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SHEVCHENKO, O.V.
The National Institute for Strategic Studies,
7a, Pyrogova St., Kyiv, 01030, Ukraine,
+380 44 234 5007, info-niss@niss.gov.ua

ELABORATION OF A MECHANISM FOR REGULATING DISPARITIES OF REGIONAL SOCIO-ECONOMIC DEVELOPMENT BY FUZZY LOGIC METHODS

Introduction. *Regions of Ukraine are characterized by a considerable level of disparities in socio-economic development. Interpretation of disparities is important in order to develop the measures preventing their aggravation.*

Problem Statement. *The indices of regional disparities are variable and heterogeneous, with different dynamics. Thus, it is difficult to estimate them with the help of conventional methods that do not allow application of intermediate indices.*

Purpose. *To formulate a mechanism for regulating regional disparities necessary for further solution of management and prognostic tasks based on innovative approaches given environmental variability, rapid, and nonlinear dynamics of disparities.*

Materials and Methods. *For estimation and interpretation of indices for regional disparities, it is advisable to use methods of fuzzy logic theory. These methods apply to quantitative estimation of qualitative information (in the case when it is indefinite), modeling of increasingly complicated economic processes given a high reliability of calculations based on fuzzy logic models.*

Results. *The mechanism for forecasting the dynamics of regional disparities by fuzzy logic methods has been presented as integration of interdependent factors ensuring development of the region under unstable conditions of external and internal environment. With the help of fuzzy logic methods, the membership function between the levels of disparities and the catalysts of disparities (retarders) has been built. The characteristics of regional disparity levels have been classified as permissible, regulated, and catastrophic. The study of dynamics of the disparity underlies elaborating public policy recommendations on the regulation of disparities.*

Conclusions. *The characteristics of disparities for each region estimated on the basis of membership function pave the way for further forecasting the dynamics of disparities and developing a strategy for the regulation of disparities in each region.*

Keywords: disparities of regional development, catalysts and retarders of disparity indicators, fuzzy logic methods, fuzzification, regulation of disparities.

The current state of the regions of Ukraine is characterized by significant disparities in socioeconomic development, the reduction of which is one of the goals of government strategy for regional development and regional development policy.

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Disparity as a dynamic economic phenomenon is considered not only as a major problem of regional development, but also as a resource for releasing the economic potential of regions. Therefore, it is important to study disparity in order to develop measures of government regional policy for its regulation. Interpretation of disparity indicators in the socioeconomic development of regions is important given the need to develop measures for preventing excessive growth of disparities and their regulation. The study of disparities and the development of ways to level them are important research and practical tasks, while the dynamics of disparities are interesting in terms of further development of practical recommendations for government policy to smooth disparities. So, it is necessary to make choice of methods for studying disparity as a dynamic phenomenon with many components that are influenced by many factors.

Disparities of socioeconomic development of regions have been studied in Ukraine and abroad. The studies related to improving the methodology of diagnosis and monitoring of disparities in socioeconomic development of regions are also noteworthy. T.S. Klebanova, T.N. Trunova, and A. Yu. Smirnova [1] have proposed an algorithm for assessing and analyzing disparities of social and economic development of regions, which allows organizing them, analyzing disparities, groupping regions by levels of social and economic development. S.G. Svetunkov, I.S. Svetunkov, M.O. Kizim, and T.S. Klebanova [2] have forecasted the regional development indicators that determine the trends and nature of the regional development dynamics and such results also have made it possible to assess regional disparities.

Foreign research works deal with the formation of regional policy aiming at supporting the equalization of disparities at the regional level in Europe and other countries. Ph. McCann [3] has examined which level, high or medium, of regional disparities there is in the United Kingdom and studied different indicators of disparities in order to understand their essence and different means of influencing them. J. Martinez-Galarraga, J.R. Roses, and D.A. Tirado [4] have shown that stable economic growth is accompanied by the evolution of disparities in regional revenues, which is also shall be studied.

L.S. Guryanova and S.V. Prokopovych [5] have assessed the convergence of territories while studying the disparities in their development; R. Martin [6] has contributed to the improvement of the methodology for the formation of regional development policy. I.Z Storonyanska [7], L.A. Chagovets, O.V. Nikiforova [8], and T.S. Klebanova [9] have assessed the disparities for the purpose of regional policy decisions.

The purpose of this research is to form a mechanism for regulating disparities in socioeconomic development of regions on the basis of innovative approaches that take into account the environment variability, rapid and nonlinear dynamics of disparities. Achieving this purpose consists of many tasks: to analyze various methods of mathematical research of economic phenomena and to identify which of them may be used to analyze the disparities in the regional development; to determine the ranges of factors influencing the disparities, variables and membership functions of disparity characteristics and the level of disparities for each region.

Influencing the disparities in the regional development is one of the goals of the government strategy for regional development and regional development policy. There is a question of application of methods for studying disparities as the dynamic phenomenon with many components that are under the influence of a set of factors. Various researchers have suggested the possibility of using fuzzy logic. The principles of modeling economic processes on the basis of heterogeneous data have been presented in research of V.M. Semyanovsky [10, 122—130] where, in particular, the possibility of using fuzzy logic methods has been substantiated. According to L.A. Zadeh, fuzzy logic allows quantifying the fuzzy linguistic characteristics of the processes and phenomena that are typical for human thinking through

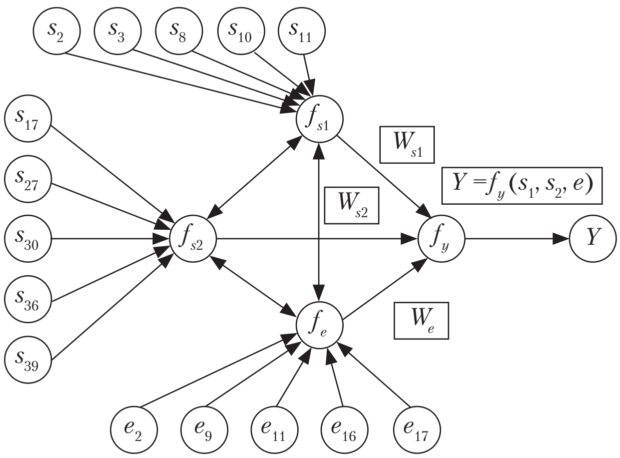

Fig. 1. Neural network of disparities in socioeconomic development of regions
Source: author's development.

special membership functions [11]. According to S.M. Marushchak, the use of a hierarchical system of fuzzy inference enables solving the problem of database dimension and adequately describing the multidimensional relationships between input and output calculations [12, 18—20], which concerns measuring disparities. Significant advantages of this approach in terms of assessing the development of economic systems of different levels have been noted by T.L. Zubko [13], S.D. Shtovba [14], L.A. Ostankova and N.Yu. Shevchenko [15], A.V. Matviychuk [16], and N.O. Ivanchenko [17]. The advantage of the fuzzy-multiple approach is the possibility of its application for quantification of qualitative information in the case of its high uncertainty.

That is, the use of fuzzy logic methods for the diagnosis of disparities in socioeconomic development of regions is appropriate, given the probabilistic nature of disparities arising in the context of the impact of catalysts and retarders on the disparities and the possibility of operating intermediate values. The choice of parameters for diagnostic assessment of regional disparities has been described by Shevchenko O.V. [18]. Based on them, the authors of [19] have calculated the integrated indicator of disparities in the socioeconomic development of territories with the use of the weighted taxonomic method. Research [20] has presented catalysts and retarders of regional development, which affect the integrated indicator of regional disparities. With this in mind, the level of disparities in the development of territories using the fuzzy logic theory can be determined by formula (1):

$$\hat{y}\,(P + 1) = f\,(\textstyle\sum_{i=1}^{n} y(P - n + 1)\, w_L, \qquad (1)$$

where $\hat{y}\,(P + 1)$ is the input variable function; f is the neuron activation function (sigmoid function); $y\,(P - n + 1)$ are linguistic variables of the i-th neuron signal; n is the number of inputs of the i-th neuron signal; w_i is weight of the i-th signal (quality term).

The fuzzy logic model of the disparities in the socioeconomic development of territories has been constructed on the basis of the neural networks method (Fig. 1) [21, 126—131]. That is, the assessment of the level of disparities in the socioeconomic development of the regions is based on the construction of a multilayer network for

Table 1. **Ranges of Variations in Catalysts (Retarders) of Socioeconomic Development of Regions**

Factor	Minimum value	Maximum value
$s^{*}2$	0.022	0.752
$s3$	0.025	0.899
$s8$	–0.241	0.685
$s10$	–0.095	0.866
$s11$	–0.315	0.761
$s17$	–0.054	0.892
$e^{**}2$	–0.016	0.682
$e9$	–0.048	0.838
$s27$	–0.034	0.913
$s30$	–0.181	0.716
$s36$	–0.042	0.841
$s39$	–0.694	0.038
$e11$	–0.046	0.911
$e16$	–0.165	0.801
$e17$	–0.877	–0.005

Note: *s is catalyst (retarder) of the social development of region, **e is catalyst (retarder) of the economic development of region.
Source: Estimated by the author based on [19].

the assessment of disparities. Such a multilayer network, according to the fuzzy logic methods, is a system of linguistic variables (model parameters) formed on universal sets and fuzzy terms.

The advantages of this method are that the use of neural network analysis does not allow restrictions on input information, and this leads to correlations on the state of socioeconomic development of regions in the internal and external environment. The construction of a fuzzy inference involves the four successive stages: fuzzification; formation of a fuzzy inference on the basis of given rules that put each value of linguistic variable in correspondence to a fuzzy subset of the set of input parameters; composition; and defuzzification. Thus, the whole process of fuzzy description of the control object can be divided into the following stages: fuzzification (values of source variables are converted into knowledge of linguistic variables with the use of the membership function), development of fuzzy rules (definition of rules that link linguistic variables), and defuzzification (transition from fuzzy values to certain parameters).

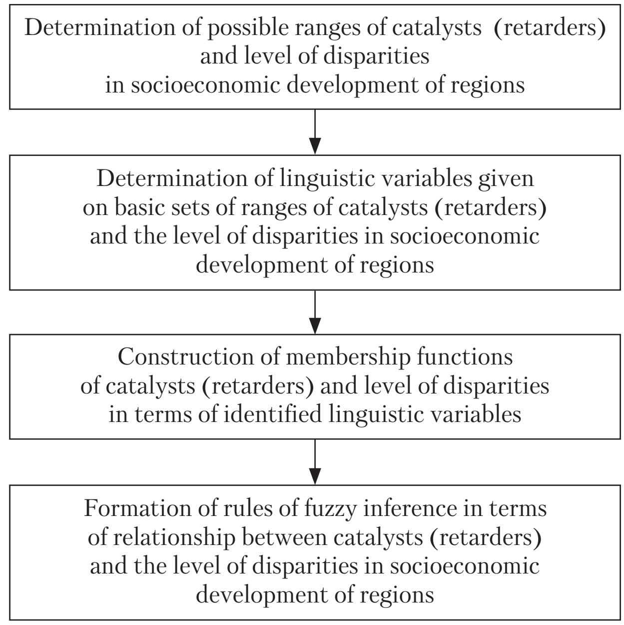

Fig. 2. Algorithm for forming qualitative relationships between catalysts (retarders) and the level of disparities in socioeconomic development of regions based on the rules of fuzzy inference
Source: author's development.

The mechanism of forecasting the dynamics of disparities in socioeconomic development of regions by fuzzy logic can be represented as the integration of interdependent and interrelated factors that ensure the development of the region in the relevant areas of instability of external and internal environment. To form qualitative relationships between catalysts (retarders) and disparities

Table 2. **Ranges of Integral Level of Disparities in the Socioeconomic Development for Each Region**

Region	Minimum value	Maximum value	Region	Minimum value	Maximum value
AR of the Crimea	0.152	0.232	Odesa Oblast	0.204	0.333
Vinnytsia Oblast	0.154	0.249	Poltava Oblast	0.180	0.316
Volhynian Oblast	0.167	0.275	Rivne Oblast	0.166	0.251
Dnipropetrovsk Oblast	0.200	0.370	Sumy Oblast	0.148	0.265
Donetsk Oblast	0.157	0.288	Ternopil Oblast	0.158	0.262
Zhytomyr Oblast	0.153	0.242	Kharkiv Oblast	0.220	0.356
Zakarpattia Oblast	0.165	0.276	Kherson Oblast	0.149	0.241
Zaporizhia Oblast	0.195	0.316	Khmelnytskyi Oblast	0.150	0.246
Ivano-Frankivsk Oblast	0.175	0.295	Cherkasy Oblast	0.159	0.260
Kyiv Oblast	0.168	0.388	Chernivtsi Oblast	0.172	0.271
Kirovohrad Oblast	0.132	0.241	Chernihiv Oblast	0.147	0.238
Luhansk Oblast	0.107	0.268	City of Kyiv	0.358	0.714
Lviv Oblast	0.193	0.334	City of Sevastopol	0.156	0.232
Mykolaiv Oblast	0.169	0.273			

Source: Estimated by the author based on [19].

in the socioeconomic development of the regions, it has been proposed to use the algorithm shown in Fig. 2. Accordingly, at the first stage, it is necessary to determine the ranges of variations in the factors that form the catalysts (retarders) of the formation of socioeconomic disparities in the regional development. These ranges are determined according to their calculations for 11 observed periods (2007—2017). For comparability of the obtained information, the data are normalized over the entire time interval and grouped by the principal components method [19]. As a result, the following ranges of catalysts (retarders) of socioeconomic development of the territories have been obtained (Table 1).

Similarly, the ranges of integral level of disparities in the socioeconomic development for each region (Table 2) have been determined.

Let us determine the linguistic variables that correspond to the listed variables (Tables 1—2) according to the range of their variations, having scaled the values of catalysts on the interval [0, 1] and retarders on the interval [−1, 0]. For the catalyst variables (Table 1), each range shall be divided

Table 3. **Determination of Linguistic Variables for Catalysts and Retarders of Disparities in Socioeconomic Development**

Input variable	Linguistic variable	Range of values	Input variable	Linguistic variable	Range of values
*s*2 catalyst	Moderate catalyst effect	(0; 0.3)	*s*30 catalyst	Moderate catalyst effect	(0; 0.33)
	Strong catalyst effect	(0.3; 0.7)		Strong catalyst effect	(0.33; 0.87)
	Excessive catalyst effect	(0.7; 1)		Excessive catalyst effect	(0.87; 1)
*s*2 retarder	Weak retarder effect	(−0.3; 0)	s36 catalyst	Moderate catalyst effect	(0; 0.23)
	Aggressive retarder effect	(−0.7; −0.3)		Strong catalyst effect	(0.23; 0.65)
	Catastrophic retarder effect	(−1; −0.7)		Excessive catalyst effect	(0.65; 1)
*s*3 catalyst	Moderate catalyst effect	(0; 0.25)	*s*39 catalyst	Moderate catalyst effect	(0; 0.4)
	Strong catalyst effect	(0.25; 0.55)		Strong catalyst effect	(0.4; 0.6)
	Excessive catalyst effect	(0.55; 1)		Excessive catalyst effect	(0.6; 1)
*s*3 retarder	Weak retarder effect	(−0.25; 0)	*e*2 catalyst	Moderate catalyst effect	(0; 0.3)
	Aggressive retarder effect	(−0.55; −0.25)		Strong catalyst effect	(0.3; 0.5)
	Catastrophic retarder effect	(−1; −0.55)		Excessive catalyst effect	(0.5; 1)
*s*8 retarder	Weak retarder effect	(−0.35; 0)	*e*9 catalyst	Moderate catalyst effect	(0; 0.28)
	Aggressive retarder effect	(−0.6; −0.35)		Strong catalyst effect	(0.28; 0.7)
	Catastrophic retarder effect	(−1; −0.6)		Excessive catalyst effect	(0.7; 1)
*s*10 catalyst	Moderate catalyst effect	(0; 0.3)	*e*11 retarder	Weak retarder effect	(−0.28; 0)
	Strong catalyst effect	(0.3; 0.6)		Aggressive retarder effect	(−0.65; −0.28)
	Excessive catalyst effect	(0.6; 1)		Catastrophic retarder effect	(−1; −0.65)
*s*11 retarder	Weak retarder effect	(−0.4; 0)	*e*16 catalyst	Moderate catalyst effect	(0; 0.45)
	Aggressive retarder effect	(−0.87; −0.4)		Strong catalyst effect	(0.45; 0.8)
	Catastrophic retarder effect	(−1; −0.87)		Excessive catalyst effect	(0.8; 1)
*s*17 catalyst	Moderate catalyst effect	(0; 0.4)	*e*17 retarder	Weak retarder effect	(−0.32; 0)
	Strong catalyst effect	(0.4; 0.7)		Aggressive retarder effect	(−0.47; −0.32)
	Excessive catalyst effect	(0.7; 1)		Catastrophic retarder effect	(−1; −0.47)
*s*27 catalyst	Moderate catalyst effect	(0; 0.35)			
	Strong catalyst effect	(0.35; 0.77)			
	Excessive catalyst effect	(0.77; 1)			

Source: Estimated by the author based on [19].

into three intervals which correspond to the linguistic variables "Moderate catalyst effect", "Strong catalyst effect", "Excessive catalyst effect". The following linguistic variables are introduced for the retarder variables: "Weak retarder effect", "Aggressive retarder effect", "Catastrophic retarder effect" [1, 11] (Table 3). It is taken into account that the indicators of the social group s2 and s3 can act as catalysts and as retarder of the territory development.

Based on certain linguistic variables, it is possible to construct membership functions for each

Table 4. **Membership Functions for Linguistic Variables of Catalysts and Retarders of Disparities in Socioeconomic Development of Regions**

Input variable	Linguistic variable	Range of variations	Input variable	Linguistic variable	Range of variations
*s*2 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.3)$ $\mu(x) = zmf(0.3; 0.7)$ $\mu(x) = smf(0.7; 1)$	*s*30 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.33)$ $\mu(x) = zmf(0.33; 0.87)$ $\mu(x) = smf(0.87; 1)$
*s*2 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.3; 0)$ $\mu(x) = zmf(-0.7; -0.3)$ $\mu(x) = smf(-1; -0.7)$	s36 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.23)$ $\mu(x) = zmf(0.23; 0.65)$ $\mu(x) = smf(0.65; 1)$
*s*3 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.25)$ $\mu(x) = zmf(0.25; 0.55)$ $\mu(x) = smf(0.55; 1)$	*s*39 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.4)$ $\mu(x) = zmf(0.4; 0.6)$ $\mu(x) = smf(0.6; 1)$
*s*3 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.25; 0)$ $\mu(x) = zmf(-0.55; -0.25)$ $\mu(x) = smf(-1; -0.55)$	*e*2 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.3)$ $\mu(x) = zmf(0.3; 0.5)$ $\mu(x) = smf(0.5; 1)$
*s*8 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.35; 0)$ $\mu(x) = zmf(-0.6; -0.35)$ $\mu(x) = smf(-1; -0.6)$	*e*9 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.28)$ $\mu(x) = zmf(0.28; 0.7)$ $\mu(x) = smf(0.7; 1)$
*s*10 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.3)$ $\mu(x) = zmf(0.3; 0.6)$ $\mu(x) = smf(0.6; 1)$	*e*11 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.28; 0)$ $\mu(x) = zmf(-0.65; -0.28)$ $\mu(x) = smf(-1; -0.65)$
*s*11 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.4; 0)$ $\mu(x) = zmf(-0.87; -0.4)$ $\mu(x) = smf(-1; -0.87)$	*e*16 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.45)$ $\mu(x) = zmf(0.45; 0.8)$ $\mu(x) = smf(0.8; 1)$
*s*17 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.4)$ $\mu(x) = zmf(0.4; 0.7)$ $\mu(x) = smf(0.7; 1)$	*e*17 retarder	Weak retarder effect Aggressive retarder effect Catastrophic retarder effect	$\mu(x) = gaussmf(-0.32; 0)$ $\mu(x) = zmf(-0.47; -0.32)$ $\mu(x) = smf(-1; -0.47)$
*s*27 catalyst	Moderate catalyst effect Strong catalyst effect Excessive catalyst effect	$\mu(x) = gaussmf(0; 0.35)$ $\mu(x) = zmf(0.35; 0.77)$ $\mu(x) = smf(0.77; 1)$			

Source: Author'sdevelopment.

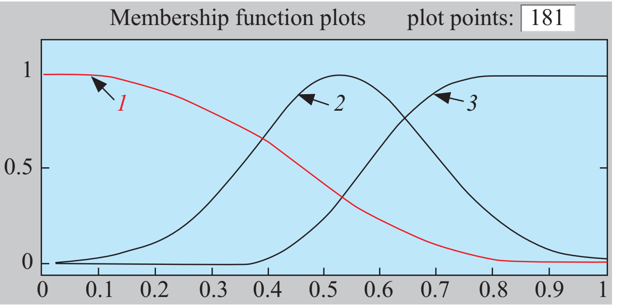

Fig. 3. The results of constructing the membership function for a fuzzy set corresponding to the linguistic variable "Moderate influence of catalyst s2" by *MathLab*: *1* — moderate effect of catalyst or weak effect of retarder; *2* — strong effect of catalyst or aggressive effect of retarder; *3* — excessive effect of catalyst or catastrophic effect of retarder. The X axis is the factor value (linguistic variable) in the range [0; 1], the Y axis is the probability of a certain value of the factor in the range [0; 1]
Source: author's development.

variable. For example, we have constructed a membership function for a fuzzy set corresponding to the linguistic variable "Moderate effect of catalyst s2", which corresponds to a range of values from 0 to 0.3, with each value of this range belonging to a fuzzy set "Moderate effect of catalyst s2" with a certain probability that for 0 is equal to 1 and decreases as range values increase. The degree of assignment of range values to a given fuzzy set is represented as a membership function of the following form (2):

$$\mu(x) = (1/0;\ 1/0.05;\ 0.8/0.1;\ 0.6/0.15;\ 0.5/0.2;\ 0.4/0.25;\ 0.3/0.27;\ 0.2/0.29;\ 0.1/0.3), \quad (2)$$

in which, for example, the element 1/0.05 means that value 0.05 of the catalyst s2 refers to a fuzzy set "Moderate effect of the catalyst s2" with a probability of 1.

The constructed membership function is approximated by means of PP *MathLab* (extension of *Fuzzy Logic Toolbox*) with the use of *Z*-function (*zmf*) with the following parameters: $\mu(x) = zmf(0; 0.3)$, which is shown in Fig. 3.

Fig. 3 features that the dependence (1 — moderate) can be mathematically described by *Z* function (having the form of the letter *Z*), in which the factor values (linguistic variable "Moderate effect of catalyst s2") are indicated on the X axis and the probability of such value of the factor are shown on the Y axis. Since the specified linguistic variable has values starting with 0, as they increase, the probability of their assignment to the set of values "Moderate effect of the catalyst" decreases.

With the use of similar considerations, on the basis of certain ranges for catalysts and retarders, the membership functions have been constructed (Table 4).

The second dependence (2 — strong) shown in Fig. 3, is mathematically described by the Gaussian function (*gaussmf*). The factor values (linguistic variable "Strong influence of the catalyst s2") and the probability of such factor value are indicated on the X axis and the Y axis, respectively. The linguistic variable values close to 0.5 have the maximum probability of "1"; as they rise and fall at regular intervals, the probability of these values decreases symmetrically.

The third dependence (3 – excessive) shown in Fig. 3 is mathematically described by the S-function (smf). The factor values (the linguistic variable "Excessive influence of the catalyst s2") are indicated on the X axis, and the probability of such factor value is indicated on the Y axis. The probability of assigning values to this fuzzy set is zero for all values less than 0.4 and further increases rapidly to 1 following the bends of the letter S. The largest values of the linguistic variable close to 1 have the highest probability of "1".

The ranges and linguistic variables for disparities in socioeconomic development of territories for each region have been determined. Let us define the linguistic variables according to the range of variations of this indicator: "Permissible disparity", "Controllable disparity", and "Catastrophic disparity" (Table 5).

The Table describes the level of disparities for each region: permissible, controllable, and catastrophic. Further, based on the defined ranges and linguistic variables of the membership function for the values of disparities in socioeconomic develop-

Table 5. **Ranges. Linguistic Variables of Integral Level of Disparities in Socioeconomic Development for Each Region**

Region	Input variable	Linguistic Variable (disparity level)	Range of values	Range of values
Vinnytsia Oblast	I_2	Permissible	(0.154; 0.19)	μ (x) = *gaussmf*(0.154; 0.19)
		Controllable	(0.19; 0.22)	μ (x) = *zmf*(0.19; 0.22)
		Catastrophic	(0.22; 0.249)	μ (x) = *smf*(0.22; 0.249)
Volhynian Oblast	I_3	Permissible	(0.167; 0.185)	μ (x) = *gaussmf*(0.167; 0.185)
		Controllable	(0.185; 0.25)	μ (x) = *zmf*(0.185; 0.25)
		Catastrophic	(0.25; 0.275)	μ (x) = *smf*(0.25; 0.275)
Dnipropetrovsk Oblast	I_4	Permissible	(0.2; 0.25)	μ (x) = *gaussmf*(0.2; 0.25)
		Controllable	(0.25; 0.3)	μ (x) = *zmf*(0.25; 0.3)
		Catastrophic	(0.3; 0.37)	μ (x) = *smf*(0.3; 0.37)
Donetsk Oblast	I_5	Permissible	(0.157; 0.2)	μ (x) = *gaussmf*(0.157; 0.2)
		Controllable	(0.2; 0.25)	μ (x) = *zmf*(0.2; 0.25)
		Catastrophic	(0.25; 0.288)	μ (x) = *smf*(0.25; 0.288)
Zhytomyr Oblast	I_6	Permissible	(0.153; 0.18)	μ (x) = *gaussmf*(0.153; 0.18)
		Controllable	(0.18; 0.2)	μ (x) = *zmf*(0.18; 0.2)
		Catastrophic	(0.2; 0.242)	μ (x) = *smf*(0.2; 0.242)
Zakarpattia Oblast	I_7	Permissible	(0.165; 0.19)	μ (x) = *gaussmf*(0.165; 0.19)
		Controllable	(0.19; 0.24)	μ (x) = *zmf*(0.19; 0.24)
		Catastrophic	(0.24; 0.276)	μ (x) = *smf*(0.24; 0.276)
Zaporizhia Oblast	I_8	Permissible	(0.195; 0.24)	μ (x) = *gaussmf*(0.195; 0.24)
		Controllable	(0.24; 0.28)	μ (x) = *zmf*(0.24; 0.28)
		Catastrophic	(0.28; 0.316)	μ (x) = *smf*(0.28; 0.316)
Ivano-Frankivsk Oblast	I_9	Permissible	(0.175; 0.21)	μ (x) = *gaussmf*(0.175; 0.21)
		Controllable	(0.21; 0.26)	μ (x) = *zmf*(0.21; 0.26)
		Catastrophic	(0.26; 0.295)	μ (x) = *smf*(0.26; 0.295)
Kyiv Oblast	I_{10}	Permissible	(0.168; 0.235)	μ (x) = *gaussmf*(0.168; 0.235)
		Controllable	(0.235; 0.315)	μ (x) = *zmf*(0.235; 0.315)
		Catastrophic	(0.315; 0.388)	μ (x) = *smf*(0.315; 0.388)
Kirovohrad Oblast	I_{11}	Permissible	(0.132; 0.165)	μ (x) = *gaussmf*(0.132; 0.165)
		Controllable	(0.165; 0.21)	μ (x) = *zmf*(0.165; 0.21)
		Catastrophic	(0.21; 0.241)	μ (x) = *smf*(0.21; 0.241)
Luhansk Oblast	I_{12}	Permissible	(0.107; 0.155)	μ(x)= *gaussmf*(0.107; 0.155)
		Controllable	(0.155; 0.221)	μ(x)= *zmf*(0.155; 0.221)
		Catastrophic	(0.221; 0.268)	μ(x)= *smf*(0.221; 0.268)
Lviv Oblast	I_{13}	Permissible	(0.193; 0.243)	μ(x)= *gaussmf*(0.193; 0.243)
		Controllable	(0.243; 0.293)	μ(x)= *zmf*(0.243; 0.293)
		Catastrophic	(0.293; 0.334)	μ(x)= *smf*(0.293; 0.334)
Mykolaiv Oblast	I_{14}	Permissible	(0.169; 0.205)	μ(x)= *gaussmf*(0.169; 0.205)
		Controllable	(0.205; 0.235)	μ(x)= *zmf*(0.205; 0.235)
		Catastrophic	(0.235; 0.273)	μ(x)= *smf*(0.235; 0.273)
Odesa Oblast	I_{15}	Permissible	(0.204; 0.245)	μ(x)= *gaussmf*(0.204; 0.245)
		Controllable	(0.245; 0.295)	μ(x)= *zmf*(0.245; 0.295)
		Catastrophic	(0.295; 0.333)	μ(x)= *smf*(0.295; 0.333)

End of the table 5

Region	Input variable	Linguistic Variable (disparity level)	Range of values	Range of values
Poltava Oblast	I_{16}	Permissible	(0.180; 0.225)	$\mu(x) = gaussmf(0.180; 0.225)$
		Controllable	(0.225; 0.265)	$\mu(x) = zmf(0.225; 0.265)$
		Catastrophic	(0.265; 0.316)	$\mu(x) = smf(0.265; 0.316)$
Rivne Oblast	I_{17}	Permissible	(0.166; 0.19)	$\mu(x) = gaussmf(0.166; 0.19)$
		Controllable	(0.19; 0.22)	$\mu(x) = zmf(0.19; 0.22)$
		Catastrophic	(0.22; 0.251)	$\mu(x) = smf(0.22; 0.251)$
Sumy Oblast	I_{18}	Permissible	(0.148; 0.185)	$\mu(x) = gaussmf(0.148; 0.185)$
		Controllable	(0.185; 0.225)	$\mu(x) = zmf(0.185; 0.225)$
		Catastrophic	(0.225; 0.265)	$\mu(x) = smf(0.225; 0.265)$
Ternopil Oblast	I_{19}	Permissible	(0.158; 0.195)	$\mu(x) = gaussmf(0.158; 0.195)$
		Controllable	(0.195; 0.235)	$\mu(x) = zmf(0.195; 0.235)$
		Catastrophic	(0.235; 0.262)	$\mu(x) = smf(0.235; 0.262)$
Kharkiv Oblast	I_{20}	Permissible	(0.220; 0.25)	$\mu(x) = gaussmf(0.220; 0.25)$
		Controllable	(0.25; 0.3)	$\mu(x) = zmf(0.24; 0.3)$
		Catastrophic	(0.3; 0.356)	$\mu(x) = smf(0.3; 0.356)$
Kherson Oblast	I_{21}	Permissible	(0.149; 0.18)	$\mu(x) = gaussmf(0.149; 0.18)$
		Controllable	(0.18; 0.215)	$\mu(x) = zmf(0.18; 0.215)$
		Catastrophic	(0.215; 0.241)	$\mu(x) = smf(0.215;0.241)$
Khmelnytskyi Oblast	I_{22}	Permissible	(0.150; 0.195)	$\mu(x) = gaussmf(0.150; 0.195)$
		Controllable	(0.195; 0.22)	$\mu(x) = zmf(0.195; 0.22)$
		Catastrophic	(0.22; 0.246)	$\mu(x) = smf(0.22; 0.246)$
Cherkasy Oblast	I_{23}	Permissible	(0.159; 0.19)	$\mu(x) = gaussmf(0.159; 0.19)$
		Controllable	(0.19; 0.23)	$\mu(x) = zmf(0.19; 0.23)$
		Catastrophic	(0.23; 0.26)	$\mu(x) = smf(0.23; 0.26)$
Chernivtsi Oblast	I_{24}	Permissible	(0.172; 0.21)	$\mu(x) = gaussmf(0.172; 0.21)$
		Controllable	(0.21; 0.24)	$\mu(x) = zmf(0.21; 0.24)$
		Catastrophic	(0.24; 0.271)	$\mu(x) = smf(0.24; 0.271)$
Chernihiv Oblast	I_{25}	Permissible	(0.147; 0.175)	$\mu(x) = gaussmf(0.147; 0.175)$
		Controllable	(0.175; 0.2)	$\mu(x) = zmf(0.175; 0.2)$
		Catastrophic	(0.2; 0.238)	$\mu(x) = smf(0.2; 0.238)$
City of Kyiv	I_{26}	Permissible	(0.358; 0.45)	$\mu(x) = gaussmf(0.358; 0.45)$
		Controllable	(0.45; 0.55)	$\mu(x) = zmf(0.45; 0.55)$
		Catastrophic	(0.55; 0.714)	$\mu(x) = smf(0.55; 0.714)$

Note: without AR of the Crimea and the city of Sevastopol taken into consideration.
Source: Author'sdevelopment.

ment for each region, it is necessary to form rules of fuzzy inference in terms of relationship between catalysts (retarders) and the level of disparities.

This research has proposed a mechanism for regulating the disparities in socioeconomic development of regions on the basis of innovative approaches with the use of fuzzy logic methods that take into account the variability of the environment, rapid and nonlinear dynamics of disparities. With the help of these methods, the ranges and linguistic variables of the integrated level of disparities in socioeconomic development for each region have been determined. Based on the identified linguistic variables, the membership functions for each variable have been constructed. The levels of disparities in regions have been classified as permissible, controllable, and catastrophic.

The calculated characteristics of the levels of disparities in each region are the basis for developing strategies to control disparities.

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О.В. Шевченко
Національний інститут стратегічних досліджень,
вул. Пирогова, 7а, Київ, 01030, Україна,
+380 44 234 5007, info-niss@niss.gov.ua

РОЗРОБКА МЕХАНІЗМУ РЕГУЛЮВАННЯ ДИСПРОПОРЦІЙ СОЦІАЛЬНО-ЕКОНОМІЧНОГО РОЗВИТКУ РЕГІОНІВ МЕТОДАМИ НЕЧІТКОЇ ЛОГІКИ

Вступ. Регіони України характеризується значним рівнем диспропорцій соціально-економічного розвитку. Інтерпретація індикаторів диспропорцій є важливою з огляду на необхідність розробки заходів з недопущення надмірного їх зростання.

Проблематика. Показники диспропорційності регіонів є швидкозмінними, із різною динамікою, різнорідними, тому їх важко оцінити за допомогою чітких традиційних методів, які не дозволяють оперувати проміжними значеннями.

Мета. Формування механізму регулювання диспропорцій регіонів для подальшого розв'язання управлінських і прогностичних завдань на основі інноваційних підходів, що передбачають урахування мінливості середовища, швидку та нелінійну динаміку диспропорцій.

Матеріали й методи. Для оцінювання та інтерпретації показників диспропорцій регіонів доцільним є використання методів теорії нечіткої логіки. Вони застосовуються для кількісного оцінювання якісної інформації в умовах її високої невизначеності, моделювання економічних процесів підвищеної складності з огляду на високу достовірність розрахунків на основі нечітко-множинних моделей.

Результати. Механізм прогнозування динаміки диспропорцій регіонів методами нечіткої логіки подано як інтеграцію взаємообумовлених чинників, що забезпечують розвиток регіону у відповідних сферах в умовах нестабільності зовнішнього та внутрішнього середовища. Використовуючи методи нечіткої логіки, побудовано функції належності між рівнями диспропорційності та каталізаторами (уповільнювачами) диспропорційності. Подано характеристику рівнів диспропорцій за регіонами: допустимий, регульований, катастрофічний. Вивчення динаміки диспропорцій складає основу для розроблення рекомендацій державної політики з регулювання диспропорцій.

Висновки. Розраховані на основі функції належності характеристики рівнів диспропорцій кожного регіону є основою для подальшого прогнозування динаміки диспропорцій і побудови стратегії регулювання диспропорцій у кожному регіоні.

Ключові слова: диспропорції розвитку регіонів, каталізатори та уповільнювачі показників диспропорцій, методи нечіткої логіки, фазифікація, регулювання диспропорцій.