). The toolbox for recognizing the groups of Ukraine's regions by indicators of disparities in their social and economic development. *Biznes Inform*, 7, 115–126. DOI: https://doi.org/10.32983/2222-4459-2021-7-115-126

Received on: 14th of October, 2022
Accepted on: 25th of November, 2022
Published on: 30th of December, 2022