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Modeling the Harmony of Economic Development of Regions in the Context of Sustainable Development

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ABSTRACT

The study simulates the harmony of economic development of the regional economic systems in the context of sustainable development for the following successive stages: separation of indicators from the array of statistics in the regional context; standardization of indicators of economic development of the regional economic systems; use of correlation analysis to determine the integrated index of economic development of the regional economic systems; taking into account the coefficients of influence of indicators on the integrated index of economic development of the regional economic systems; determining the harmony of economic development of the regional economic systems using the hyperbolic Fibonacci cone; approbation of modeling the harmony of economic development of the regional economic systems. In accordance with the outlined stages, the proposed method was tested for the regions of Ukraine and an example was given in relation to the economic component of sustainable development. The highest integrated index of economic development is observed in Kyiv, and the lowest in Luhansk region, the difference between the values is 17.6 times. According to the results of calculations, the regions are grouped according to the harmonies of economic development, and cartographic analysis is given.

1. INTRODUCTION

For more than a decade, the fundamental paradigm of society has been the paradigm of sustainable development. It determines the evolutionary progress of social development. At the present stage, the world community is experiencing a turning point in evolution, aimed at reorienting planetary development in the direction of supporting human life and caring for the environment. Such a paradigm of social development corresponds to sustainable development, which provides for simultaneous economic, social and environmental orientation.

The issue of sustainable development, for many years in a row, is covered in scientific publications, due to the complexity, multifaceted nature and importance of this process. The issues of sustainable development covered are interdisciplinary, its aspects are revealed within the framework of philosophy, ecology, economics, law, sociology, economic and mathematical modeling and other disciplines.

However, despite significant achievements in the direction of the study of sustainable development, this phenomenon requires further study, including in the direction of modeling the harmony of economic development of regions in the context of sustainable development.

The purpose of this study is to substantiate the modeling of the harmony of the regional economic development in the context of sustainable development and testing of the proposed developments on the example of the regions of Ukraine. To achieve this goal, the authors proposed the guidelines for modeling the harmony of sustainable development of regions; the approbation of the offered developments on an example of the regions of Ukraine is carried out; the obtained results are worked out and the directions on increase of the harmony of the regional economic development are offered.

2. LITERATURE REVIEW

Many scientific works of domestic and foreign scientists are devoted to the study of sustainable development, including economic, social and environmental components. Among them should be noted: Abramova et al. [1]; Anishchenko et al. [2]; Barkhatov [3]; Bresciani et al. [4]; Chichkanov et al. [5]; Grigoraș-Ichim et al. [6]; Kosach et al. [7]; Li and Liu [8]; Mikayilova and Alekperov [9]; Nosova et al. [10]; Kharchenko et al. [11]; Raszka et al. [12]; Rokhim et al. [13]; Nusinova et al. [14]; Urasova et al. [15]; Viknianska et al. [16]; Yakovenko et al. [17]; Yan et al. [18] and other.

The authors of the article [9] segment economic areas in order to determine their prospects and investment attractiveness, using fuzzy set theories. Scientists conducted experimental research on the example of automatic classification of economic regions of the Republic of Azerbaijan by macroeconomic indicators.

The authors' study [18] assessed the intensity of energy saving in the European Union, which, unlike other studies, aims to determine whether efficient European countries are increasing the financing of electricity in their economies. According to the study, researchers have found that Germany, Sweden and Austria achieve reliable environmental measures and are environmentally efficient compared to other countries such as Denmark, Belgium, Spain, France or Ireland.

Researchers argue [4] that innovation and environmental sustainability are the key elements of a country's development and are important to ensure their continued competitiveness in the marketplace. The authors argue that the severity of the environmental policy has a positive effect on the effectiveness of innovation, showing a positive link between development, innovation and environmental sustainability.

The aim of the study [17] is to analyze the socio-economic sustainability of municipalities in the region by assessing its performance. The authors use a systematic approach to a comprehensive, structured and dynamic study of the socio-economic sustainability of municipalities in the region. The authors believe that the regional policy measures to equalize the level of socio-economic development should be developed taking into account the identified features of territorial development of municipal districts.

Scientists [15] are convinced that the process of developing and applying modern tools for analysis and assessment of spatial and sectoral features of regional development is extremely important. The authors argue the need for regular monitoring and application of the results of the analysis in the development and adjustment of strategies or plans for spatial and sectoral development.

The authors of the article [12] analyze the development potential of cities and municipalities of Walbrzych County in terms of social, economic and environmental potential. According to the study, researchers conclude that the municipal policy should be aimed at improving the living conditions of residents by creating new jobs, providing appropriate living conditions and services, as well as various sports and tourism.

At the heart of the article [10], it is noted that in the well-known definition of factors of sustainable economic development of steppe areas, territorial planning and formation of nature management structures were considered the most important. The authors argue that the basis for comprehensive programs of environmental, economic and noosphere development of the regions should be an innovative territorial approach through the rapid development of digital technologies, as well as the growth and rapid promotion of digital innovations.

Scientists from China [8] offer a comprehensive system for estimating the TOPSIS index based on the entropy weight method from five aspects of economic aggregate, economic structure, economic viability, development potential and living standards of the people of each province. Researchers have studied the asymmetry, inequality and imbalance of economic development in the central and western regions. The authors of the article are convinced that central and western regions have a certain economic potential and space for further development, which can be deeply explored.

Scientists [3] emphasize that problems of stability of the regional economies are especially important in modern conditions. The tendencies of instability of the indicators of social and economic development of the regions are revealed: gross regional product, investments in fixed capital, industrial production, consumer prices. The authors investigated that the dynamics of growth rates of these indicators is not constant. Scholars claim that socio-economic development of the regions is unstable. It has been studied that the instability level in the regions with a lower level of development is higher than in more developed ones.

The aim of the article [5] is a comprehensive assessment of well-being, taking into account economic factors of potential and growth. Scientists have proposed a diagnostic approach to assessing the state of the region's economy, taking into account the dynamics of indicators and the behavior of the impulse response of turning points. The authors used the method of rapid diagnostics, which made it possible to investigate, analyze and evaluate the trajectory of development in modern turbulent conditions.

Indonesian researches [13] have developed a model for assessing the effectiveness of local economic development. The authors identified two models that contribute to local productivity. Scientists believe that the business strategy is positively influenced by human resources, infrastructure, social capital and financial capital. The authors argue that the entrepreneurial strategy has a positive impact on local economic development.

The considered scientific researches of leading scientists are important for studying the economic component of sustainable development of regions, but the issue of modeling harmony of economic development in the context of sustainable development, which will determine a certain balance and proportionality of regional economy, requires in-depth scientific study and analysis.

3. METHODOLOGY

Theories of sustainable development distinguish different approaches to assessing the sustainable development of economic systems, which include both approaches to comparing the sustainability of countries and the author's methods for assessing sustainable development of economic systems at different levels. To assess sustainable development, the process system of indicators is most often used, which makes it possible to determine integrated indices of both sustainable development in general and its social, economic and environmental components. In addition, a common approach is based on modeling the provision of socio-economic system with natural resources, which makes it possible to build the models for the development of economic systems taking into account a set of heterogeneous factors of influence. Recently, due to the strengthening of decentralized management of economic systems, much attention is paid to the development of methodological approaches to assessing sustainable development at the local and regional levels. This and other things determine the relevance of modeling the harmony of the components of sustainable development of the regional economic systems.

The authors of the study propose to determine the harmony of economic development of the regional economic systems in the context of sustainable development. To this end, a process system of indicators on social, economic and environmental components in the context of sustainable development was identified, on the basis of which it was proposed to determine the integrated index and the harmony of the regional economic development in the context of sustainable development.

In this paper, the authors chose only the economic

component of sustainable development for further research. However, this does not mean that the economic component is more important or dominant in the definition of sustainable development. Further research will analyze environmental and social components of the proposed assessment methodology. The separation of only the economic component of sustainable development is due to the need to present a more thorough analysis and the results of calculations that more fully demonstrate scientific and practical value of this study.

To calculate the integrated index of the economic component of sustainable development of the regional economic systems, on the example of the regions of Ukraine, the indicators were identified, which are given in Table 1.

Table 1. Indicators for determining the integrated index of the regional economic development in the context of sustainable development

№	Indicators	Variables
1	GRP per capita (UAH)	x_1
2	Production of agricultural products per capita (at constant 2010 prices, UAH)	x_2
3	Volume of sold industrial products (goods, services) per capita (UAH)	x_3
4	Profitability of operating activities of enterprises (percent)	x_4
5	Capital investments, per capita (UAH)	x_5
6	Direct investment (share capital) per capita by regions of Ukraine (USD)	x_6
7	Total exports of goods (million USD)	x_7
8	Total exports of services (million USD)	x_8
9	Density of public railways (km per 1000 km of territory)	x_9
10	Density of public paved roads (km per 1000 km² of territory)	x_{10}
11	Freight turnover of road transport (million tons per km)	x_{11}
12	Passenger turnover of buses (million passenger km)	x_{12}
13	Departure of passengers by rail (million people)	x_{13}

Source: compiled and substantiated by the authors

The official source of statistics of Ukraine is the main source of the indicators separation. These indicators are generally defined macroeconomic indicators of the national accounts system and represent the results of regional entities that are unified in terms of the requirements for the implementation of the national accounts system. It should be noted that the indicators presented in Table 1 may be changed depending on changes and specifics of statistics of different countries. That is, some indicators can be added or removed. The proposed methodology of harmony of economic development of regions in the context of sustainable development is flexible in relation to the separation of indicators.

For further calculations of the harmony of the regional economic development in the context of sustainable development, it is necessary to calculate the integrated index of economic development of the regions. To find it, the authors proposed to use the definition of the integral index based on correlation analysis. Correlation analysis is the most optimal because it allows not only to calculate integrated indices on large arrays of statistical indicators, but also to take into account the importance of the impact on the integrated index of indicators, which gives more accurate calculations. The influence of indicators on the integrated index is taken into account due to impact factors and reveals the impact of changes in the integrated index of the regional economic development in the context of sustainable development depending on the changes in the most influential indicator in the form of regression.

Moreover, since statistical indicators have different dimensions, the procedure of their standardization is necessary to level the impact of their discharges on the calculation of the integrated index. The formula is used to standardize indicators of economic development in the context of sustainable development:

$$X_{ij} = \frac{x_{ij} - (x_{ij})\min}{(x_{ij})\max - (x_{ij})\min}, \quad (1)$$

where, X_{ij} - the standardized value of the i-th indicator in the j-th year;

x_{ij}, $\max(x_{ij})$, $\min(x_{ij})$ - respectively, the maximum or minimum value of the non-standardized value of the i-th indicator in the j-th year.

Further economic and mathematical modeling of the integrated index is done by building a matrix of standardized values of the regional economic development, namely:

$$A = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{18} \\ X_{21} & X_{22} & \dots & X_{28} \\ \dots & \dots & \dots & \dots \\ X_{is} & X_{is} & \dots & X_{ij} \end{bmatrix}, \quad (2)$$

where, A - matrix of standardized indicators of economic development of regions in the context of sustainable development for the study period;

X_{ij} - normalized values of statistical indicators of the regional economic development in the context of sustainable development.

As already mentioned, the degree of influence of the indicators of economic development on the integrated index of economic development in the context of sustainable development is determined by the impact factor (KE), which is calculated by the formula:

$$K_e = \left[(A^T \cdot A)^{-1} A^T\right] \cdot I_e, \quad (3)$$

where, A, A^T - respectively the matrix and the transposed matrix of standardized indicators of the regional economic development in the context of sustainable development;

I_e - integrated index of the regional economic development in the context of sustainable development.

The integrated index of the regional economic development in the context of sustainable development is calculated by the formula, which has the form:

$$Ie = K_0 + \sum_{j=1}^{m} K_{ei} \cdot x_i \quad (4)$$

where, K_0 - became a component of the coefficient of influence of the indicator;

K_{ei} - weight coefficient of the corresponding indicator-indicator of the regional economic development in the context of sustainable development;

x_i - indicator for assessing the regional economic development in the context of sustainable development.

However, the main idea of the authors is not to define an integrated indicator of economic development, but to model harmony of economic development of regions in the context of sustainable development.

Integrated indicators are often used to assess sustainable development, which is justified because sustainable development has a large number of indicators, and the use of integrated methods allows to take into account the relationships between them and determine the impact of individual indicators on the integrated index.

Without denying the importance and necessity of calculations of integrated indicators, I would like to emphasize that in sustainable development it is important not only the numerical value of the obtained integrated indicator, but also its harmony. This is especially important in relation to the monitoring of regions, as all regions have their own characteristics and potential, and taking into account harmony makes it possible to assess the effectiveness of the potential of the region in relation to sustainable development.

To model the harmony of economic development, you can use the "golden section" method. The Golden ratio method has been known since the time of Pythagoras. At the heart of this method is the principle of dividing the segment in the proportions of the golden section, which is the principle of solving optimization problems. To calculate the harmony, it is proposed to use the Fibonacci method, this is possible in our case, as the number of iterations is limited. The formula of the hyperbolic Fibonacci cone has the form:

$$H_e = \frac{(\lambda^{2\cdot(f)} - \lambda^{-2\cdot(f)})}{\mu}, \quad (5)$$

where, H_e - harmony of the regional economic development in the context of sustainable development of the i-th region according to the calculations of the golden ratio;

f^{10} - index of harmony of economic development in the context of sustainable development of the i-th region;

λ - set a constant to calculate the value of the "golden ratio", namely: $\lambda = 1{,}618$;

μ - established constant for the formula of the hyperbolic Fibonacci cone, namely: $\mu = 2{,}236$.

Definition of the harmony provides not only to determine the dynamics of economic development in the context of sustainable development, but also to establish a balance between the components of sustainable development, which allows to suggest ways to optimize development of economic systems in the context of sustainable development.

Summarizing the proposed methodology for modeling the harmony of the regional economic development in the context of sustainable development, we can identify the following stages (Figure 1):

firstly, the separation of indicators from the array of statistics by the regional context;

secondly, the standardization of the indicators of economic development of the regional economic systems in the context of sustainable development;

thirdly, the use of correlation analysis to determine the integrated index of economic development of the regional economic systems in the context of sustainable development;

fourthly, taking into account the coefficients of influence of the indicators on the integrated index of economic development of the regional economic systems in the context of sustainable development;

fifthly, using the Fibonacci hyperbolic cone to determine the harmony of the economic development of regional economic systems in the context of sustainable development;

sixthly, testing the modeling of the harmony of economic development of the regional economic systems in the context of sustainable development.

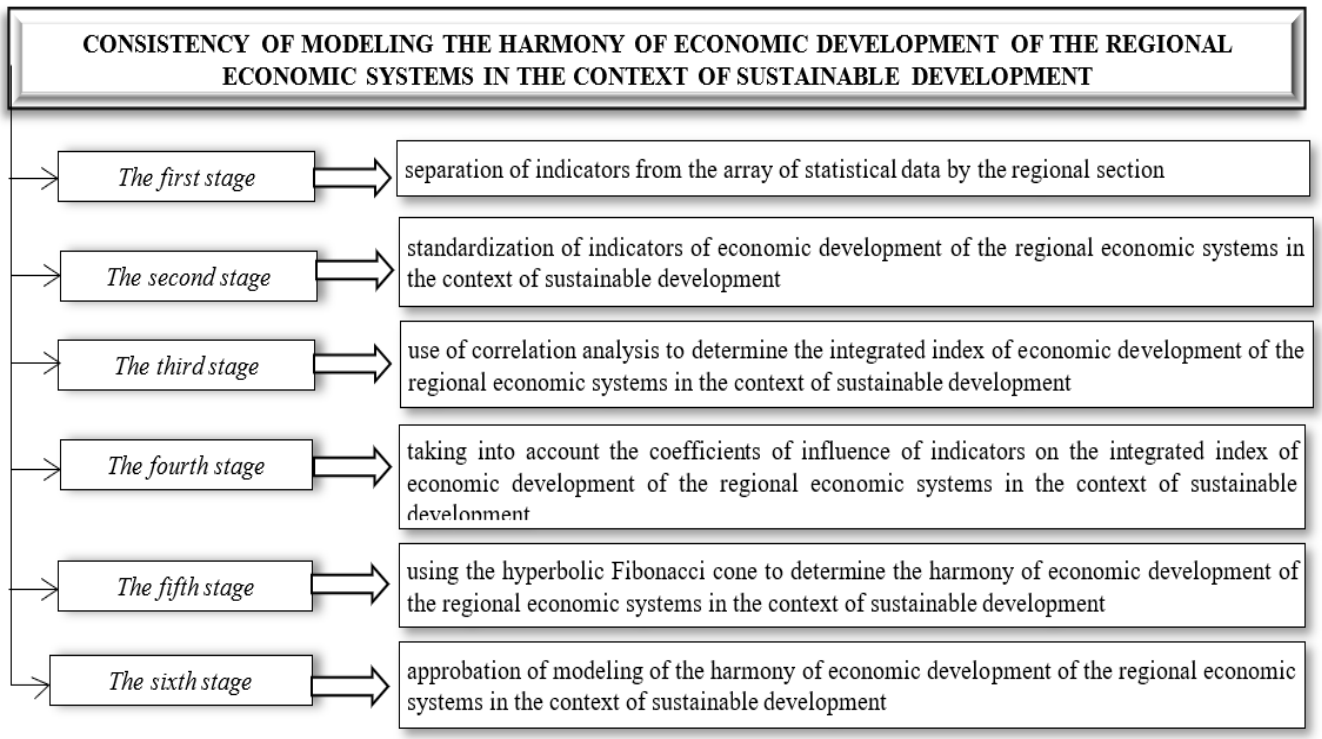

Figure 1. Sequence of modeling the harmony of economic development of the regional economic systems in the context of sustainable development

4. RESULTS

The sequence of calculations of the harmony of economic development of the regional economic systems in the context of sustainable development became the basis of the calculations of the harmony on the example of the regions of Ukraine. The approbation was performed using the MathCad-15 software, which is optimal for such calculations using a large array of statistical indicators and matrix calculations. MathCad-15 is a computer algebra system software for performing heterogeneous mathematical calculations. The use of this software makes it possible to obtain calculations with a high degree of accuracy and minimal errors. The built-in functions of the computer algebra system of this software make it possible to automatically design and facilitate the modeling of complex processes, which include harmony of economic development of the regional economic systems in the context of sustainable development.

According to the calculations according to the proposed sequence (see Figure 1), the calculations of the integrated index of the regional economic development in the context of sustainable development for the period from 2013 to 2020 were performed. The results of calculations are presented in Table 2.

The arithmetic mean value of the integrated index of the regional economic development in the context of sustainable development for all regions allows us to note that in 2013-2015 in Ukraine as a whole there is an increase in the value of the integrated index. Which changed to the opposite and in 2017-2018 was observed at a low level, namely the arithmetic mean index was 0.208. Over the last two years, the values of the integrated index have shown positive dynamics. In 2020, the integrated index was 0.062 more than the arithmetic mean of 2013.

In twelve regions during the study period, according to the results of calculations, there was a steady increase in the value of the integrated index of the regional economic development in the context of sustainable development. Such regions include Vinnytsia, Transcarpathian, Zaporizhia, Ivano-Frankivsk, Lviv, Mykolaiv, Odesa, Poltava, Sumy, Kherson, Khmelnytsky and Cherkasy regions.

It should also be noted that most of these regions in which during the study period there was an annual increase in the values of the integrated index of economic development in the context of sustainable development, have an average integrated indicator of the economic component of sustainable development below the arithmetic mean $I_{e\ avg.} = 0.221$. In other words, it can be noted that the most positive dynamics was shown by regions that are not leaders in economic development and have a greater potential to use available resources.

The results of calculations showed that nine regions, such as: Vinnytsia *($I_{e\ avg.} = 0.273$)*, Dnipropetrovsk *($I_{e\ avg.} = 0.315$)*, Zaporizhia *($I_{e\ avg.} = 0.273$)*, Kiev *($I_{e\ avg.} = 0.299$)*, Poltava *($I_{e\ avg.} = 0.261$)*, Kharkiv ($I_{e\ avg.} = 0.312$), Khmelnytsky *($I_{e\ avg.} = 0.299$)*, Chernihiv *($I_{e\ avg.} = 0.235$)* and Kyiv city *($I_{e\ avg.} = 0.739$)* have the average value of the integrated economic index development of regions in the context of sustainable development for the period under study more than the arithmetic mean $I_{e\ avg.} = 0.221$.

The highest integrated index of economic development in the context of sustainable development is observed in Kiev *($I_{e\ avg.} = 0.739$)*, and the lowest in Luhansk region *($I_{e\ avg.} = 0.042$)*, the difference is 17.6 times.

The next stage of the methodology proposed by the authors is to determine the harmony of economic development of regional economic systems in the context of sustainable development using the formula of the hyperbolic Fibonacci cone (see Formula 5). The calculations obtained using the software *MathCad-15* are presented in Table 3.

Table 2. Calculations of the integrated index of the regional economic development in the context of sustainable development (*Ie*) for 2013-2020

Region	I_e								$I_{e\ avg.}$
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Average value**
Vinnytsia	0.224	0.234	0.249	0.256	0.271	0.298	0.315	0.335	0.273
Volyn	0.071	0.074	0.076	0.075	0.074	0.089	0.096	0.106	0.083
Dnipropetrovsk	0.307	0.348	0.343	0.326	0.274	0.272	0.303	0.351	0.315
Donetsk	0.057	0.067	0.074	0.071	0.069	0.059	0.040	0.015	0.057
Zhytomyr	0.097	0.107	0.117	0.118	0.116	0.120	0.139	0.151	0.121
Transcarpathian	0.078	0.080	0.081	0.082	0.086	0.091	0.098	0.102	0.087
Zaporizhia	0.277	0.279	0.285	0.289	0.298	0.305	0.328	0.347	0.301
Ivano-Frankivsk	0.160	0.170	0.177	0.185	0.190	0.203	0.208	0.217	0.189
Kiev	0.813	0.911	0.982	0.897	0.756	0.805	0.968	1.038	0.897
Kirovohrad	0.160	0.129	0.152	0.368	0.173	0.147	0.173	0.158	0.183
Luhansk	0.039	0.042	0.039	0.036	0.033	0.027	0.023	0.020	0.042
Lviv	0.173	0.188	0.195	0.206	0.214	0.221	0.235	0.253	0.211
Mykolaiv	0.093	0.096	0.099	0.103	0.105	0.110	0.118	0.128	0.106
Odessa	0.161	0.174	0.182	0.183	0.118	0.174	0.218	0.222	0.179
Poltava	0.217	0.242	0.252	0.261	0.270	0.278	0.282	0.285	0.261
Rivne	0.087	0.102	0.131	0.137	0.122	0.119	0.085	0.056	0.105
Sumy	0.085	0.097	0.101	0.101	0.102	0.105	0.107	0.108	0.101
Ternopil	0.075	0.078	0.089	0.097	0.087	0.107	0.116	0.118	0.096
Kharkiv	0.301	0.343	0.343	0.331	0.275	0.266	0.295	0.338	0.312
Kherson	0.067	0.072	0.076	0.078	0.083	0.087	0.092	0.098	0.082
Khmelnytsky	0.236	0.271	0.287	0.303	0.314	0.317	0.329	0.335	0.299
Cherkasy	0.077	0.087	0.091	0.091	0.091	0.095	0.097	0.098	0.091
Chernivtsi	0.147	0.152	0.165	0.166	0.175	0.176	0.184	0.170	0.167
Chernihiv	0.189	0.205	0.214	0.222	0.239	0.252	0.263	0.300	0.235
Kyiv city	0.653	0.710	0.740	0.747	0.666	0.468	0.890	0.987	0.739
The arithmetic mean of the integral index in Ukraine ($I_{e\ avg.}$)	0.193	0.210	0.223	0.229	0.208	0.208	0.240	0.255	0.221

According to the presented results of the harmony of economic development of the regional economic systems in the context of sustainable development, it can be determined that such regions as: Khmelnytsky ($H_{e.\ avg.} = 0.895$), Dnipropetrovsk ($H_{e.\ avg.} = 0.844$), Poltava ($H_{e.\ avg.}$ = 0.833), Chernivtsi ($H_{e.\ avg.} = 0.803$) and Kirovohrad ($H_{e.\ avg.} = 0.767$) regions. The least harmonious economic development of regional economic systems in the context of sustainable development are: Volyn ($H_{e.\ avg.} = 0.239$), Ternopil ($H_{e.\ avg.} = 0.235$), Luhansk ($H_{e.\ avg.} = 0.358$), Kherson ($H_{e.\ avg.} = 0.372$) and Donetsk ($H_{e.\ avg.} = 0.377$) regions.

Such regions as Vinnytsia ($H_{e.\ avg.} = 0.378$), Volyn ($H_{e.\ avg.} = 0.239$), Donetsk ($H_{e.\ avg.} = 0.377$), Transcarpathian ($H_{e.\ avg.} = 0.383$), Luhansk ($H_{e.\ avg.} = 0.358$), Sumy ($H_{e.\ avg.} = 0.606$), Ternopil ($H_{e.\ avg.} = 0.235$), Kherson ($H_{e.\ avg.} = 0.372$), Cherkasy ($H_{e.\ avg.} = 0.604$) regions had an average value of the harmony during the study period economic development in the context of sustainable development is less than the arithmetic mean for all regions ($H_{e.\ avg.} = 0.617$).

Table 3. The value of the harmony of economic development of the regional economic systems in the context of sustainable development (*He*) for 2013-2020

Region	H_e								$H_{e\ avg.}$
	2013	2014	2015	2016	2017	2018	2019	2020	Average value
Vinnytsia	0.312	0.350	0.385	0.400	0.397	0.389	0.392	0.403	0.378
Volyn	0.222	0.221	0.186	0.295	0.178	0.311	0.218	0.279	0.239
Dnipropetrovsk	0.409	0.636	0.872	0.982	1.004	1.020	0.966	0.859	0.844
Donetsk	0.429	0.410	0.395	0.398	0.417	0.428	0.373	0.165	0.377
Zhytomyr	0.587	0.541	0.629	0.721	0.670	0.651	0.755	0.792	0.669
Transcarpathian	0.361	0.343	0.352	0.383	0.402	0.399	0.397	0.424	0.383
Zaporizhia	0.755	0.745	0.738	0.737	0.738	0.744	0.752	0.763	0.747
Ivano-Frankivsk	0.590	0.634	0.734	0.815	0.806	0.746	0.703	0.722	0.718
Kiev	0.685	0.787	0.834	0.795	0.710	0.683	0.719	0.713	0.740
Kirovohrad	0.768	0.690	0.757	0.701	0.849	0.744	0.813	0.816	0.767
Luhansk	0.414	0.356	0.321	0.332	0.388	0.432	0.389	0.228	0.358
Lviv	0.758	0.737	0.735	0.746	0.752	0.745	0.728	0.713	0.739
Mykolaiv	0.634	0.640	0.652	0.660	0.663	0.668	0.683	0.708	0.663
Odesa	0.428	0.668	0.761	0.614	0.455	0.684	0.781	0.601	0.624
Poltava	0.714	0.673	0.704	0.832	0.959	0.983	0.898	0.897	0.833
Rivne	0.584	0.694	0.752	0.791	0.801	0.756	0.595	0.206	0.648
Sumy	0.561	0.575	0.578	0.595	0.625	0.646	0.642	0.628	0.606
Ternopil	0.198	0.206	0.244	0.250	0.240	0.252	0.254	0.241	0.235
Kharkiv	0.770	0.779	0.767	0.744	0.714	0.692	0.699	0.722	0.736
Kherson	0.349	0.345	0.342	0.351	0.374	0.397	0.408	0.405	0.372
Khmelnytsky	0.738	0.837	0.888	0.932	0.961	0.964	0.939	0.902	0.895
Cherkasy	0.559	0.592	0.594	0.595	0.603	0.618	0.634	0.640	0.604
Chernivtsi	0.805	0.750	0.770	0.781	0.865	0.806	0.809	0.834	0.803
Chernihiv	0.677	0.635	0.647	0.722	0.821	0.872	0.848	0.798	0.752
Kyiv city	0.724	0.794	0.744	0.696	0.741	0.644	0.669	0.659	0.708
The arithmetic mean of the harmony in Ukraine ($H_{e\ avg.}$)	0.561	0.585	0.615	0.635	0.646	0.651	0.642	0.605	0.617

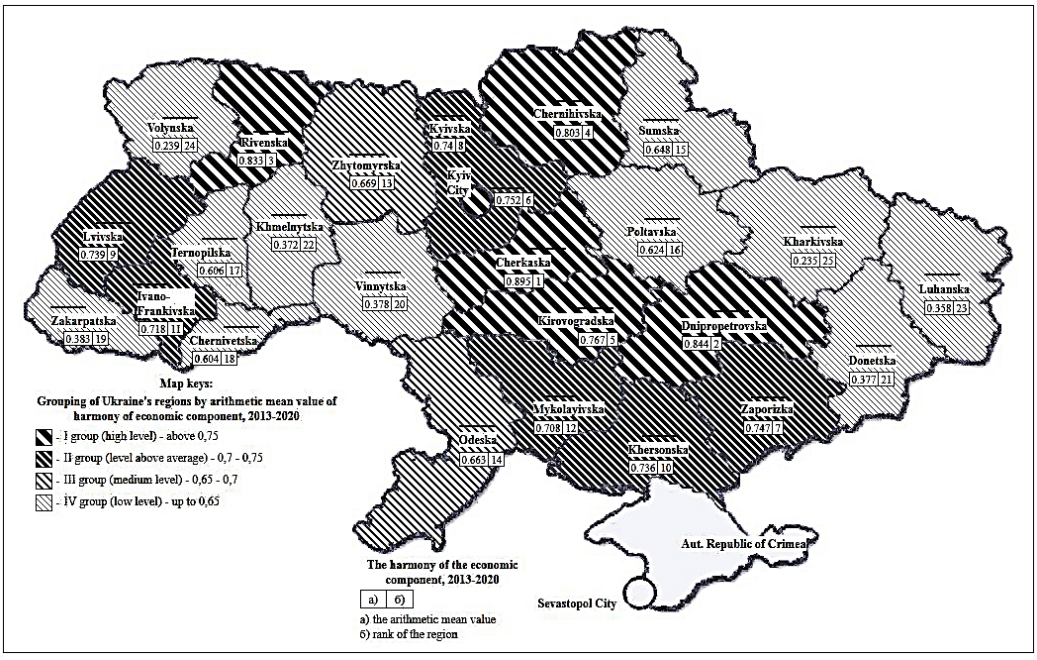

Figure 2. Grouping of regions of Ukraine by the importance of the harmony of economic development of the regional economic systems in the context of sustainable development

The highest level of harmony was observed on average during the study period in Khmelnytsky region ($H_{e.\ avg.} = 0.895$), and the lowest in Volyn region ($H_{e.\ avg.} = 0.239$). At the same time, the differentiation in harmony between these regions is 3.7 times, which is much smaller in relation to the asymmetry of the integrated index of economic development in the context of sustainable development.

The arithmetic mean of the harmony of economic development in all regions from 2013 to 2017 had a tendency to increase, but after that the positive trend changed to the opposite. In 2020, the arithmetic mean of the harmony of economic development ($H_{e.\ avg.} = 0.617$) was less than the value of the harmony of 2016-2019 ($H_{e.\ avg.} = 0.635$; $H_{e.\ avg.} = 0.646$; $H_{e.\ avg.} = 0.651$; $H_{e.\ avg.} = 0.642$ respectively). The lowest value of the harmony for the study period was observed in 2013 $H_{e.\ avg.} = 0.561$.

According to the authors, it is appropriate to group regions by the importance of the harmony of economic development of the regional economic systems in the context of sustainable development. This will provide an opportunity to suggest ways to increase the harmony of economic development in the context of sustainable development. The grouping of regions is presented in Figure 2.

Regions such as Khmelnytsky, Dnipropetrovsk, Poltava, Kirovohrad, Chernivtsi, Chernihiv belong to the first group of regions and are most important for the harmony of economic development in the context of sustainable development.

The second group of regions that have more importance than harmony are Zaporizhia, Ivano-Frankivsk, Kiev, Lviv, Kharkiv regions and the city of Kyiv.

Zhytomyr, Mykolaiv, and Odesa regions belong to the third group of regions with an average value of the harmony of economic development.

The fourth group of regions has low values of the harmony of economic development of Vinnytsia, Volyn, Donetsk, Transcarpathian, Luhansk, Ternopil and Kherson regions.

5. CONCLUSIONS

Modeling the harmony of the regional economic development in the context of sustainable development makes it possible to take into account such principles of sustainable development as ensuring economic growth while preserving the environment, improving the social sphere, balancing innovation and technological and economic development.

The scientific novelty of the study is the development of modeling the harmony of economic development in the context of sustainable development, which involves a sequence of such methodological stages as: separation of indicators, their standardization, and determination of integrated economic development index using correlation the analysis development through the use of the formula of the hyperbolic Fibonacci cone.

It should be noted that regions do not always have the same levels of harmonization and integrated index of economic development in the context of sustainable development. This suggests that the regions that may have a low integrated index of economic development may demonstrate its high harmony, and vice versa. That is, high economic performance does not necessarily show high harmony, and vice versa. The harmony states the relationship between economic, environmental and social components in the context of sustainable development. And higher values of economic development require greater efforts to protect the environment and ensure social development, which is not always the case.

The harmony of economic development of the regional economic systems in the context of sustainable development makes it possible to determine a certain balance and proportionality of the state of the regional economy.

Modeling the harmony of economic development on the example of the regions of Ukraine showed that the asymmetry between Khmelnytsky ($H_{e.avg.} = 0.895$) and Volyn ($H_{e.avg.} = 0.239$) regions is 3.7 times, which is less than the asymmetry between regions in terms of the integrated index of economic development.

Further research requires the inclusion of inclusive social development of the regional economic systems in the context of sustainable development.

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