International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Economic-Mathematical Modeling and Forecasting of Competitiveness Level of Agricultural Sector of Ukraine by Means of Theory of Fuzzy Sets under Conditions of Integration into European Market

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Abstract: ***The processes of integration of Ukraine into the European Economic Community, the presence of powerful competitors in the European markets encourage the formation of a set of measures with the distinction of tools to ensure the competitiveness of the agro-industrial complex of the state. The necessity of ensuring the competitiveness of Ukraine's agro-industrial complex on the basis of determining the competitive advantages dictate the urgency of scientific search for new methods, forms, tools for its enhancement, which will further promote the market relations in Ukraine and will have a direct impact on the well-being of the population. The aim of the work is to develop an innovative economic-mathematical model for assessing and forecasting the grade of competitiveness of the agricultural sector of Ukraine based on fuzzy sets, which will allow acceleration of the process of Ukraine integration into the European market. The object of the research is the process of ensuring the competitiveness of the Ukrainian agricultural sector. The subject of the research is methodological aspects of economic and mathematical modeling of the competitiveness of the agrarian sector of Ukraine. The methodology of the study is based on the principles and mathematical provisions of fuzzy sets, which allows to use both qualitative and quantitative indicators of influence on the process under study. As a result of the research, based on fuzzy set theory, which allows taking into account both quantitative and qualitative factors of influence on the level of competitiveness, an innovative economic-mathematical model of valuation and forecasting of the grade of competitiveness of the agricultural sector of Ukraine has been developed.***

The classification of factors influencing the level of agrarian industry competitiveness has been formed. The forecast of the grade of competitiveness of the agricultural sector of Ukraine in 2025 has been made, which will allow formulating a strategy of development of the agricultural sector of Ukraine.

Keywords: modeling, modeling, forecasting, agrarian industry, competitiveness, fuzzy set theory, integration, Ukraine.

Jel Classification: C45, C53, O13

Manuscript published on November 30, 2019.
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I. INTRODUCTION

Modern economic processes in Ukraine in context of integration into the European economic community, the presence of strong competitors in the European markets and high requirements for both quality and food safety, condition the formation of a set of measures with the distinction of methodological tools to ensure the competitiveness of the national agro-industrial complex, which is directly related to the country's food security. In addition, it is important to address the problematic issues of entering the European market for the sectors of production, storage, processing and sale of agricultural products, as well as industries that directly manufacture the means of production and service for the agro-industrial complex in the context of integration processes.

At the same time, considering the constant increase of the level of markets openness and decrease in the degree of protectionism, competitiveness will be one of the most important factors that will determine in the future the ability of a product, an agricultural producer, agrarian industry and the country as a whole to face the challenges in the domestic and European markets. The need to ensure the competitiveness of the national agro-industrial complex based on determination of competitive advantages and modern economic and mathematical methods dictate the relevance of the research topic. While paying tribute to the scientific knowledge base of existing developments in the field of justification of the sectoral competitiveness model, it should be noted that the task of provide the competitive advantages of the agrarian sector of Ukraine in the context of European integration sets new challenges for science to solve.

One of them is the problem of entry of industrial producers into the EU market. Conceptual approaches to enhancing the competitiveness of the agro-industrial complex in the context of the Deep and Comprehensive Free Trade Area between Ukraine and the European Union require further scientific substantiation. There is an objective need for further reflection on the methodological component of national agricultural policy formation, which can be developed based on modern economic and mathematical methods.\

II. LITERATURE REVIEW

A review of the literature on the provided goal of this paper shows that few studies have been devoted to modeling the level agricultural sector competitiveness of Ukraine. Existing studies on the use of methods of economic- mathematical modeling, methods theory of fuzzy set, have not previously been used to address the aim of this work.

Thus, O. Nykolyuk (2016) states that the imperfection of the institutional environment is an essential condition for shaping the competitiveness of agricultural enterprises. This can be solved by modeling the process of consolidation of agricultural enterprises [14].

J. Diachenko (2017) has another approach to the use of economic and mathematical methods. He notes that to achieve the quality of forecasting of the level of competitiveness in the agricultural sector, it is advisable to use SPACE analysis, which means selection of certain evaluation criteria and finding the integral development vector [3].

Nanette J. Bulger (2016) offers modern insights into the solving of competitiveness modeling task. She solves this problem using integrated economic intelligence systems. This integrated intelligence model means that competitive intelligence capabilities must include economic, market, competitive, commissioned and technological intelligence [12].

S. Badu (2017) believes that it is possible to ensure the competitiveness of the agricultural sector by developing a typology of impact factors based on the distinction of food security components [1].

J. Yaro et al. (2017) proved that the effects of the models on household and local development are coproduced by their interaction with pre-existing conditions and wider national economic structures [24].

J. Squalli et al. (2008), based on the report on the Global Competitiveness of the World Economic Forum, suggested using structural modeling that determines the weights of the competitiveness index. At the same time, this method is very difficult to implement, as it takes a very large amount of information and time to process it [22].

P. Mobius (2018) in his work provides a thorough research on the definition of sustainable competitiveness and economic and mathematical methods of its description. The aforementioned scientist proposed an approach to determining the level of competitiveness based on structural equation models and economic statistics. This approach allows evaluating the causal link between the various bases of sustainable competitiveness and empirical evidence [11].

It is determined that the most modern method of estimating the economic state of any processes is the methods of fuzzy set theory. The application of fuzzy set theory to solve the problem of economic evaluation in the agrarian sector of the Ukrainian economy is presented in the work by S. Kozlovskyi et al. (2018) [6]. The use of fuzzy set theory (Zadeh, 1965) makes it possible to operate both qualitative and quantitative indicators, to form an artificial intelligence system and to develop forecasts of the level of rating [26]. The fuzzy set theory is an innovative mathematics that can be used to solve a research problem. Advantages of fuzzy set theory over other mathematical methods are provided in the work by Nikolenko et al, (2018) [13] and A. Matviychuk (2013) [10], which confirm the effectiveness of using fuzzy logic theory to solve the research problem.

Therefore, it is advisable to use a modeling method based on theory fuzzy set to model, evaluate and predict the level of competitiveness of the Ukrainian agricultural sector.

III. AIMS

The aim of the work is to develop an innovative economic-mathematical model for assessing and forecasting the grade of competitiveness of the agricultural sector of Ukraine based on fuzzy sets, which will allow acceleration of the process of Ukraine integration into the European market.

IV. METHODOLOGY

The methodological basis of the study is the economic and mathematical apparatus of the theory of fuzzy sets. The factual basis for the study is economic information on the development of the economy of Ukraine and its industries. Expert information used in the research is information from experts from both Ukraine and the European Union..

The general modeling methodology based on fuzzy logic theory assumes the following tasks (S. Kozlovskyi and V. Kozlovskyi, 2005) [5]:

– identification of the main factors of influence that characterize the competitiveness of the national agro-industrial complex;
– formalizing the relationship between the factors of influence in a generalized form;
– definition and formalization of linguistic assessments of factors of influence;
– building a fuzzy knowledge base that identifies relationships between factors of influence;
– inference of fuzzy logical equations on the basis of linguistic assessments and fuzzy knowledge base;
– optimization of fuzzy model parameters.

The basic principles of fuzzy set theory and fuzzy logic, which are needed for further study, were provided by A. Rotshtein (1999) [19]; Y. Panoshichen and O. Kozachko (2010) [17]; A. Rotshtein and S. Shtovba (2009) [20].

V. RESULTS

Based on the theory of fuzzy set, the input parameters of the assessment and forecasting model of the level of competitiveness will be the indicators developed by the authors in the scientific work by N. Varshavska (2018) [23]. These parameters are grouped in the following way: production and economic (v); financial (f); spatial (p) - Table 1.

Using the classification links provided in the Table 1, the linguistic variables of the factors v, f, p will be marked through the following relations:

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$$v = f_v(x_1, x_2, x_3, x_4, x_5, x_6), \quad (1)$$

$$f = f_e(x_7, x_8, x_9, x_{10}), \quad (2)$$

$$p = f_p(x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}), \quad (3)$$

where $x_1 \ldots x_6$ – production and economic factors; $x_7 \ldots x_{10}$ – financial factors; $x_{11} \ldots x_{17}$ – spatial factors.

The initial value, i.e. the level of competitiveness of the agrarian sector of Ukraine, can be determined by the formula (4):

$$K = f_K(v, f, p, t), \quad (4)$$

where *v, f, p* and *t* are linguistic variables describing, respectively, production and economic, financial, spatial factors of impact and forecasting period. The prediction period *t* will then be encoded by two characters according to the pattern: (6M, 1Y, 2Y, 3Y where the letters M and Y mean month and year respectively).

Table 1. Input factors of the model

Input parameter (variable)	Input parameter name (variable)	Change range of input parameter	Linguistic evaluation of input parameters (terms)
Classification of production and economic factors (v)			
x_1	Gross production volume of agro-industrial complex	200-900 UAH billion.	Low, 200-300, (H) Medium, 300-700, (C) High, 700-900 (B)
x_2	Number of enterprises in agro-industrial complex	10-100 thousands of units	Low, 10-30, (H) Medium, 30-50, (C) High, 50-100, (B)
x_3	Number of employed population in agro-industrial complex	0,5-7 million people	Low, 0,5-2, (H) Medium, 2-4, (C) High, 4-7, (B)
x_4	Labor productivity of agro-industrial complex enterprises	100-800 thousands UAH per 1 employee	Low, 100-200, (H) Medium, 200-400, (C) High, 400-800, (B)
x_5	Activities profitability level of agro-industrial complex enterprises	0-100 %	Low, 0-20, (H) Medium, 20-50, (C) High, 50-100, (B)
x_6	Production quality level of agro-industrial complex (generalized)	0-100 points	Low, 0-30, (H) Medium, 30-60, (C) High, 60-100, (B)
Classification of financial factors (f)			
x_7	Price indices of agro-industrial production	0-100 %	Low, 100-105, (H) Medium, 105-110, (C) High, 110-130, (B)
x_8	Net profit of agro-industrial complex enterprises	10-200 UAH billion.	Low, 10-30, (H) Medium, 30-60, (C) High, 60-200, (B)
x_9	Capital investment in agro-industrial complex	5-100 UAH billion.	Low, 5-30, (H) Medium, 30-60, (C) High, 60-100, (B)
x_{10}	Inflation level in Ukraine	1-50 %	Low, 1-3, (H) Medium, 3-8, (C) High, 8-50, (B)
Classification of spatial factors (p)			
x_{11}	Social space development level in agro-industrial complex	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{12}	Level of information and cyberspace development in agro-industrial complex	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{13}	Level of infrastructure development in agro-industrial complex	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{14}	The level of innovative technologies application in agro-industrial complex	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{15}	The level of economic stability of Ukraine	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{16}	The level of political stability of Ukraine	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)
x_{17}	Level of international impact on development of agro-industrial complex	0-100 points	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)

Developed by the authors based on N. Varshavska (2018)

Using expert advice (Ministry of Economic Development, Trade and Agriculture of Ukraine) [16] and according to the specific context in the agrarian ambit, the level of competitiveness can be characterized by the following grade (on a scale of "0" to "100"):

- K_1 (85-100) – High competitiveness grade (class 1);
- K_2 (66-84) – Medium competitiveness grade (class 2);
- K_3 (51-65) – satisfactory competitiveness grade (class 3);
- K_4 (31-50) – unsatisfactory competitiveness grade (class 4);
- K_5 (0-30) – no competitiveness (class 5).

Based on the proposed impact factors (see Table 1). a generalization of model inputs is made and a single point scale with a range from zero to one hundred points is given (see Table 2).

The structure of the economic-mathematical model of estimation and forecasting of the competitiveness grade of the agrarian industry of Ukraine will be presented in the form of "logical tree". Logical tree is a picture that shows logical connections between the forecast indicator К and factors {x1…x17}, that influence this forecast indicator K being subject to the relations given in the formulas (1)-(3). A structural model for assessing and forecasting the competitiveness grade of the agrarian industry will have the form shown in Fig. 1.

Table 2. Generalized indicators

Name	Indication	Inputs	Inputs linguistic evaluation (terms)
Production and economic factors	v	$x_1 \ldots x_6$	Low, 0-30, (H) Medium, 30-60, (C) High, 60-100, (B)
Financial factors	f	$x_7 \ldots x_{10}$	
Spatial factors	p	$x_{11} \ldots x_{17}$	
Status determination period (or forecasting)	t	t	t_1=6 months; t_2=12 months; t_3=12 months; t_4=36months

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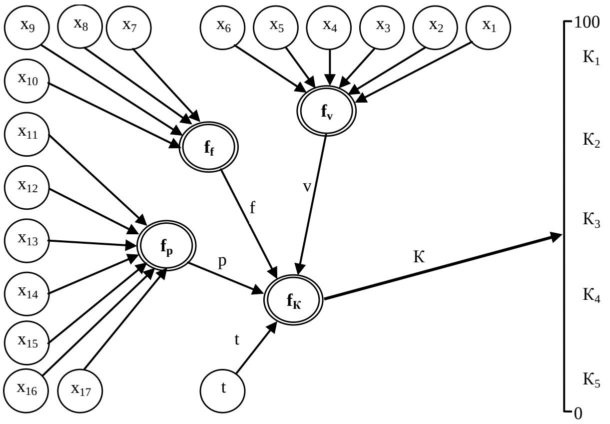

Figure 1. A structural model for assessing and forecasting the competitiveness level of the agrarian industry of Ukraine

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The vertices of the "logical tree" are interpreted as follows: the root of the tree f_K corresponds to the level of competitiveness of the agricultural industry; terminal vertices $x_1 \ldots x_{17}$ are the relevant factors of influence; non-terminal vertices f_v, f_f, f_p are a set of partial factors of influence in their totality.

It is worth noting that when constructing the model, the input quantitative and input qualitative parameters were used simultaneously at the same time. Input parameters $\{x_1 \ldots x_5, x_7 \ldots x_{10}\}$ are quantitative, and statistics were used to describe them; parameters $\{x_6, x_{11} \ldots x_{17}\}$ are qualitative, so a point scale from 0 to 100 points was used to describe them.

Since the theory of fuzzy sets involves determining the levels (terms) of changes in the output index, according to the described model, three output indicators were received, which are used to estimate fuzzy terms with the scales given in Table 2. Each term is represented by a fuzzy set in the form of a membership function.

To describe the terms, the method described in works of S. Kozlovskyi et al., A. Rotshtein (1999), A. Rotshtein and S. Shtovba (2009) will be used. In this case, the terms are presented in the form of fuzzy sets, using the model of membership function [6, 19, 20]:

$$\mu^T(x) = \frac{1}{1 + \left[\frac{x-b}{c}\right]^2}, \qquad (5)$$

where b i c – parameters of membership function (MF);

b – function maximum coordinate;

c – stretching concentration factor.

The values of the coefficients *b* and *c* for the variables x_1 та x_{17}, *v*, *f*, *p*, *K* are presented in Table 3.

The membership function of this type (see formula 5) was chosen because this function is quite flexible and simple.

The next step in modeling the level of competitiveness of Ukraine's agricultural sector is building a hierarchical knowledge base. For knowledge base creation the information was used (Ministry of Economic Development, Trade and Agriculture of Ukraine) [16], as well as factual information of the central executive bodies of Ukraine and information of experts in this field.

The correlation (4) will be considered further. To estimate the value of linguistic variables, which show the causal relationship between the grade of competitiveness of the agricultural industry *K* and production and economic, financial, spatial factors of influence, the term-sets system was used, which is shown in Table 2. Then the knowledge base for the variable *K*, which characterizes the competitiveness level of the agricultural sector, will have the form shown in Table 4.

Table 4. Base of variable K

v	f	p	t	K	w
H	H	H	t_1	K_5	w_1
H	C	C	t_2	K_5	w_2
C	H	C	t_4	K_5	w_3
H	C	H	t_2	K_4	w_4
C	C	H	t_3	K_4	w_5
C	H	C	t_1	K_4	w_6
C	C	C	t_4	K_3	w_7
B	H	C	t_1	K_3	w_8
B	H	B	t_2	K_3	w_9
C	B	C	t_3	K_2	w_{10}
B	C	C	t_2	K_2	w_{11}
B	B	B	t_1	K_2	w_{12}
B	B	B	t_3	K_1	w_{13}
B	C	B	t_4	K_1	w_{14}
C	B	B	t_2	K_1	w_{15}

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DOI:10.35940/ijrte.D7541.118419
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It is known that every rule of the knowledge base is an expression of "IF THEN". Rules that have the same output parameter are combined in rows of tables by a logical expression «OR». The weight of rule *w* expresses the subjective confidence of the expert in this rule. At the stage of forming the structure of the fuzzy model, weights of all rules of the knowledge base were considered as one [17]. In order to realize a fuzzy logical conclusion, it is necessary to make the transition from logical statements to fuzzy logical equations A. Rotshtein and A. Teodorescu (1998) [21].

Table 3. Values of the parameters *b* and *c* of variables membership function $x_1 \ldots x_{17}$, *v, f, p, K*

Input variables (parameter)	Input variable name	Terms	b	c
x_1	Gross production volume of agro-industrial complex	Low, 200-300, (H) Medium, 300-700, (C) High, 700-900 (B)	220 350 800	100 150 120
x_2	Number of enterprises in agro-industrial complex	Low, 10-30, (H) Medium, 30-50, (C) High, 50-100, (B)	15 40 75	20 30 25
x_3	Number of employed population in agro-industrial complex	Low, 0,5-2, (H) Medium, 2-4, (C) High, 4-7, (B)	1 3 5	2 3 2
x_4	Labor productivity of agro-industrial complex enterprises	Low, 100-200, (H) Medium, 200-400, (C) High, 400-800, (B)	150 300 600	100 180 150
x_5	Activities profitability level of agro-industrial complex enterprises	Low, 0-20, (H) Medium, 20-50, (C) High, 50-100, (B)	10 35 75	10 25 20
x_6	Production quality level of agro-industrial complex (generalized)	Low, 0-30, (H) Medium, 30-60, (C) High, 60-100, (B)	15 45 80	10 15 20
x_7	Price indices of agro-industrial production	Low, 100-105, (H) Medium, 105-110, (C) High, 110-130, (B)	102 107 120	12 12 15
x_8	Net profit of agro-industrial complex enterprises	Low, 10-30, (H) Medium, 30-60, (C) High, 60-200, (B)	15 45 140	30 50 65
x_9	Capital investment in agro-industrial complex	Low, 5-30, (H) Medium, 30-60, (C) High, 60-100, (B)	15 45 80	20 25 20
x_{10}	Inflation level in Ukraine	Low, 1-3, (H) Medium, 3-8, (C) High, 8-50, (B)	2 6 25	3 10 20
x_{11}	Social space development level in agro-industrial complex	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{12}	Level of information and cyberspace development in agro-industrial complex	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{13}	Level of infrastructure development in agro-industrial complex	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{14}	The level of innovative technologies application in agro-industrial complex	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{15}	The level of economic stability of Ukraine	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{16}	The level of political stability of Ukraine	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
x_{17}	Level of international impact on development of agro-industrial complex	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
v,f,p	Production and economic factors. Financial factors. Spatial factors.	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
K	Competitiveness level of national agro-industrial complex	1 class, (1) 2 class, (2) 3 class, (3) 4 class, (4) 5 class, (5)	90 70 60 40 15	10 12 15 20 25

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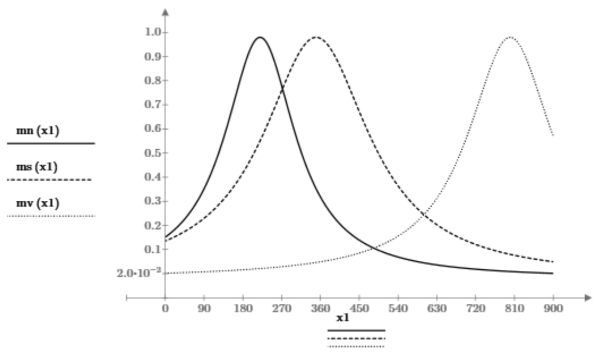

Figure 2.1. Membership function for variable x_1

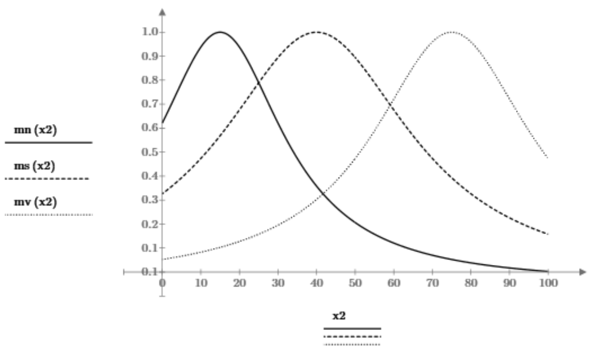

Figure 2.2. Membership function for variable x_2

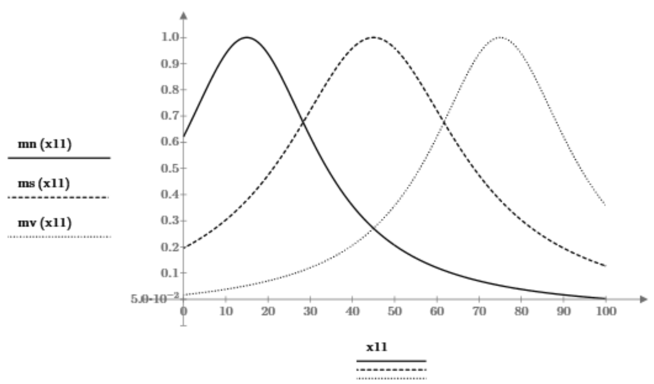

Figure 2.3. Membership function for variables

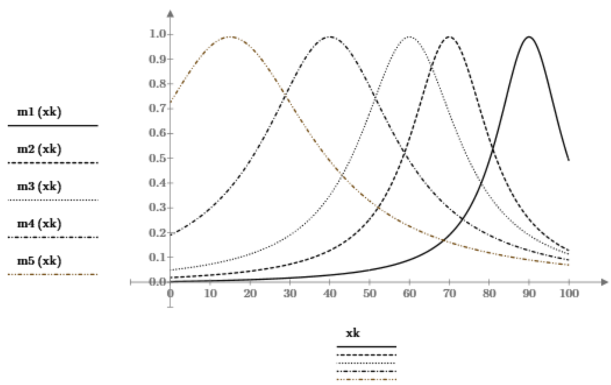

Figure 2.4 Membership function for output indicator К

Figure 2. Membership function for variables x_1, x_2, x_{11}…x_{17}, v, f, p, К

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Thus, following fuzzy logical equations will correspond to linguistic statements from Table 4 (see formulas 6-10).

$$\mu^{\text{К}_5}(\text{К}) = w_1 \cdot [\mu^{\text{Н}}(v) \cdot \mu^{\text{Н}}(f) \cdot \mu^{\text{Н}}(p) \cdot \mu^{t_1}(t)] \vee w_2 \cdot [\mu^{\text{Н}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_2}(t)] \vee w_3 \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{Н}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_4}(t)]; \quad (6)$$

$$\mu^{\text{К}_4}(\text{К}) = w_4 \cdot [\mu^{\text{Н}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{Н}}(p) \cdot \mu^{t_2}(t)] \vee w_5 \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{Н}}(p) \cdot \mu^{t_3}(t)] \vee w_6 \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{Н}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_3}(t)]; \quad (7)$$

$$\mu^{\text{К}_3}(\text{К}) = w_7 \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{Н}}(p) \cdot \mu^{t_4}(t)] \vee w_8 \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{Н}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_1}(t)] \vee w_9 \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{Н}}(f) \cdot \mu^{\text{В}}(p) \cdot \mu^{t_2}(t)]; \quad (8)$$

$$\mu^{\text{К}_2}(\text{К}) = w_{10} \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{В}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_3}(t)] \vee w_{11} \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{С}}(p) \cdot \mu^{t_2}(t)] \vee w_{12} \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{В}}(f) \cdot \mu^{\text{В}}(p) \cdot \mu^{t_1}(t)]; \quad (9)$$

$$\mu^{\text{К}_1}(\text{К}) = w_{13} \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{В}}(f) \cdot \mu^{\text{В}}(p) \cdot \mu^{t_3}(t)] \vee w_{14} \cdot [\mu^{\text{В}}(v) \cdot \mu^{\text{С}}(f) \cdot \mu^{\text{В}}(p) \cdot \mu^{t_4}(t)] \vee w_{15} \cdot [\mu^{\text{С}}(v) \cdot \mu^{\text{В}}(f) \cdot \mu^{\text{В}}(p) \cdot \mu^{t_2}(t)]. \quad (10)$$

The values of the degrees of membership functions in equations (6) - (10) are determined by fuzzy knowledge bases that characterize production and economic, financial, and spatial factors of influence.

Eequations (6) - (10) are a mathematical implementation of the model of estimation and forecasting of the level of competitiveness of the agrarian industry of Ukraine.

The dephasification procedure is the last stage of modeling and is the inverse transformation of the found fuzzy logical statement (conclusion) into the original estimation or forecast parameter that is subject to modeling and forecasting. There are various methods of defuzzification, the choice and application of which depends on the object of modeling [26].

To solve this equation, we choose a method of dephasing, called the "center of gravity method extended" described in works by A. Rotshtein (1999) [19]; A. Rotshtein and S.Shtovba (2009) [20] was chosen. In this case, to determine the "center of gravity" it is necessary to artificially expand the range of the output parameter. The center of gravity will be the value of the abscissa, which determines the position of the "center of gravity" that lies below the graph of its membership function.

The calculation of the "center of gravity" is given by formula 11:

$$K = \frac{\sum_{i=1}^{n}\left[K_E+(i-1)\cdot\frac{K_A-K_E}{n-1}\right]\cdot\mu^{K_i}}{\sum_{i=1}^{n}\mu^{K_i}} \quad (11)$$

where n – the number of terms of variable «K»;

$K_E(K_A)$ – bottom (top) limit of range of variable «K»;

μ^{K_i} – membership function of variable «K» to fuzzy term «K_i».

There was an experiment in Matlab 6.1 mathematical package (Pratar, 1999) [18] that used the above-mentioned method. The result of the assessment and forecasting of the grade of competitiveness of the agricultural sector of Ukraine until 2025 is shown in Fig. 3. The results were obtained based on the analysis of the values of factors of influence for 2012-2016.

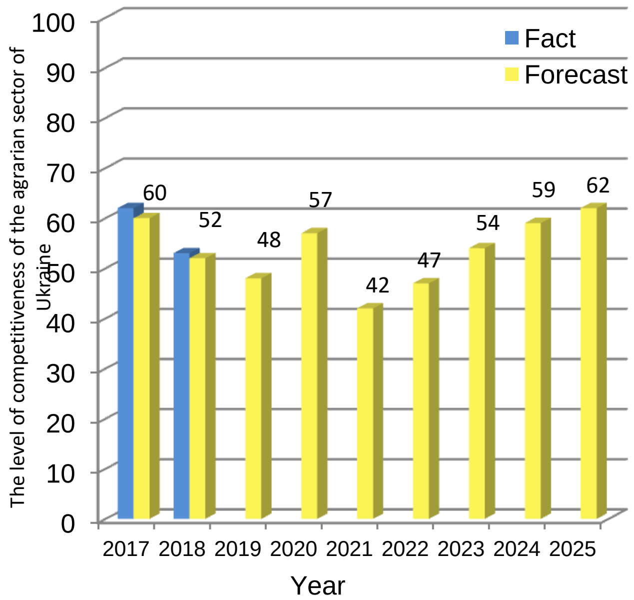

Figure 3. Appraisal and forecasting of the grade of competitiveness of the agrarian sector of Ukraine

Own development

Analyzing the results of modeling the level of competitiveness of the agricultural sector of Ukraine for the years 2020-2025, the following forecast can be made: in 2020 and 2023-2025 the competitiveness level of the agrarian industry will be assigned to the class 3 - "satisfactory competitiveness level". In 2021, the forecast competitiveness level of the agrarian industry will deteriorate to class 4 - “poor competitiveness level”.

To improve the reliability of the forecast of the grade of competitiveness of the national agro-industrial complex, it is necessary to optimize this economic-mathematical model, but this task is beyond the scope of this study.

VI. CONCLUSION

The developed economic-mathematical model of forecasting the state and level of competitiveness of the agrarian sector of Ukraine in the context of integration into the EU markets based on fuzzy sets theory allows determining the state and competitiveness level of the agrarian sector of Ukraine with the dynamic change of the linguistic parameters of the model. This model makes it possible to make a linguistic assessment of competitiveness factors that influence the effectiveness of managerial decisions that are not quantifiable, which is especially relevant today.

Using this economic-mathematical model in practice will allow heads of state institutions, businessmen, agrarians, EU representatives to be able to make an assessment and forecast the level of competitiveness of the agricultural sector of Ukraine. In turn, this assessment will allow making justified business decisions. In addition, it will reduce business risks and implement effective economic policies.

The developed economic-mathematical model of appraisal and forecasting of the level of competitiveness of the agrarian sector of Ukraine in the conditions of integration into the EU markets can be considered as typical for this class of objects. The modeling methodology developed on its basis can be used to model any economic processes characterized by fuzzy connection between input and output parameters, significant difficulties in formalizing the factors of influence and the ability to involve linguistic statements of experts to build a model etc.

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