

# ECONOMICS AND NATIONAL MANAGEMENT

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## DETERMINING DISPARITIES LEVEL IN UKRAINE'S REGION ON THE BASE OF FUZZY-PLURAL APPROACH

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**Introduction.** Disparities are inherent to socio-economic processes at different levels – from community to region. In a negative context in all spheres of life, disparities cause widespreading of economic depression on territories and sharp differences between living standards for population. However, on the other hand, disparities are an incentive to develop the potential of communities, regions and countries. Elaboration of incentive effects for economic development, given by disparities, implies the formulation of strategic guidelines aimed at regulation of regional unevenness.

**Overview of the latest sources of research and publications.** Present research on regional economics concerns various aspects of disparities: e.g. improvement of methodology for disparities diagnosing and monitoring (paper by T.S. Klebanova et al.) [1] offers an algorithm for assessing and analyzing the disparities of regional development in order to range regions and further group them on the basis of social and economic development; paper by S.G. Svetunkov et al. [2] assesses regional disparities by forecasting regional development indicators), formulate policies aimed at balancing regional disparities in European countries, etc (Ph. McCann [3] examines the levels of regional disparities in the UK, and different indicators of disparities with comprehension of their essence; J. Martinez-Galarraga, et al. [4] studies disparities of regional income, which depends on stable economic growth), assessment of territorial convergence through the study of uneven development (paper by L.S. Guryanova and S.V. Prokopovich [5]), advancement of methodology for implementing regional development policy (R. Martin [6]), estimation of disparities for regional policy (S.L. Shults and I.Z. Storonianska [7], I.Z. Storonianska and L.Ya. Benovska [8], L.A. Chagovets and O.V. Nikiforova [9], T.S. Klebanova and T.N. Trunova [10]). Influence of disparities and economy structural changes on the development of regions is shown in the paper by A.O. Dvihun [11].

**Unsolved issues.** Analysis of studies on regional disparities has revealed a lack of papers formulating a general approach to study disparities and their regulation, taking into account rapid change of disparities' indicators and their nonlinear dynamics. Present work is devoted to the formulation of such approach.

**Setting objectives.** The aim of the study is to create an instrument regulating the disparities of regional socio-economic development, taking into account nonlinear dynamics of disparities. Achieving the goal involves the performing of the following tasks: analyzing methods of mathematic study of economic

processes and identifying those that can be applied to the analysis of regional disparities; formulating rules of correspondence between factors of influence on disparities and level of disparities of regional socio-economic development (on the basis of predefined factors influencing disparities, variables, and membership functions for values of disparities for each region).

**Basic material and results.** Impact on regional imbalances is one of the goals of regional policy. The realization of this goal should be based on the preliminary analysis of an array of many heterogeneous data. Since disparities is a dynamic phenomenon with many components influenced by many factors, it is advisable to choose fuzzy logic methods for their analysis. Various authors discuss such option. S.M. Marushchak proves that fuzzy inference can overcome the database dimension problem and adequately analyze multidimensional relationships between input metrics and output calculations [12, p. 18-20]. Advantages of fuzzy inference methods are presented in the papers by T. L. Zubko [13], L. A. Ostankova and N.Yu. Shevchenko [14], N.O. Ivanchenko [15, p. 863-866], V.M. Semianovskiy [16].

The fuzzy-plural approach is used to quantify qualitative information accounting the high uncertainty and to solve management and prognostic tasks, which fully relate to the analysis of regional disparities and the formation of regional development strategies. Fuzzy logic methods are relevant for diagnosis of disparities taking into account the probabilistic nature of disparities arising during catalysts and retarders influence on disparities [17]. The choice of the parameters for the diagnostic assessment of regional disparities is described in this paper. Based on findings from this paper, the integral index of disparities was calculated using a *weighted taxonomic method* (in paper [18]).

Socio-economic catalysts and retarders of regional development that influence the integral index of disparities of regional socio-economic development were also identified. The study identifies ranges, linguistic variables, and membership functions for values of disparities of socio-economic development for each region. The linguistic variables were determined according to the range of changes of this indicator: "Permissible level of disparities", "Regulated level of disparities", "Catastrophic level of disparities".

In the next stage, the rules of fuzzy inference basing on the *Mamdani algorithm* are formed. The fuzzy inference mechanism relies on a knowledge base formed by domain experts or as a result of additional research in the form of a set of fuzzy predicative rules of appearance [19]:

П1: if  $x$  is  $A_1$ , then  $y$  is  $B_1$ ;

П2: if  $x$  is  $A_2$ , then  $y$  is  $B_2$ ;

П $n$ : if  $x$  is  $A_n$ , then  $y$  is  $B_n$ ,

where  $x$  – input variable,  $y$  – output variable,  $A$  and  $B$  – the accessory functions defined respectively by  $x$  and  $y$ .

Thus, based on defined ranges of factors and constructed membership functions, the rules of correspondence between catalysts/retarders and the level of disparities of regional socio-economic development are formed. Zaporizhzhya region could serve as an example. Rules for this region are listed in table 1, where the following designations are used for linguistic variables: MCE – moderate catalyst effect, SCE – strong catalyst effect, ECE – excessive catalyst effect, WRE – weak retarder effect, ARE – aggressive retarder effect, CRE – catastrophic retarder effect, PLD – permissible level of disparities, RLD – regulated level of disparities, CLD – catastrophic level of disparities.

In practice, the following methods are used to receive a defuzzified result:

1. The maximum height method [20, p. 54]. Applies in case the membership function has a certain absolute maximum. The advantage of the method is easy application; the drawback – membership function is not considered in the entire definition area, but only in maximum positions, and above could lead to unacceptable results.

2. The average maximum method [21, p. 78]. If the membership function has several relative maxima, then a weighted average can be used. This method is better than the previous one. It can also be applied if the membership function is constant at certain intervals of a variable, since it is possible to treat the centers of each interval as relative local maxima, and then averaging the values.

3. Center of gravity method [19, p. 202]. The graphical representation of the membership function in Descartes coordinates is a curve that, along with the abscissa axis, upper and lower bounds of the variable, limits some plane.

Table 1

## Rules of fuzzy logical inference based on linguistic variables for Zaporizhzhia region

№	Factor	Rule 1	Rule 2	Rule 3	Rule 4	Rule 5	Rule 6	Rule 7	Rule 8	Rule 9	Rule 10
1	s2	MCE	WRE	SCE	ARE	ECE	CRE	MCE	CRE	MCE	WRE
2	s3	MCE	WRE	SCE	ARE	ECE	CRE	MCE	CRE	MCE	WRE
3	s8	WRE	WRE	ARE	ARE	CRE	CRE	WRE	CRE	WRE	WRE
4	s10	MCE	MCE	SCE	SCE	ECE	ECE	MCE	ECE	MCE	MCE
5	s11	WRE	WRE	ARE	ARE	CRE	CRE	WRE	ECE	WRE	WRE
6	s17	MCE	MCE	SCE	SCE	ECE	ECE	MCE	ECE	MCE	MCE
7	e2	MCE	MCE	SCE	SCE	ECE	ECE	MCE	ECE	MCE	MCE
8	e9	MCE	MCE	SCE	SCE	ECE	ECE	MCE	ECE	MCE	MCE
9	s27	MCE	MCE	SCE	SCE	ECE	ECE	ECE	MCE	SCE	ECE
10	s30	MCE	MCE	SCE	SCE	ECE	ECE	ECE	MCE	SCE	ECE
11	s36	MCE	MCE	SCE	SCE	ECE	ECE	ECE	MCE	SCE	ECE
12	s39	MCE	MCE	SCE	SCE	ECE	ECE	ECE	MCE	SCE	ECE
13	e11	WRE	WRE	ARE	ARE	CRE	CRE	CRE	WRE	ARE	CRE
14	e16	MCE	MCE	SCE	SCE	ECE	ECE	CRE	MCE	SCE	ECE
15	e17	WRE	WRE	ARE	ARE	CRE	CRE	CRE	WRE	ARE	CRE
	$I_{20}$	PLD	PLD	RLD	RLD	CLD	CLD	RLD	RLD	CLD	CLD

Created by the authors. Letter designation:

s \* is a catalyst (retarder) of disparities of social indicators,

e \* is a catalyst (retarder) of disparities of economic indicators.

Thus, based on the Mamdani algorithm, rules of fuzzy logical inference were developed and they describe the qualitative relationships between the factors.

The fuzzy logic inference are input into the Fuzzy module (MathLab), and based on these rules, the level of disparities in a particular region is predicted. To perform the simulation, a set of values of input factors is established, and the simulation result is formed on the basis of previously formed rules of fuzzy logical inference.

The visualization of the constructed fuzzy model for forecasting the level of disparities of the region (on the example of Zaporizhzhya region) is shown in Fig. 1. The columns in Fig. 1 (except the latter) correspond to the initial factors – catalysts and retarders of regional development, red vertical bar – to the predetermined level of the input factor. Rows in Fig. 1 correspond to the formed rules of fuzzy logical inference. The last column shows the predictive value of the resulting variable – the level of regional disparities according to each rule, and the red line shows the most likely predictive value of the variable.

Fuzzy inference allowed us to obtain following results. Based on the established rules, the relationship between catalysts (retarders) and the level of disparities in regional socio-economic development is simulated.

In accordance to the levels of catalysts (retarders) influencing regional socio-economic development, based on the established rules, the constructed system displays the numerical value of the change in the factor of influence (a consequence) of the disparities of socio-economic development. For general analysis of the developed model, it is advisable to visualize the corresponding surface of fuzzy inference, which allows to establish the dependence of the values of the resulting variable on the input variables.

An example of input values of s2, s3, s8, s10, s11, s17, and e2 catalysts and retarders for Zaporizhzhia region is shown in Fig. 2.

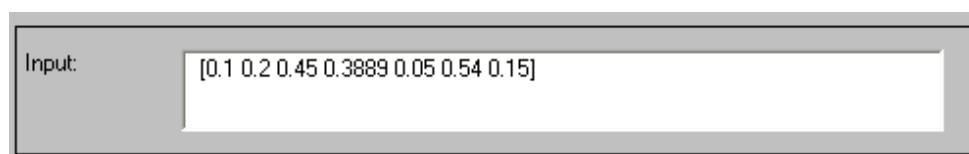


Fig. 2. Input values of factors influencing the disparities of socio-economic development for Zaporizhzhia region.

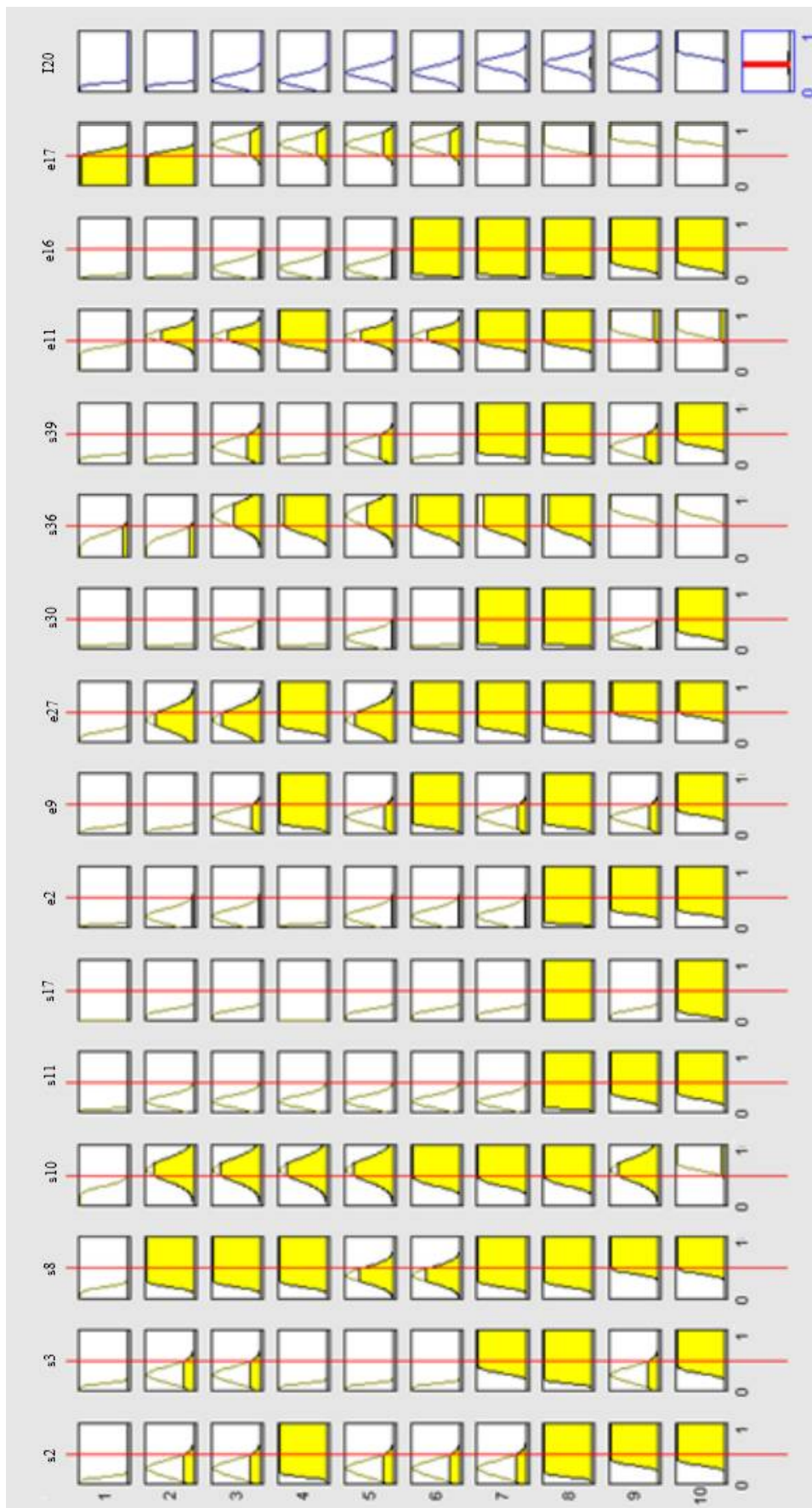
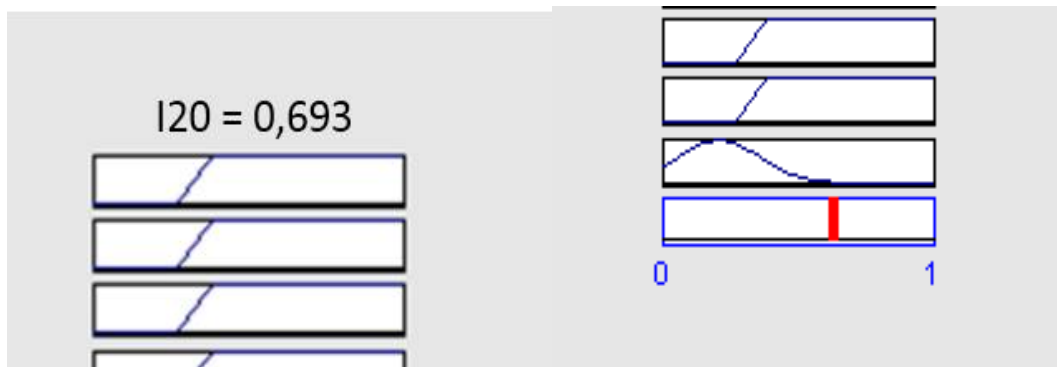


Fig. 1. Modeling of rules for fuzzy logical conclusion for disproportions of socio-economic development of regions (on the example of Zaporizhzhia region).

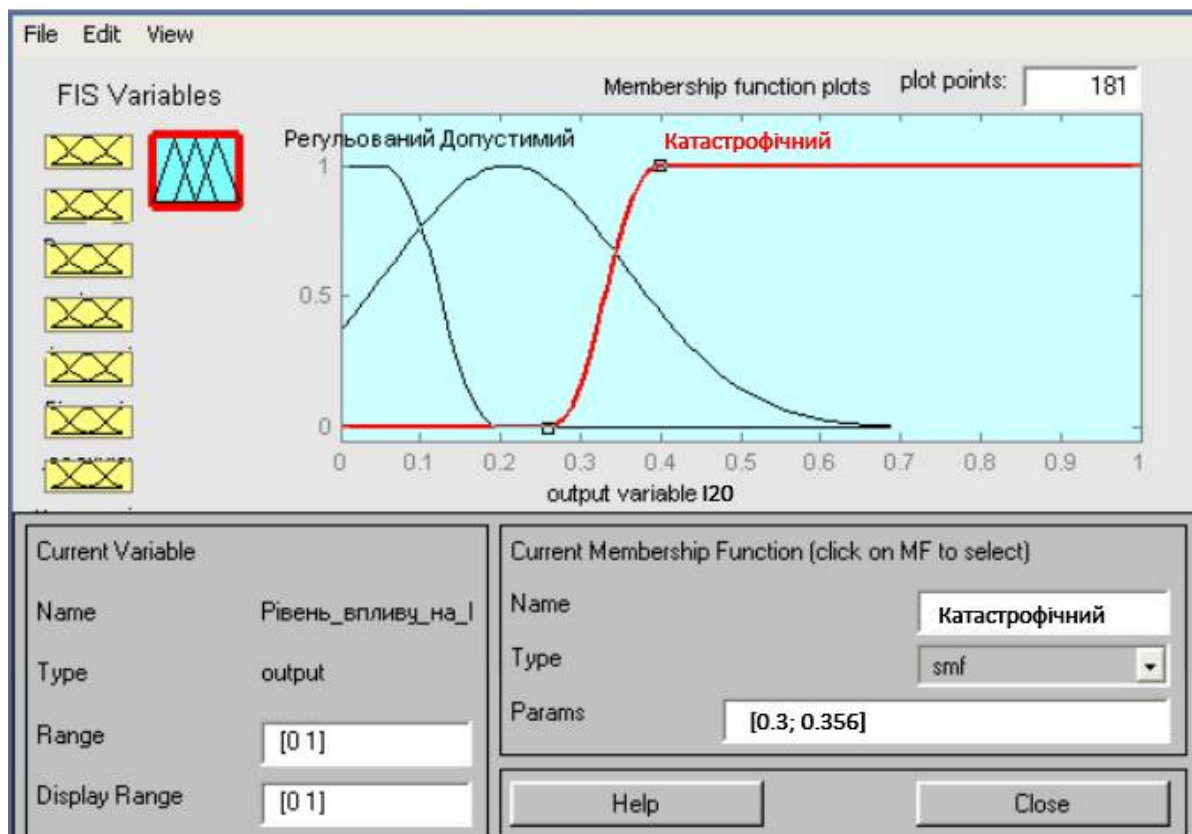
Designed by the authors

Application of fuzzy logical inference of the level of disparities of Zaporizhzhia region after influence of the given combination of factors' levels is shown in fig 3.



**Fig. 3. The result of fuzzy logical inference of factors influence on disparity level of socio-economic development for Zaporizhzhia region.**

Explanation: The result of influence of factors on the level of disparities of socio-economic development will make 0,639, which with probability 1 refers to the fuzzy set "Catastrophic level of disparities", which clearly confirms the graph of the fuzzy set shown in Fig. 4.



**Fig. 4. The result of the algorithm of fuzzy logical inference of the influence of factors on the disparities of socio-economic development for Zaporizhzhia region**

Fig. 5-6 shows a surface rendering a fuzzy inference model for a combination of catalyst and retarder values.



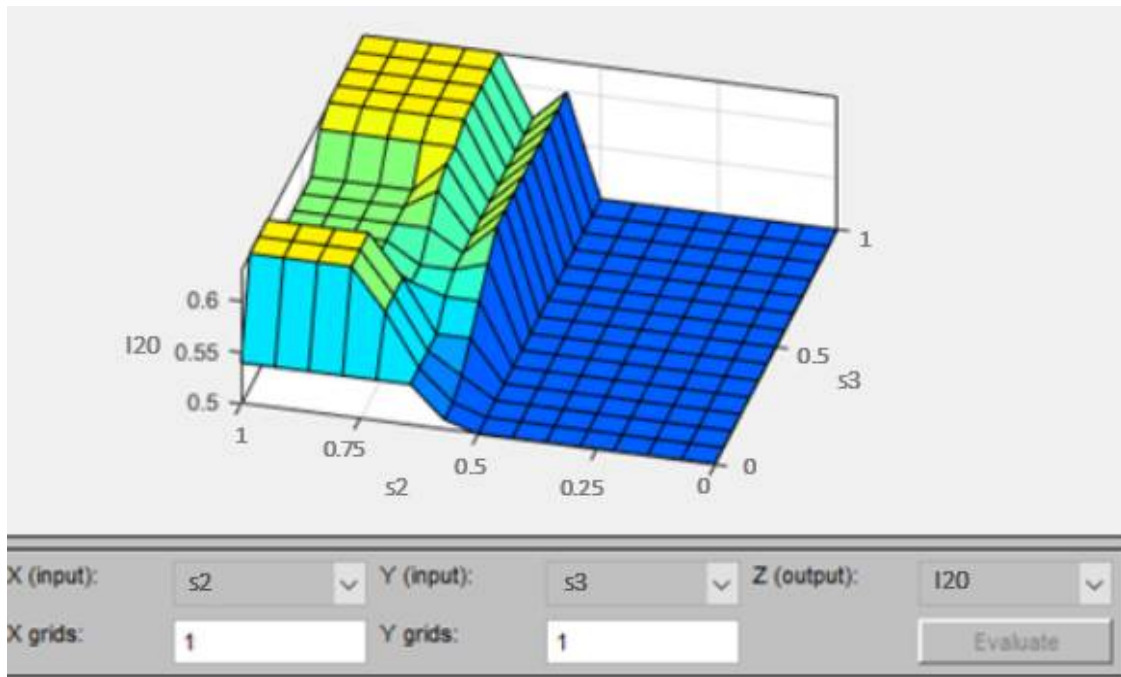


Fig. 5. Surface of fuzzy inference model for input variables s2 (migration) and s3 (natural population growth) (data combination is arbitrary).

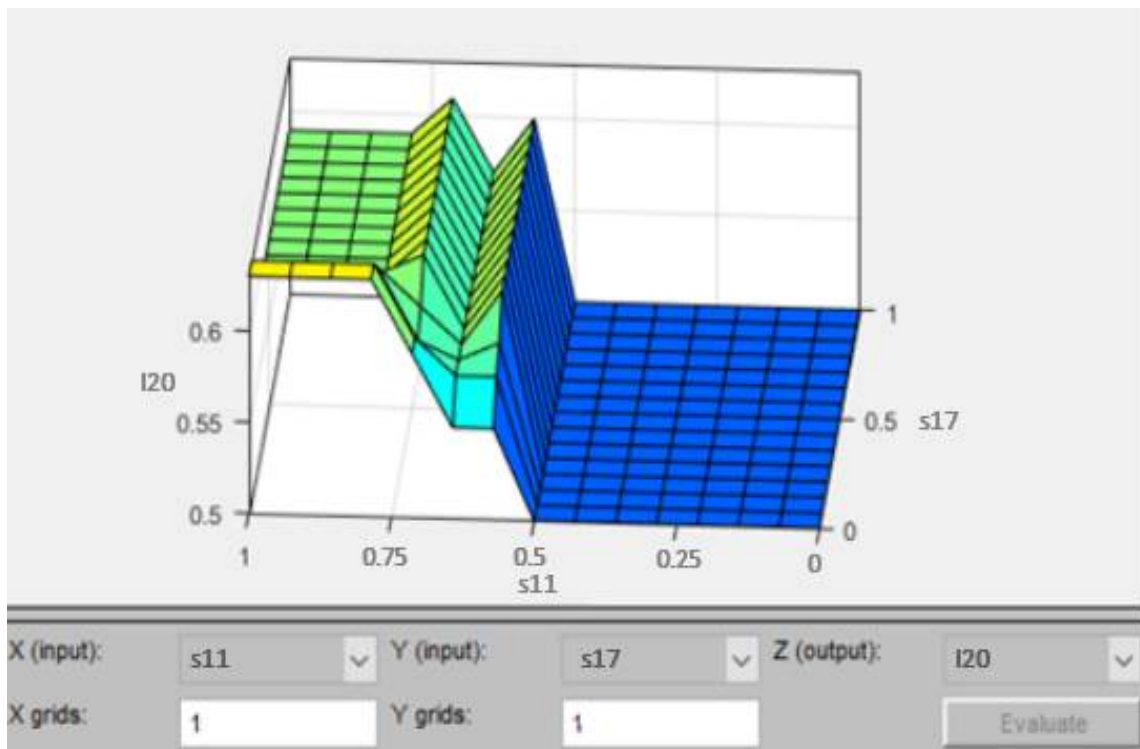


Fig. 6. Surface of fuzzy inference model for input variables s11 (number of pensioners) and s17 (specific gravity of the total area equipped with hot water supply) (data combination is arbitrary).

Similarly, we apply the Mamdani algorithm to formulate fuzzy inference rules for the rest of Ukraine's regions. This makes it possible to predict the impact of catalysts and retarders of socio-economic development on the level of regional disparities.

Table 2 summarizes the results of modeling the level of disparities of socio-economic development for each region using the Mamdani algorithm.

Table 2

Results of fuzzy modeling of the influence of catalyst and retarders of socio-economic development on the level of regional disparities.

Region	The predictive value of the original variable	The predictive value of a linguistic variable
Vinnnytska	$I_2 = 0,169$	«Permissible level of disparities»
Volynska	$I_3 = 0,178$	«Permissible level of disparities»
Dnipropetrovska	$I_4 = 0,274$	«Regulated level of disparities»
Donetska	$I_5 = 0,261$	«Catastrophic level of disparities»
Zhytomyrska	$I_6 = 0,173$	«Permissible level of disparities»
Zakarpatska	$I_7 = 0,209$	«Regulated level of disparities»
Zaporizka	$I_8 = 0,693$	«Catastrophic level of disparities»
Ivano-Frankivska	$I_9 = 0,196$	«Permissible level of disparities»
Kyivska	$I_{10} = 0,295$	«Regulated level of disparities»
Kirovohradska	$I_{11} = 0,147$	«Permissible level of disparities»
Luhanska	$I_{12} = 0,248$	«Catastrophic level of disparities»
Lvivska	$I_{13} = 0,271$	«Regulated level of disparities»
Mykolaivska	$I_{14} = 0,262$	«Catastrophic level of disparities»
Odeska	$I_{15} = 0,319$	«Catastrophic level of disparities»
Poltavska	$I_{16} = 0,287$	«Catastrophic level of disparities»
Rivnenska	$I_{17} = 0,174$	«Permissible level of disparities»
Sumska	$I_{18} = 0,150$	«Permissible level of disparities»
Ternopil'ska	$I_{19} = 0,187$	«Permissible level of disparities»
Kharkivska	$I_{20} = 0,261$	«Regulated level of disparities»
Khersonska	$I_{21} = 0,258$	«Catastrophic level of disparities»
Khmelnyska	$I_{22} = 0,236$	«Permissible level of disparities»
Cherkaska	$I_{23} = 0,178$	«Permissible level of disparities»
Chernivetska	$I_{24} = 0,314$	«Catastrophic level of disparities»
Chernihivska	$I_{25} = 0,192$	«Regulated level of disparities»
Kyiv city	$I_{26} = 0,750$	«Catastrophic level of disparities»

Source: developed by the authors. Excluding TOT AR Crimea, Sevastopol city, parts of Donetsk and Luhansk regions (Donetska and Luhanska oblasts).

We group the regions according to the estimated level of disparities in table. 3.

Table 3

Grouping of regions by the results of fuzzy modeling of the impact of catalysts and retarders of socio-economic development on the level of disparities.

Disparity level	Regulated	Permissible	Catastrophic
Region	Dnipropetrovska	Volynska	Donetska
	Zakarpatska	Zhytomyrska	Zaporizka
	Kyivska	Ivano-Frankivska	Luhanska
	Lvivska	Kirovohradska	Mykolaivska
	Kharkivska	Rivnenska	Odeska
	Chernihivska	Sumska	Poltavska
		Ternopil'ska	Khersonska
		Khmelnyska	Chernivetska
	Cherkaska	Kyiv city	

Source: developed by the authors. Excluding TOT AR Crimea, Sevastopol city, parts of Donetsk and Luhanska oblasts.

**Conclusions and prospects for the further research.** Thus, based on the algorithm of fuzzy inference by Mamdani, a mechanism for predicting the level of disparities in regional socio-economic development has been developed. The levels of disparities for each region are determined as follows: catastrophic, permissible, and regulated. It is established that the mechanism of forecasting the development of disparities in regional socio-economic development by methods of fuzzy logic is a complex and interrelation of factors that will determine the development of the region in the relevant directions of activity in an unstable external and internal environment.

The obtained results can be used for determining current and forecasting level of disparities. This makes it possible to prevent possible deviations from trajectory set out in the strategic documents and to take appropriate measures to adjust the development goals.

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**Ключові слова:** диспропорції розвитку регіонів, каталізатори та уповільнювачі розвитку регіонів, метод нечіткої логіки, нечітке логічне виведення, регулювання диспропорцій.

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**Varnalii Zakharii**, Doctor of Economics, Professor. Taras Shevchenko National University of Kyiv. **Olha Shevchenko**, Ph.D. (Economics), Senior Researcher, Head of Regional Strategies Department of the Regional Studies Center at the National Institute for Strategic Studies, Kyiv. **Determining Disparities Level in Ukraine's Region on the Base of Fuzzy-Plural Approach.** A toolkit for regulating the disparities of regional socio-economic development based on fuzzy logic methods, and accounted unstable environment and nonlinear dynamics of disparities, are proposed. The levels of disparities are determined as follows: catastrophic, permissible, and regulated. On the basis of established ranges of factors influencing the disparities, and variables and membership functions for values of disparities levels calculated for each region, fuzzy logical inference is formed – rules of correspondence between factors of influence on disparities and levels of disparities for each region.

**Key words:** disparities of regional development, catalysts and retarders of regional development, fuzzy inference system, fuzzy logic methods, regulation of disparities.

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**Ключевые слова:** диспропорции развития регионов, каталізатори и замедлители развития регионов, метод нечеткой логики, фазификация, регулирование диспропорций.