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Fuzzy Analysis of the Development of Regional Labour Markets of Ukraine

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Abstract:

Purpose: *We propose to apply the theory of fuzzy logic and fuzzy sets, as well as modern information technologies, as neural networks, to assess the state of the labor market.*
Design/Methodology/Approach: *The article considers the procedure of fuzzy assessment of the state of the regional labor market on the basis of the construction of a generalized indicator, the value of which increases with the improvement of the state. In the process of calculations, 16 primary indicators were used, the values of some of which were obtained statistically, and others - by experts. In this paper, the values of the result generalized indicator "Level of development of the regional labor market" for the regions of Ukraine for 2007-2017 are obtained. The Fuzzy Logic Toolbox module of the MatLab program was used to automate the calculations.*
Findings: *The results show that the global financial and economic crisis of 2008 and the Russian aggression in eastern Ukraine in 2014 affected the state of its regional labor markets. However, the regulatory measures used by the state in these markets were able to significantly offset this impact.*
Practical implications: *The research uses advanced mathematical tools to analyze the labor market. In particular, the logic of fuzzy sets and fuzzy logic were used.*
Originality/Value: *The research can be used for a comparative analysis of selected labor markets. The applied research metrology as a universal method enables the assessment and forecast of local markets.*

Keywords: *Labor market; Fuzzy set theory, neural networks, fuzzification procedure, linguistic variable, membership function.*

JEL classification: *J00, J01, J20, J40.*

Paper Type: *Research paper.*

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1. Introduction

The effectiveness of regulatory actions of state institutions depends, in particular, on the optimal combination of interests of the entire state and its individual regions. The progressive development of any country as a whole, including Ukraine, significantly depends on the comprehensive and balanced development of its regions, the rational use of natural resources, production, labor and scientific and technical potential of its territories.

The same approach to all its regions, ignoring their specifics, differences in socio-economic development can increase disintegration processes, social and political tensions and instability in Ukraine. Both internal and external enemies of the Ukrainian state are interested in this, of which there are many in the current conditions of Russian aggression in the east of the country. Therefore, scientific research of the socio-economic situation both in Ukraine in general and in its regions is relevant. It is necessary to constantly monitor this situation, to study the reaction of regional socio-economic systems to certain regulatory actions of national and regional authorities.

This also applies to the labor market, especially the regional labor market, as at the regional level, many issues are addressed that relate directly to the person, his daily life, life and well-being. The peculiarity of the functioning of regional labor markets in Ukraine at the present stage of its development is due to a system of factors, namely: the significant baggage of the post-Soviet system; the crisis of the transition period, the incomplete reform of labor market regulation mechanisms; military aggression in Russia. The transformation of the economic system took place in the conditions of established Soviet institutions and mechanisms of regulation and was accompanied by a recession. As a result, there was an increase in unemployment, lower wages, structural imbalances in the labor market. Throughout the period after the start of economic reforms, the state failed to formulate a holistic concept of labor market policy. As a result, Ukraine's modern labor market is immature, unbalanced and inefficient. National and regional labor markets are characterized by structural disparities in supply and demand; low wage standards; weakness of state regulation; ineffective institutions of labor law. Modern geopolitical challenges superimposed on all this The revolution of dignity, Russia's annexation of Crimea and its undeclared war against our country, financial, economic and banking crises, other events and processes have led not only to change the economic situation in the regions of Ukraine, but also to redirect both domestic and foreign migration flows. As a result of these processes, the labor situation has changed. In some regions, labor supply and labor demand decreased, while in others they increased.

Therefore, in order to develop an effective employment policy, it is necessary to analyze the state of Ukraine's regional labor markets, to study the changes that have taken place in them, to determine the level of development of these markets and to study their dynamics. To conduct such an analysis, you can use the classical methods of multidimensional statistics, which use quantitative information to perform

calculations. However, in many tasks of economic analysis, including the tasks of assessing the state and dynamics of the labor market, taking into account qualitative information gives a more accurate result. Such estimates can be performed using modern mathematical methods, including fuzzy set theory, and new information technologies.

2. Literature Review

A large number of publications are devoted to the description of the results of scientific research in the field of labor. Many of them concern the study of labor market problems, in particular the analysis of its regional features. The interest of scientists in this issue is due to the fact that it is quite painful for everyone. Let us consider in more detail the results of the study of regional labor markets of some countries, which are performed by their scientists, presented in the literature.

Thus, in the scientific work (Pintilescu, 2012) conducted a comprehensive analysis of the factors that allow to assess the state of the regional labor market in Romania. The main parameters of the regional labor market, according to the author, are the level of employment, unemployment and labor force participation. In general, the study of the regional labor market in the North-Eastern region of Romania is based on the hypothesis that economic growth is due to exogenous employment growth. Peculiarities of youth unemployment in the Czech Republic are considered in (Göttlichová, 2020). The main attention of the author is aimed at identifying promising areas to increase the competitiveness of graduates of Czech universities in the regional labor market. Similar problems are investigated by the authors of the scientific article (Vasilescu and Cristescu, 2017). The article examines the youth labor market of Romania, conducts a comparative analysis with EU countries, identifies factors determining the status of youth in the labor market.

Peculiarities of the geographical distribution of unemployment in Turkey are analyzed in (Kantar and Aktaş, 2016). The authors studied the spatial patterns of regional unemployment rates in the provinces of Turkey using cartographic analysis and spatial autocorrelation.Scientific articles are devoted to the study of the situation on the regional labor markets of Poland (Ginter, 2014; Markowicz, 2013) and others. The authors of these studies conclude that the economic activity of the Polish population, despite slow growth, has not reached the level observed in the European Union. There is a significant difference in the situation on the regional labor markets of Poland, which is largely due to historical conditions. The worst situation is in eastern and northwestern Poland. The best situation is in large cities and areas around these cities. Ukrainian researchers have not escaped the study of regional labor markets. Conceptual bases of research of the regional labor market are stated in the monograph (Sadova and Semiv, 2000). Its authors revealed the principles and features of the territorial organization of the labor market of Ukraine, proposed models for forecasting its development.

Problems of integration of regional labor markets of Eastern European countries to the European market and prospects of the mentioned process for Ukraine are investigated in scientific work (Hrishnova and Risnyi, 2017). This is not a complete list of researchers in the regional labor market and areas of research on this issue. However, methods for estimating the level of development of regional labor markets, which would be based on the latest mathematical theories and models, use modern information technologies, in particular, data mining tools, would allow to take into account not only quantitative but also qualitative information, obtained by experts. In this regard, the purpose of the study is based on the use of fuzzy logic and intelligent information technology to assess the state of regional labor markets in Ukraine and analyze the changes that have occurred in these markets in recent years.

To achieve this goal, the primary factors that characterize the state of the region's labor market were identified, a hierarchical system of fuzzy inference was constructed, according to which the values of integrated assessments of the levels of development of these markets are obtained, the base of fuzzy knowledge and fuzzy logical equations are formed. carried out with the use of modern information technologies calculations of the values of these integrated estimates, the results of which allow to perform a comparative analysis of the situation in the studied markets in both territorial and temporal dimensions.

3. Research Method

It is possible to judge the state of the labor market of a certain region on the basis of the value of only one primary indicator. The "unemployment rate" indicator is the most suitable for this role. The higher its level, the worse the state of the relevant labor market. However, first, Ukraine calculates two levels of unemployment for each region. The first is the level of registered unemployment. It is calculated as the ratio of the number of registered unemployed to the average annual population of working age (now to the economically active population of working age). The second of these indicators is the level of total unemployment. The International Labor Organization (ILO) methodology is used to calculate it.

If we consider the values of these indicators for the regions of Ukraine for a certain period of time (Table 1), it is impossible to make a comparative analysis of the state of the respective regional labor markets. The columns of this table, marked with the letter «R», show the values of the indicator "registered unemployment rate", and the letter «M» - the indicator "ILO unemployment rate". To illustrate the impossibility of assessing the state of the regional labor market at the same time on these two indicators, consider their values, for example, for Vinnytsia and Volyn regions in 2007. In terms of the “registered unemployment rate” indicator among these two oblasts, the state of the regional labor market is the best in Volyn region this year, and in terms of the second of the considered indicators - in Vinnytsia region.

Table 1. *The level of registered unemployment (R) and unemployment calculated according to the ILO (M) methodology in Ukraine and its oblasts in 2007-2017, as a percentage **

Region \ Year	2007		2009		2013		2015		2017	
Method of calculation	R	M	R	M	R	M	R	M	R	M
Ukraine	3,3	6,4	3,4	8,8	2,4	7,2	2,7	9,1	2,1	9,5
Vinnytsia	4,4	6,1	4,6	10,6	3,6	8,4	3,3	8,9	3	10,7
Volyn	4,1	8,1	4,3	9,4	2,7	7,8	2,7	9,8	2,3	12,5
Dnipropetrovsk	2,3	5,0	3	7,8	2,1	6,5	2,2	7,2	1,9	8,5
Donetsk	2	5,6	2,7	9,4	1,6	7,8	2,6	13,8	1,6	14,6
Zhytomyr	4,7	8,6	5,1	10,7	3,6	9,3	3,8	11,3	2,9	10,8
Zakarpattia	3,5	6,3	3,3	9,9	2,3	7,8	1,6	9,3	1,1	10,5
Zaporizhzhia	3,2	6,0	3,9	8,1	2,8	6,6	3,4	9,7	2,6	10,7
Ivano-Frankivsk	5	8,0	4,5	9,0	2,9	7,2	2,6	8,4	1,9	8,5
Kyiv	2,6	5,9	3,1	8,1	2,2	6,1	2,5	6,4	1,8	6,5
Kirovohrad	4,4	8,1	4,7	9,9	3,8	7,9	4,5	11,4	3,7	12,2
Luhansk	2,8	6,6	2,6	7,7	2,1	6,2	2,8	15,6	2,1	16,6
Lviv	3,5	7,7	3,3	8,5	2,3	7,1	2,1	8,2	1,4	7,5
Mykolaiv	3,8	8,5	3,9	9,3	3,2	7,4	3,2	8,9	2,9	10,3
Odesa	2,4	4,4	2,1	6,8	1,4	5,3	1,3	6,5	1,1	7,3
Poltava	4,7	6,6	5,4	10,2	3,5	8,2	4,2	12,1	3,2	12,0
Rivne	6,2	9,0	5	12,7	3,5	9,4	3,5	9,9	3	11,6
Sumy	4,2	7,5	5	11,1	3,3	7,7	3,5	10,1	2,9	9,1
Ternopil	3,9	8,6	4,8	11,3	3,4	9,4	2,8	11,8	2,2	11,9
Kharkiv	3	5,4	3,1	7,7	2,1	6,4	2,1	7,1	1,7	6,1
Kherson	3,8	8,3	2,8	9,5	2,3	8,5	2,7	10,2	1,9	11,1
Khmelnytskyi	4,4	8,1	4,3	9,5	2,8	8,0	2,8	10,2	2,4	8,9
Cherkasy	5,1	8,3	5,4	10,8	3,9	8,9	4,2	9,8	3,1	10,2
Chernivtsi	4,7	8,6	3,8	9,4	2,8	7,4	2,4	9,3	2	8,4
Chernihiv	4,3	7,7	5,1	11,1	3,2	9,3	3,4	10,7	2,6	11,2

Note: ** Built by the authors on the basis of official statistics (Official site of the State Statistics Service of Ukraine).*

Source: *Own study.*

Second, any regional labor market is characterized by some other primary factors. For example, the level of admission of the unemployed to a new job, the level of retirement, the average duration of job search, the workload of registered unemployed or registered unemployed per vacancy or vacancy, and so on. Hence, when choosing methods for assessing the state of the regional labor market must take into account its multidimensionality. To perform this assessment, it is necessary to use the values of not one, but several primary factors that characterize this market. Moreover, these factors may have the same priority or their priorities may differ.

If all the primary factors used for analysis are quantitative, then from a mathematical point of view in the process of solving the problem there is a need to compare two or

more vectors of the same dimension. In the simplest case, these are two vectors, for example, $\bar{a} = (a_1,\ a_2,\ \dots,\ a_n)$ and $\bar{b} = (b_1,\ b_2,\ \dots,\ b_n)$, where *n* is their dimension. In mathematics, an unambiguous result can always be obtained only by comparing two numbers. When comparing vectors, an unambiguous result can be guaranteed only in some cases. In general, this cannot be guaranteed. To confirm this, we assume that all the factors whose values were formed by the vectors $\bar{a}$ and $\bar{b}$ are stimulators. We assume that the vector $\bar{a}$ (state of the regional labor market) is better than the vector $\bar{b}$ if $\forall i, a_i \geq b_i$ and $\exists k, a_k > b_k$. Then, in the case of approximately the same priority of the first two factors, when $a_1 > b_1$, and $a_2 < b_2$ it is impossible to determine which of the considered vectors is the best.

If the priority factors of the primary factors differ significantly, then to compare the vectors (ranking regions by the state of their labor market from best to worst), you can use a fairly simple method called lexicographic. Its essence is as follows. Assume that the n factors we use are stimulants and they are all ranked in order of importance. First, the first elements of the vectors $\bar{a}$ and $\bar{b}$ are compared, ie the elements a_1 and b_1. If $a_1 > b_1$, then the vector $\bar{a}$ is better than $\bar{b}$ and vice versa, if $a_1 < b_1$, then the vector $\bar{a}$ is worse than $\bar{b}$. In the case $a_1 = b_1$ compare the second elements of these vectors a_2 and b_2, etc.

In the case when the primary factors are ordered and their priority coefficients are almost indistinguishable from each other, or in the presence of several unranked factors that cannot be sorted, to solve this problem you can use a certain algorithm to build a complex (integrated or generalized) indicator. The value of this indicator, which we call the "Level of development of the regional labor market" - is a multifactorial assessment of quantitative and qualitative hierarchically interrelated parameters of the conceptual model of the regional labor market, which determines the effectiveness of its operation. For the case of using only the quantitative components of this generalized indicator, scientists have developed many algorithms for its construction (Panek and Zwierzchowski, 2013). These are various algorithms of so-called multidimensional statistics, in which statistical data are used for calculations. However, the available statistical information on the state of the labor market does not always fully characterize this state. There are many research tasks, which include the task of assessing the state and trends of the labor market, in solving which it is advisable to use quality information obtained from experts. Taking expert information into account in these studies will lead to a more accurate result, but then it will be impossible to use the methods of multidimensional statistics. The use of the latest mathematical methods and information technologies, in particular, the theory of fuzzy logic and fuzzy (blurred) sets and intelligent data processing systems is required (Siavavko, 2007).

The theory of fuzzy logic and fuzzy sets was developed relatively recently in order to be able to formalize qualitative information. The famous American mathematician Lotfi A. Zadeh proposed this theory and developed its basic provisions in the 1960s. A clear (classical) set theory uses Archimedes' law of the absence of a third, according to which

a certain element belongs or does not belong to a given set. Instead, in fuzzy set theory, this element may belong to a set not only in whole but also in part, in particular, 70%, half, a third or another part. To indicate the strength of a given element to a certain fuzzy set, the corresponding number from the interval [0, 1] is used, which is called the membership function (Siavavko 2007). This function is given by a fractional number and indicates how much the expert is sure that the given value x of the base set X corresponds to the fuzzy set $\hat{B}$. If the universal (base) scale (set), i.e. the clear set from which the elements for the fuzzy set are selected, is denoted by X, then the fuzzy set $\hat{B}$ is a set of pairs of the form:

$$\hat{B} = \{(x,\ \mu_{\hat{B}}(x)),\ x \in X\} \quad (1)$$

where $\mu_{\hat{B}}(x)$ is a membership function that takes values from the segment [0, 1]. This number reflects how much, according to the expert, $x \in X$ corresponds to $\hat{B}$.

We used this theory to determine the value of the indicator "The level of development of the regional labor market" on the basis of primary indicators. The Fuzzy Logic Toolbox module of the MatLab program was used to automate the calculations. In the course of the research, the priority was to select primary indicators that would sufficiently characterize the state of the regional labor market. This first stage of our study is quite complex, as various scientists and institutions in their research offer their own list of such indicators.

For example, the ILO assesses the state of the labor market on 17 indicators, including those relating to full and part-time employment, unemployment, wages, education, labor productivity, employment in the informal economy, and others (Key Indicators of the Labor Market 2016). The Polish Ministry of Labor and Social Policy uses employment, unemployment, the mismatch between labor supply and demand and labor movement to analyze the regional labor market (Góra and Sztanderska, 2006). According to the author of the scientific work (Kvasha, 2018) the main categories that characterize the effectiveness of the labor market are: economically active population; economically inactive population; unemployed and employed. Analyzing the labor market of Ukraine, it uses indicators of employment, unemployment, wages, labor migration, demand and supply of labor. A review of other literature sources on this issue showed that most researchers use indicators of economic activity, employment and unemployment, wages and labor movement to assess the state of the labor market.

Having analyzed these and other scientific works, for the analysis of regional labor markets of Ukraine we have selected 16 primary indicators (in parentheses indicate the appropriate designations): the level of economic activity of the population aged 15-70 (x_1); employment rate of the population aged 15-70 (x_2); unemployment rate aged 15-70 (x_3); the average duration of job search by the unemployed aged 15-70 (x_4); average monthly salary of full-time employees (x_5); wage arrears (x_6); average monthly salary of full-time employees of agriculture (x_7); the ratio of wages of women and men (x_8);

registered unemployed in% to the economically active population of working age (x_9); youth unemployment rate (x_{10}); unemployment benefit on average per 1 person (x_{11}); average duration of registered unemployment (x_{12}); workload of the unemployed population (registered unemployed) per one vacancy (x_{13}); number of vacancies (x_{14}); hired, % to the average number of full-time employees (level of employment) (x_{15}); dismissed (retired) from the place of work,% to the average number of full-time employees (the level of dismissal of employees from the place of work) (x_{16}). And half of them, namely x_1, x_2, x_5, x_7, x_8, x_{11}, x_{14}, x_{15}, are stimulants, and all others are destimulants.

The second stage of determining the state of regional labor markets in Ukraine was the choice of values of these primary indicators. Due to the lack of statistical data on the general level of youth unemployment in the calculations, the initial data for the factor x_{10} were obtained with the involvement of experts. For all other factors in the process of calculations used official data of the State Statistics Service of Ukraine (Official site of the State Statistics Service of Ukraine). The values of cost factors are listed taking into account inflation.

Next, you need to perform the procedure of fuzzification, i.e. reduce the value of all primary indicators to a fuzzy form, construct membership functions for all linguistic variables, design a fuzzy knowledge base for the initial indicator and perform other actions, including the defuzzification procedure, i.e., go from fuzzy to clear initial value. Each of these actions is associated with certain difficulties, but the most time-consuming procedure is to build a fuzzy knowledge base. It is easy to prove that if the number of term sets of this indicator is denoted by *m*, and the number of input factors that form this indicator by *s*, then the largest in this database can be m^s rules. This indicates a too rapid increase in the maximum dimension of the knowledge base and, accordingly, a sharp increase in the difficulties of its creation with an increase in the number of primary factors of the generalized indicator. Thus, in our case, using the data of 16 primary factors and three term sets for an integrated indicator, this dimension can reach more than 43 million rules, and five term sets - 3.5 thousand times larger. Despite the fact that the knowledge base should reflect only the basic rules, for experts this is an impossible task. Therefore, it is recommended to combine the primary factors into groups and form intermediate integral indicators in such a way that each of them forms no more than five components, i.e. that there are no more than five inputs for each of them. In order to be able to use a smaller total number of rules in the design of all necessary for the calculation of fuzzy knowledge bases, 16 of these primary factors were combined into 5 groups (in parentheses indicate the appropriate designations):

1. The level of development of the full labor market (y_1);
2. The level of wages (y_2);
3. The level of development of the registered labor market (y_3);
4. Demand and supply in the labor market (y_4);
5. The movement of labor (y_5).

That is, the generalized indicator "Level of development of the regional labor market" z depends on these five indicators, which are also generalized:

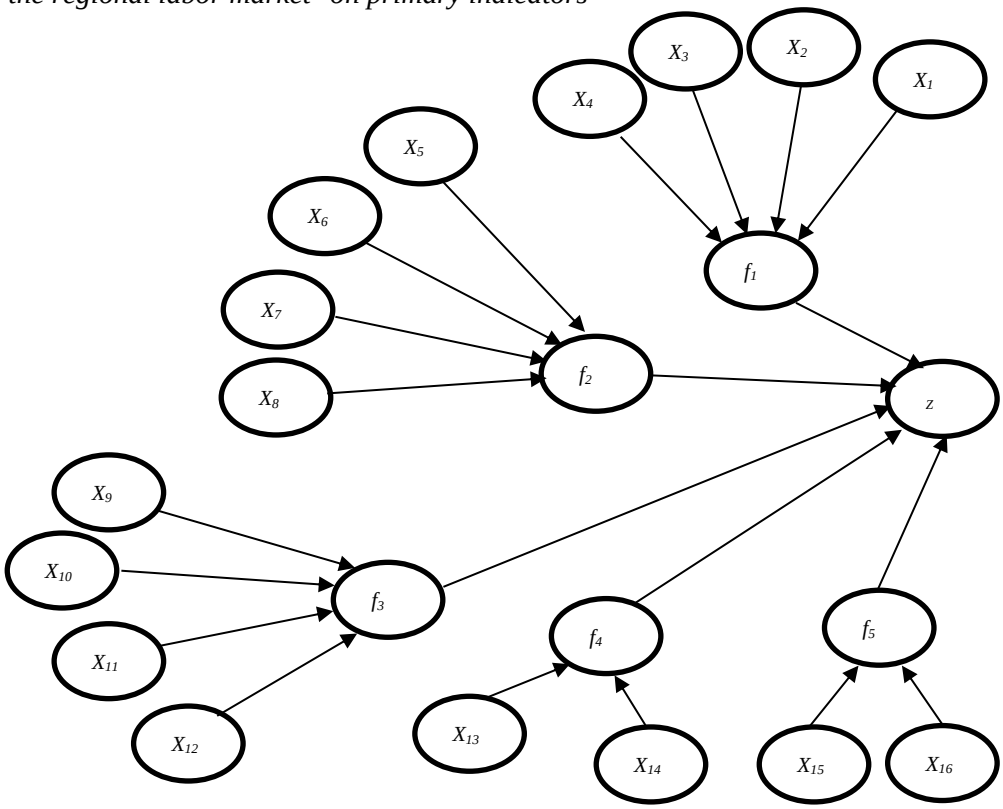
$$z = f(y_1,\ y_2,\ y_3,\ y_4,\ y_5). \tag{2}$$

Moreover, these intermediate generalized indicators depend on the following primary factors:

$$y_1 = f_1(x_1,\ x_2,\ x_3,\ x_4), \tag{3}$$
$$y_2 = f_2(x_5,\ x_6,\ x_7,\ x_8), \tag{4}$$
$$y_3 = f_3(x_9,\ x_{10},\ x_{11},\ x_{12}), \tag{5}$$
$$y_4 = f_4(x_{13},\ x_{14}), \tag{6}$$
$$y_5 = f_5(x_{15},\ x_{16}). \tag{7}$$

As a result, we obtained a hierarchical dependence (tree of dependencies) of the studied factor z on 16 primary indicators $x_1, x_2, \ldots, x_{16}$ (Fig. 1), in which $y_1, y_2, \ldots, y_5$ – considered intermediate integral indicators (aggregated factors of influence).

Figure 1. *Tree of dependencies of the generalized indicator "Level of development of the regional labor market" on primary indicators*



Source: *Own study.*

The next stage of our study was the implementation of the fuzzification procedure. First, we determined the term sets of linguistic variables that correspond to the indicators we use. For each input indicator x_j $(j = \overline{1,16})$, the set of its values was divided into three subsets: L – "low level of indicator x_j", A – "average level of indicator x_j", H – "high level of indicator x_j" and the ranges of change of the corresponding linguistic terms are set. A similar division into the same three subsets is made for the intermediate generalized exponents y_i $(i = \overline{1,5})$.

At the output of the model, many states of the labor market of Ukraine are identified. They are divided into five fuzzy subsets $A_j (j = \overline{1,5})$, which generally intersect. We assume that A_j is a fuzzy subset of labor market states, the level of development of which is L - low $(j = 1)$, BA - below average $(j = 2)$, A - average $(j = 3)$, AA - above average $(j = 4)$, H - high $(j = 5)$. That is, the term set of the linguistic variable "The level of development of the labor market of Ukraine" consists of five components.

Next, the membership functions of these fuzzy subsets were constructed. In the process of calculations for all linguistic variables was chosen bell-shaped type of membership functions (Siavavko, 2007):

$$\mu^T(X) = \frac{1}{1 + \left(\frac{X - b_T}{c_T} \right)^2} \tag{8}$$

where *c* is the coefficient of concentration-stretching of the function, *b* is the coordinate of the maximum of the function; *T* is a linguistic term, the value of which for all primary x_j $(j = \overline{1,16})$ and generalized intermediate y_i $(i = \overline{1,5})$ indicators was chosen from the set {L, A, H} and for the final generalized indicator *z* - from the set {L, BA, A, AA, H}.

To model the resultant indicator *z* and intermediate generalized indicators y_1, y_2, ..., y_5 on the basis of dependences (2) - (7) in the paper fuzzy expert knowledge bases of Mamdani type are designed. Moreover, the output variable of one knowledge base is the input for the knowledge base of the highest level of the hierarchy. That is, the knowledge base for the initial indicator – «the level of development of the regional labor market» depends on the knowledge base for y_1, y_2, ..., y_5. For simplicity of calculations, all the rules in the knowledge bases were considered equivalent and did not differ in their weights.

Table 2 shows a fragment of one of these knowledge bases, which is formed to model the generalized indicator y_1. Moreover, it takes into account that the indicators x_1 and x_2 are stimulants, and x_3 and x_4 – destimulants.

Table 2. *A fragment of a fuzzy knowledge base for the indicator* y_1

x_1	x_2	x_3	x_4	y_1
H	H	L	L	H
H	H	A	L	H
H	A	L	A	H
L	H	L	L	H
H	A	L	L	H
…	…	…	…	…

Source: *Own study.*

To implement a clear logical conclusion, the transition from statements to a system of fuzzy logical equations is performed. The first equation of this system corresponds to that specified in Table 2 fragments of the fuzzy knowledge base will look like (Siavavko, 2007):

$$\mu^{\mathrm{B}}(y_1) = \mu^{\mathrm{B}}(x_1) \wedge \mu^{\mathrm{B}}(x_2) \wedge \mu^{\mathrm{H}}(x_3) \wedge \mu^{\mathrm{H}}(x_4) \vee$$
$$\vee\, \mu^{\mathrm{B}}(x_1) \wedge \mu^{\mathrm{B}}(x_2) \wedge \mu^{\mathrm{C}}(x_3) \wedge \mu^{\mathrm{H}}(x_4) \vee \mu^{\mathrm{B}}(x_1) \wedge \mu^{\mathrm{C}}(x_2) \wedge \mu^{\mathrm{H}}(x_3) \wedge \mu^{\mathrm{C}}(x_4) \vee$$
$$\vee\, \mu^{\mathrm{H}}(x_1) \wedge \mu^{\mathrm{B}}(x_2) \wedge \mu^{\mathrm{H}}(x_3) \wedge \mu^{\mathrm{H}}(x_4) \vee \mu^{\mathrm{B}}(x_1) \wedge \mu^{\mathrm{C}}(x_2) \wedge \mu^{\mathrm{H}}(x_3) \wedge \mu^{\mathrm{H}}(x_4). \quad (9)$$

Continuation of Table 2, description of fuzzy knowledge bases for other generalized indicators y_2, ..., y_5, z and their corresponding systems of fuzzy logical equations are not given here because of their large volumes and what, according to the authors, to understand the essence of the relevant stage used in the research method of table 2 and formula (9) is sufficient.

The solution of the system of fuzzy logical equations is a fuzzy logical conclusion, i.e. a set of values of the membership function of the original variable. The transition to a clear value of this variable, i.e., the defuzzification procedure was performed by the center of gravity method (Siavavko, 2007).

In this paper, using this theory, the values of all intermediate generalized indicators y_1, y_2, ..., y_5 and the integrated indicator "Level of development of the regional labor market" for all regions of Ukraine for 2007, 2009, 2013, 2015 and 2017 are calculated. The time intervals for the analysis were chosen taking into account the possibility to draw a conclusion about the impact on the regional labor markets of Ukraine of the global financial and economic crisis of 2008 and the Russian aggression of 2014.

4. Results

In this work, as a result of calculations, we obtained the values of the resulting generalized indicator z - "Level of development of the regional labor market", as well as the values of intermediate integrated indicators y_1, y_2, ..., y_5, which correspond to the labor market of each region of Ukraine in 2007, 2009, 2013, 2015 and 2017. The values of these indicators can take values from the range [-50, 50]. The time intervals

for the analysis were chosen taking into account the possibility to draw a conclusion about the impact on the regional labor markets of Ukraine of the global financial and economic crisis of 2008 and the Russian aggression of 2014. The results of calculating the values of the generalized indicators "Level of development of the full labor market of regions of Ukraine" and "Level of development of the registered labor market of regions of Ukraine" are presented in table 3, "Level of wages in regions of Ukraine" – in table 4, "Demand and supply in the labor market Ukraine" and "Labor Movement in the Regions of Ukraine" - Table 5 and the indicator "Level of Development of Regional Labor Markets of Ukraine" – Table 6. Moreover, the calculations were performed for all regions and all time periods. Hence, the values of these indicators can be used not only to compare the regions in a given year, but also to compare how the value of a certain indicator has changed in a given region over several years.

Table 3. *Values of indicators "Level of development of the full labor market of the regions of Ukraine" and "Level of development of the registered labor market of the regions of Ukraine" in 2007-2017 **

Region \ Labor market	Full labor market					Registered labor market				
Year	2007	2009	2013	2015	2017	2007	2009	2013	2015	2017
Vinnytsia	6	0	13	2	-3	-2	-5	3	7	9
Volyn	6	2	15	-4	-35	-4	-5	-7	5	9
Dnipropetrovsk	13	10	19	11	3	-3	-3	9	9	17
Donetsk	18	2	23	-11	-23	-3	-9	9	6	28
Zhytomyr	8	6	20	-2	4	-9	-11	-4	5	5
Zakarpattia	14	1	7	0	-3	-9	-9	-4	9	24
Zaporizhzhia	10	7	16	-3	-3	-9	-9	4	0	9
Ivano-Frankivsk	-5	-10	-3	-3	0	-10	-9	-8	5	9
Kyiv	13	3	15	5	1	-3	7	9	7	21
Kirovohrad	5	-2	13	5	-3	-2	-5	-4	-3	9
Luhansk	6	-1	13	-4	0	-9	-6	9	9	12
Lviv	-1	1	5	-3	-1	-9	-9	-3	9	11
Mykolaiv	6	6	24	7	0	-9	-3	7	3	9
Odesa	6	6	15	2	-4	7	2	23	36	34
Poltava	12	-1	4	-1	-1	-8	-14	4	3	36
Rivne	-3	-3	15	7	-3	-33	-10	-4	-1	1
Sumy	8	-2	19	-2	2	-6	-10	3	4	9
Ternopil	-5	-5	5	-9	-16	-2	-7	-10	4	10
Kharkiv	12	7	35	12	23	-5	-8	15	9	34
Kherson	8	7	16	-2	-3	-3	4	9	4	35
Khmelnytskyi	6	7	16	-7	-1	-2	-1	4	3	9
Cherkasy	5	2	13	-3	-1	-4	-12	3	5	9
Chernivtsi	-3	5	8	-3	-3	-9	-8	4	9	14
Chernihiv	10	6	32	-3	-3	-5	-13	2	2	9

Note: ** Built by the authors on the basis of official statistics (Official site of the State Statistics Service of Ukraine).*

Source: *Own study.*

As the data in Table 3 show, in almost all regions of Ukraine during the period under study, the state of their full labor markets generally deteriorated, and the number of registered ones improved. The global financial and economic crisis of 2008 "affected" only some full regional labor markets of Ukraine, which cannot be said about the Russian aggression in 2014. Compared to 2013, in 2015 the state of the full labor market significantly deteriorated in Volyn, Donetsk, Zhytomyr, Zaporizhzhia, Luhansk, Sumy, Kharkiv, Kherson, Chernihiv and some other regions. In some of these areas, this deterioration continued over the next two years. As a result, the worst situation in this market in 2017 was in Volyn, Donetsk and Ternopil regions. As for the registered regional labor markets of Ukraine, these "disturbances" had little effect on their condition, and in some areas this effect was even positive.

Table 4. *The value of the indicator "The level of wages in the regions of Ukraine" in 2007-2017**

Region \ Year	2007	2009	2013	2015	2017
Vinnytsia	-3	2	6	-2	18
Volyn	-3	5	5	-3	7
Dnipropetrovsk	-6	-4	-2	-1	12
Donetsk	-35	-25	-4	-2	3
Zhytomyr	-3	-3	7	0	7
Zakarpattia	-1	-3	3	6	12
Zaporizhzhia	-1	0	-3	0	11
Ivano-Frankivsk	5	0	4	-3	34
Kyiv	-3	-3	-2	-3	13
Kirovohrad	-3	-3	4	-3	8
Luhansk	-24	-18	-3	-1	7
Lviv	-2	-2	1	-3	21
Mykolaiv	-2	5	-1	-3	16
Odesa	-3	-1	4	-4	18
Poltava	-10	-2	2	-2	20
Rivne	-2	-2	7	0	8
Sumy	5	-2	2	0	12
Ternopil	-4	-3	6	12	14
Kharkiv	-2	-6	0	-3	6
Kherson	-1	-1	7	16	16
Khmelnytskyi	-2	-3	4	-3	11
Cherkasy	-3	6	8	4	12
Chernivtsi	-3	-2	7	15	35
Chernihiv	-3	-4	7	-3	18

Note: ** Calculated by the authors on the basis of official statistics (Official site of the State Statistics Service of Ukraine).*
Source: *Own study.*

The calculations showed that the value of the generalized indicator "The level of wages in the regions of Ukraine", which combines four primary indicators, in 2007 for all but two regions of Ukraine was negative, and in 2017 - positive (see Table 4). The global financial and economic crisis of 2008 and the Russian aggression in 2014 slightly changed the value of this indicator, which increased for most regions of Ukraine only in 2017.

Table 5. *Values of indicators "Demand and supply in the labor market of the regions of Ukraine" and "Movement of labor in the regions of Ukraine" in 2007-2017**

Region \ Labor market	Full labor market					Registered labor market				
Year	2007	2009	2013	2015	2017	2007	2009	2013	2015	2017
Vinnytsia	5	-9	-37	19	-1	-8	-14	-6	-8	-2
Volyn	2	-10	0	5	5	-1	-25	-6	-12	-3
Dnipropetrovsk	34	10	14	0	3	-3	-22	3	-10	-22
Donetsk	37	1	-10	-17	-2	-2	-17	-7	-35	-20
Zhytomyr	2	5	5	5	-10	-6	-21	-7	-12	-7
Zakarpattia	-10	-2	-2	-4	-2	-8	-14	-15	-21	-8
Zaporizhzhia	11	-1	-1	-37	-1	-2	-23	-12	-12	-3
Ivano-Frankivsk	5	-37	-3	-1	-2	-1	-4	-2	-10	-7
Kyiv	14	-10	5	-2	4	-36	-13	-35	-9	-12
Kirovohrad	1	-2	-1	-5	-2	-6	-15	-11	-5	-13
Luhansk	5	-10	-2	-33	-2	-5	-21	-12	-35	-29
Lviv	2	0	0	-2	7	-6	-2	-4	-14	-4
Mykolaiv	0	5	-10	-2	5	-35	-9	-12	-7	-8
Odesa	7	5	5	5	1	-9	-13	-31	-20	-5
Poltava	8	0	5	0	5	-7	-9	-3	-12	-10
Rivne	2	-1	5	-1	-2	-9	-15	-10	-18	-13
Sumy	-2	-2	0	-1	-2	-3	-33	-16	-10	-4
Ternopil	5	-10	-10	-10	-2	-7	-19	-8	-20	-7
Kharkiv	36	0	2	5	1	-15	-17	-8	-13	-3
Kherson	0	-10	-2	-4	-1	-37	-12	-36	-34	-10
Khmelnytskyi	-1	-18	-36	-7	-2	-10	-25	4	-18	0
Cherkasy	-1	-37	-7	-6	-34	-23	-8	-10	-10	-7
Chernivtsi	-10	-1	-2	5	-2	-3	-18	-3	-18	5
Chernihiv	3	5	-2	-1	-2	-11	-25	-9	-20	-4

Note: ** Built by the authors on the basis of official statistics (Official site of the State Statistics Service of Ukraine).*
Source: *Own study.*

Table 5 shows that in more than half of the regions of Ukraine the value of the generalized indicator "Demand and supply in the labor market of the regions of Ukraine" during the study period did not change. The considered external crisis and military "disturbances" affected the value of this indicator only for some areas. In particular, in 2009 the value of this indicator decreased compared to 2007 in Dnipropetrovsk, Donetsk, Ivano-Frankivsk, Kyiv, Luhansk, Ternopil, Kharkiv,

Khmelnytskyi and Cherkasy regions, and in 2015, compared to 2013 – in Dnipropetrovsk, Donetsk, Zaporizhzhia and Luhansk regions. At the same time, in 2015, compared to the pre-war year, in Vinnytsia and Khmelnytskyi regions the value of this indicator increased.

As for the generalized indicator "Labor movement in the regions of Ukraine", for almost all regions of Ukraine its value for the entire study period was negative. This value was positive only for Dnipropetrovsk and Khmelnytskyi regions in 2013 and Chernivtsi region in 2017. Very low values of this indicator for some years took place for Donetsk, Kiev, Luhansk, Mykolaiv, Odesa and Kherson areas. Both the global financial and economic crisis of 2008 and the Russian aggression of 2014 had a negative impact on the value of this indicator for most regions of Ukraine. The latter has significantly reduced its importance in Donetsk and Luhansk regions.

Table 6. *The value of the indicator "Level of development of regional labor markets of Ukraine" in 2007-2017 **

Region \ Year	2007	2009	2013	2015	2017
Vinnytsia	-4	-4	-22	-5	-4
Volyn	-4	-13	-4	-2	-20
Dnipropetrovsk	8	-10	3	-4	-8
Donetsk	4	-13	-3	-20	-12
Zhytomyr	-4	-10	3	-2	-4
Zakarpattia	-4	-4	-5	-9	3
Zaporizhzhia	-4	-11	-2	-22	-4
Ivano-Frankivsk	-4	-22	-4	-4	-7
Kyiv	-17	-3	-20	-4	1
Kirovohrad	-3	-5	-1	-3	-3
Luhansk	-11	-9	-2	-20	-16
Lviv	-4	-4	-4	-4	1
Mykolaiv	-20	-4	-3	-4	-4
Odesa	-4	-3	-8	-7	15
Poltava	-4	-4	-4	-2	18
Rivne	-19	-5	-4	-7	-3
Sumy	-4	-19	-6	-4	-4
Ternopil	-3	-8	-4	-9	-5
Kharkiv	-5	-6	-13	-3	17
Kherson	-22	-2	-20	-20	14
Khmelnytskyi	-4	-13	-20	-7	-4
Cherkasy	-11	-22	-4	-4	-20
Chernivtsi	-4	-7	-4	-7	11
Chernihiv	-1	-13	-2	-9	-4

Note: ** Calculated by the authors on the basis of official statistics (Official site of the State Statistics Service of Ukraine).*
Source: *Own study.*

Summarizing the data in Table 6, it can be stated that the value of the generalized indicator "Level of development of regional labor markets of Ukraine" during the study period was mostly negative, except for two or three regions in 2007 and 2013 and eight regions in 2017. The global financial and economic crisis of 2008 and the Russian aggression of 2014 mainly negatively affected the state of labor markets in the regions of Ukraine. The consequences of the first of these events for Ukraine's regional labor markets were more striking than the consequences of the second. If the Russian aggression in 2014 mainly worsened the labor markets of Donetsk, Luhansk and some adjacent regions, then at the beginning of the global financial and economic crisis of 2008 - the deterioration of the studied markets occurred in many more regions. From 2007 to 2009, the value of this generalized indicator decreased the most in Dnipropetrovsk, Donetsk, Ivano-Frankivsk, Sumy, Cherkasy and Chernihiv regions. Although for some oblasts with a low value of this indicator in 2007, its value has become much higher over the next two years. This took place in Kyiv, Mykolaiv, Rivne and Kherson regions. That is, the beginning of this crisis had a positive impact on the labor markets of these areas. In 2017, the worst state of the labor market was in Volyn, Donetsk, Luhansk and Cherkasy, and the best - in Odessa, Poltava, Kharkiv, Kherson and Chernivtsi regions.

It should be emphasized that the situation on regional labor markets in Ukraine is constantly in the field of attention of the state. The state policy of labor market regulation is paying off. Calculations have shown that despite the negative impact of these events on these markets, the condition of most of them has improved after these external "disturbances".

5. Conclusions

Studies have shown that for the comparative analysis of regional labor markets it is advisable to use fuzzy set theory and the latest information technology. There is no description of scientific researches of the specified problems with application of the considered technique in literature sources. The results of a vague assessment of labor markets in the regions of Ukraine showed that the global financial and economic crisis and Russian aggression have in some way affected their situation.

Based on the calculations, the following conclusions can be drawn:

1. Despite the economic, financial, political and other disturbances in Ukraine, the situation on the labor markets of some of its regions during the study period was quite stable. Among these are the labor markets of Kirovohrad, Lviv, Zakarpattia and some other regions.
2. For the vast majority of regions during the study period, the value of the generalized indicator "The level of development of regional labor markets of Ukraine" was negative. This indicates the need to improve regional employment policy in Ukraine.

3. The global financial and economic crisis has mostly had a negative impact on the state of many regional labor markets in Ukraine. The state of labor markets in 10 regions of Ukraine in 2009, compared to 2007, deteriorated significantly, and another 10 almost did not change. Only in those four oblasts (Kyiv, Mykolaiv, Rivne and Kherson), where the value of the integrated indicator of the level of labor market development in 2007 was the lowest, this situation has improved. Moreover, these changes occurred mainly together with similar changes in the values of the intermediate generalized indicators "Demand and supply in the labor market" and "Labor movement".
4. The Russian aggression in the east of the country in 2014 and the annexation of Crimea had a certain impact on the situation on Ukraine's regional labor markets. Compared to 2013, the situation on the labor market in 2015 deteriorated in 11 regions of Ukraine. Significant deterioration of this situation during this period occurred in Donetsk, Zaporizhia and Luhansk regions. At the same time, during this period there decreased the values of the intermediate integrated indicators "Level of development of the full labor market", "Supply and demand in the labor market" and "Labor movement". Although in Vinnytsia, Kyiv, Kharkiv and Khmelnytsky oblasts the situation on their labor markets has improved.
5. The worst state of the regional labor market in 2017 was in Volyn, Cherkasy, Donetsk and Luhansk, and the best - in Odessa, Poltava, Kharkiv, Kherson and Chernivtsi regions. Compared to 2015, it deteriorated in Volyn and Cherkasy and improved - in these five regions, where it was the best in 2017. The labor market of Kherson region is characterized by a particularly significant improvement during this period.
6. If the values of the intermediate generalized indicators "Level of development of the full labor market" and "Demand and supply in the labor market" for 2017 were negative for some areas, and others – positive, the indicators "Level of wages" and "Level of development registered labor market "for all regions this year were positive, and the indicator" Labor Movement "for all but Khmelnytsky and Chernivtsi regions were less than zero.
7. In most regions of Ukraine, the state of their labor markets has improved after the global financial and economic crisis of 2008 and the beginning of Russian aggression in eastern Ukraine in 2014. This indicates that the state is constantly monitoring the situation in these markets. Its policy of regulating these markets is paying off.

That is, the global financial and economic crisis of 2008 and the Russian aggression in eastern Ukraine in 2014 affected the state of its regional labor markets. Moreover, this crisis had a more devastating impact on these markets compared to Russian aggression, which hit the labor markets of the Donbass region quite painfully and slightly changed the situation in the relevant markets of some other regions of Ukraine. However, the regulatory measures used by the state in these markets were able to significantly reduce the impact of these events on them. The impact of the annexation of Crimea on the labor market of this peninsula could not be assessed due to the lack of reliable statistics.

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