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НЕЙРОМАРКЕТИНГОВІ ДОСЛІДЖЕННЯ: ЕТИКА, ПРОЦЕДУРИ ТА ПЕРЦЕПЦІЯ УЧАСНИКАМИ

У цій статті обговорюється нейромаркетінг як метод дослідження починаючи з визначень та наявного інструментарію і закінчуючи аналізом етичних проблем в даній області. Новизна дослідження полягає в тому, що представлені перцепції і досвід практиків нейромаркетінга, що сприяє формуванню знань про цей тип маркетингових досліджень.

Ключові слова: нейромаркетінг; етика нейромаркетінга; дослідний зразок.

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НЕЙРОМАРКЕТИНГОВЫЕ ИССЛЕДОВАНИЯ: ЭТИКА, ПРОЦЕДУРЫ И ПЕРЦЕПЦИЯ УЧАСТНИКАМИ

В настоящей статье обсуждается нейромаркетинг как метод исследования, начиная с определений и существующего инструментария и заканчивая анализом этических проблем в данной области. Новизна исследования состоит в том, что представлены перцепции и опыт практиков нейромаркетинга, что способствует формированию знаний об этом типе маркетинговых исследований.

Ключевые слова: нейромаркетинг; этика нейромаркетинга; исследовательский образец.

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NEURO-FUZZY MODELING THE RATE OF INTERNATIONAL MIGRATION IN UKRAINE

This article presents a new methodological approach for estimating the rate of international migration in Ukraine based on the experience of other territories and the application of neuro-fuzzy modeling. Firstly, using the results of previous studies, the factors affecting the decision of the person to migrate are determined. Following that, the most vital features found by regression-correlation analysis are used for grouping the countries into clusters in order to determine the list of states, which are similar to Ukraine with regards to migration climate. Based on the data of analogous countries, this study demonstrates the process of developing an adaptive neuro-fuzzy inference system (ANFIS) for modeling the migration rate in Ukraine and provides some recommendations for further research.

Keywords: international migration, migration modeling, clustering, fuzzy logic, neuro-fuzzy modeling.

Introduction. Migration processes, as a result of demographic growth, economic needs, climate change, lack of educational opportunities, military conflicts and other reasons, have always been a part of human history and played an essential role in shaping the population of individual countries and territories. However, since the middle of the nineteenth century, in terms of intensification of globalization, development of transport, information and communication technologies, growing demand for cheap labor in economically developed regions, the nature and directions of migration flows began to change radically. From the irregular movement of people, migration turned into a stable and large-scale public process that involves, as a rule, representatives of the labor force. Thus, according to the International Organization for Migration (IOM), over the past 20 years, the total number of international migrants has increased by 49%, accounting for one-thirtieth of the world's population, or 258 million people. Moreover, the issue of external migration is particularly crucial for Ukraine, where in recent decades, in comparison with other countries, increased migration activity is observed.

Undoubtedly, a growth in the mobility of the population guarantees the effective allocation of labor forces between territories, the exchange of labor skills and production experience, the accumulation of knowledge, which generally contributes to boosting the standard of living of the world's society. At the same time, migration tends to change the overall size and structure of the territory's population, the level of availability of resources, which may have a negative impact on the economic, social, political, cultural and other aspects of society.

Considering the global nature of modern migration, its intensification and adverse impact on the national development of the participating countries by changing their labor-power potential, today the crucial task is to study the causes and patterns of migration as a phenomenon, constantly monitor its trends in order to develop and implement the migration policy both at the global and national levels. In turn, the implementation of this task requires the use of economic and mathematical methods, information technologies and models that increase the efficiency of such systems.

Today in the scientific literature there are many models and approaches have been formed, which allow not only to estimate the number of migrants, but also to identify the main reasons influencing the individual's decisions to migrate, to analyze the migratory attitudes of the population and to develop forecasts of potential migration flows in the future. In this case traditional qualitative approaches (questionnaire surveys, expert assessments) and mathematical models, including gravity models and their modifications, econometric, stochastic, agent-oriented and neural network approaches, play a vital role. However, the lack of data, the large degree of abstraction and the unrealistic model assumptions, the incorrect assessment of uncertainty, the calculations complexity and the need of specialized software, the lack of a logical interpretation of the modeling process and other disadvantages still make it impossible to choose the generalized methodology to evaluate the migration, so encourage researchers to look for alternative approaches.

Literature review. There are many research papers of foreign and domestic specialists of various scientific fields

which are devoted to the study of migration processes. In particular, the essential theoretical and methodological foundations of the study of migration were described in the works of A. Gaidutsky, O. Pelikh, L. Rybakovsky, O. Rovenchak [2-5]. In addition, the attention of many scientists was attracted by the problems of mathematical modeling of migration processes. Thus, the development of modified gravity models was carried out in the study of E. Vakulenko [6] concerning the analysis of the interregional migration in Russia, M. Poprawe [7] with regard to the evaluation the external migration rate in 230 countries, R. Ramos and J. Surinach [8] regarding the creation of a 10-year forecast of the level of international migration for 183 countries, V. Shumov [9] in relation to the analysis of the emigrant flows from Ukraine, Belarus, Russia, Armenia, Kazakhstan and Uzbekistan during 2009-2014. Methods of time series extrapolation for short-term forecasting of the rate of migration were used in the works of R. Alho and N. Keilman [10]. Several econometric approaches were also combined in the works of the Ukrainian researcher E. Chernyak [11]. Other scientists, including A. Constant, J. Azose and J. Raymer [12-14] highlighted the importance of the uncertainty in the modeling of population migration and used Markov chains, the methods of Bayes and Monte Carlo in their studies.

Completely new views on modeling migration began to emerge at the end of the twentieth century with the development of the behaviorism. Then many scientific papers were devoted to the issues of development the agent-oriented models (AOM). Specifically, examples of such works may include the studies of A. Klabunde [15] on the assessment of cyclic labor migration from Mexico to the United States, D. Kniveton [16] regarding the prediction of migration flows under the influence of climate change in Burkina Faso, V. Makarov [17] in relation to the study of migration flows from Russia to China.

In recent years, in terms of migration modeling, other technologies of data mining have become quite popular. Several studies, such as the works of D. Akin and J. DeWaard [18-19] considered the possibilities of using cluster analysis for more detailed investigation of the migration features between regions. O. Ovchinnikova [20] examined the migration processes in Ukraine using fuzzy sets to assess the degree of migration readiness of the population based on qualitative estimates of migration factors. In this case, the primary indicator could take values in the range from 0 to 1, where 0 indicated the absolute impossibility of migration abroad, and 1, on the contrary, indicated complete readiness for migration. Another modern method for migration modeling was realized with the use of neural networks in the studies of O. Holubnik, N. Zvirid, P. Svarc [21-23] and others. At the same time, in some works, neural network modeling was used separately, while in others it was combined with AOM technology to simulate the creation and evolution of migration links between agents and the influence of these links on the decision of agents to migrate.

Methodology. Taking into account the practice of migration modeling, in this study it is proposed to use a new methodological approach in order to evaluate the migration climate in Ukraine and to develop the corresponding set of mathematical models. Such models would provide a possibility to identify the main factors influencing the migration willingness of the population, to recognize groups of countries with similar migration patterns and based on the experience of countries, which are similar to Ukraine, to determine the potential international migration rate of Ukrainian citizens.

In order to accomplish this task, the methods of correlation-regression and cluster analysis are applied, as well as tools of fuzzy logic, through combining them into a model, the main stages of development of which are depicted in figure 1.

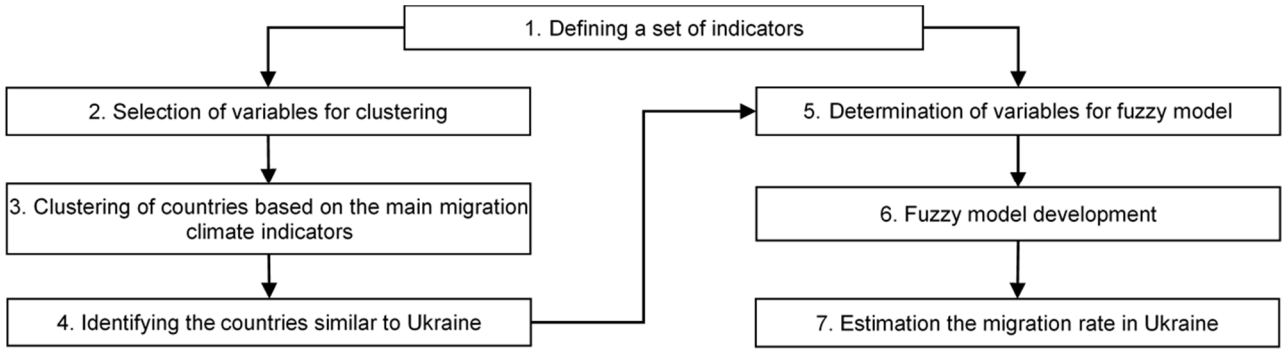

Fig. 1. Stages of development the model for evaluating the rate of international migration in Ukraine

Source: elaborated by authors.

Thus, the process of the model development begins with a choice of input and output variables for different countries (1), which are capable to extensively describe a causal relationship between migration rates (output) and living standards (input) in a particular territory. This stage is implemented based on the results of previous studies and subjective authors' opinions, which is followed by the numerical (correlation-regression) analysis (2) by which the list of the most significant input variables for further research is obtained. Afterward, most essential features let to arrange the countries into groups using cluster analysis (3) and identify the set of countries where the migration behavior of the population is similar to that in Ukraine (4). Data from the analogous countries, therefore, let to develop a fuzzy model (5-6) and, ultimately, evaluate the potential migration rate in Ukraine based on the experience of other countries (7).

The open statistics of international organizations, in particular, the World Bank [24] and the United Nations (UN) [25] are used as sources of data for the proposed model. At the same time, the period from 1998 to 2017 is considered.

It should be noted that this modeling approach was used in the study of Ukrainian scientists O. Lukyanenko and I. Miroshnichenko [26], where the high efficiency of such set

of models was demonstrated and the appropriateness of using this model toolkit for assessing the investment potential of Ukraine was confirmed. Given this, there are reasons to consider the concept developed by the researchers as a new approach to the modeling and forecasting of socio-economic processes and to check the effectiveness of the use of such methodology for assessing the potential international migration rate in Ukraine.

The purpose of this article is to develop and implement a new methodological approach to modeling and forecasting international migration rate in Ukraine based on the methods of data mining that may be useful in producing recommendations for state migration policies.

Results. The process of the research and the results obtained at each stage of the model development for evaluating the rate of potential migration in Ukraine is described below.

1. Defining a set of indicators. The primary task of the first stage is the formation of the set of factors affecting the decision of a person to migrate, as well as the selection of the output indicator, on which the level of migration will be evaluated.

Note that the study of migration factors is still a significant issue in the theory of migration since the directions and scale of migration processes can be formed under the influence of various factors. Such factors may include economic, political, social, demographic, cultural, environmental, psychological and other circumstances. At the same time, although most studies prove a much more significant impact on the migration of socio-economic factors, other indicators cannot be completely neglected. Therefore, in this paper, a number of statistical indicators are selected for consideration of the migration processes, which can reflect different aspects of the country's migration climate, for both donor and recipient countries.

Consequently, for this study 34 input indicators x_i, $i=\overline{1,34}$ are selected that describe the macroeconomic state of the country ($x_{1\text{-}6}$: GDP, total; GDP per capita; GDP annual growth rate; inflation (GDP deflator); foreign direct investment (FDI), net inflow; FDI per capita), its social and demographic conditions ($x_{7\text{-}16}$: population ages 15-64; population ages 65 and above; urban population; population density; life expectancy at birth; mortality rate, infant; mortality rate, adults (male); mortality rate, adults (female); gender development index), labor market and household income ($x_{17\text{-}21}$: unemployment rate, total; unemployment rate, youth; waged workers, total; household consumption expenditure, total; household consumption expenditure per capita), government activity ($x_{22\text{-}26}$: current health expenditure per capita; government final consumption expenditure per capita; government final consumption expenditure in GDP; military expenditure per capita; military expenditure in GDP), the level of education and technological development ($x_{27\text{-}30}$: education index; access to electricity, mobile cellular subsriptions; number of Internet users), as well as the ecological situation in the country ($x_{31\text{-}34}$: CO_2 emissions; Environmental Performance Index (EPI); environmental health; ecosystem vitality).

As output indicator y, the migration rate is taken, which is the difference between the number of people who arrived in a particular country (immigrants) and the number of people who left this country (emigrants) for a specified period (in this case, 5 years) per 1000 population.

Since the migration rate is measured globally only every five years, each of the outlined input variables is presented for each country as the average values for 1998-2002, 2003-2007, 2008-2012, and 2013-2017 years. At the same time, the study excluded the countries for which most of the data was missing. As a result, a database is created for 140 countries.

2. Selection of variables for clustering. In order to determine the most influential factors on the migration rate, based on which countries will be clustered, a correlation-regression analysis is carried out.

As a result, 16 indicators are assigned to statistically significant variables with a significance level of 5%, among which there are representatives of each of the 6 groups, specifically: GDP per capita (x_2), FDI per capita (x_6), population ages 15-64 (x_7) population ages 65 and above (x_8), urban population (x_9), population density (x_{10}), life expectancy at birth (x_{11}), mortality rate (male and female), adults (x_{14}та x_{15}), unemployment rate, total (x_{17}), waged workers (x_{19}), government final consumption expenditure per capita (x_{23}), military expenditure per capita (x_{25}), access to electricity (x_{28}), number of Internet users (x_{30}) and EPI (x_{32}).

3. Clustering of countries based on the main migration climate indicators. Cluster analysis can be defined as partitioning a given sample of objects into a subset called clusters so that each cluster consists of similar objects, and the objects of different clusters differ significantly from one another.

In this case, it is assumed that the results of clustering will provide the selection of groups of countries that by their features are similar to Ukraine, so their data can be used in further research. The application of this approach will, first of all, compensate the lack of migration data for a particular country, and consider the experience of other countries in assessing factors that determine the migration processes in society at the global level.

Given this, a clustering of 140 countries is carried out during the four periods, depending on the migration rate and the 16 leading migration climate indicators that were obtained at stage 2.

Since in this situation there is a relatively small set of data, and no objective estimation of the required number of clusters, it is appropriate to choose the hierarchical agglomeration clustering algorithm as a method of cluster analysis. Applying this approach will let to simply analyze the outcome of the algorithm and the degree of similarity of the countries in one group, based on which to identify the required number of clusters for further analysis.

The implementation of this algorithm is carried out using the Python programming language with the Hierarchical clustering package from the SciPy library. In this case, the Euclidean distance is used as a metric, and the Ward method is used to split objects into clusters.

The results of cluster analysis are investigated using horizontal dendrograms and 4 clusters are allocated in each of the periods. An example of clustering results for two periods with a corresponding cut of dendrograms is shown in figure 2.

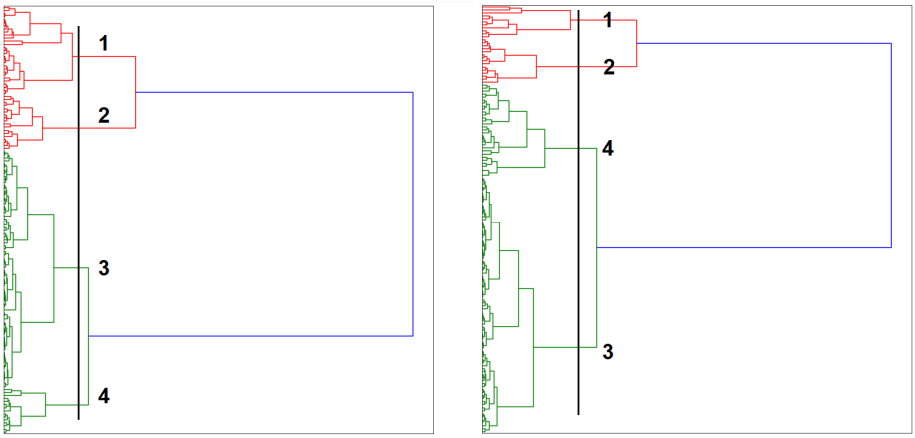

Fig. 2. Results of grouping the countries according to the migration climate indicators for 1998-2002 (left) and 2013-2017 (right) based on hierarchical agglomerative methods

Source: output obtained in Jupyter Notebook.

After analyzing the characteristics of the clusters obtained, it can be concluded that the first cluster represents a group of the most underdeveloped countries. Geographically, it is mostly the African countries (Ethiopia, Madagascar), as well as some of the Asian lands (Afghanistan, Nepal).

The second cluster is quite similar to the first, which is confirmed by the dendrograms, but is better, in particular, in terms of economic development. Moreover, after analyzing the dynamics of changes in the elements of these clusters, it can be seen that the size of the first cluster, which includes the most underdeveloped countries, over time is steadily decreasing since some countries are moving to the more advanced second cluster.

The third cluster is the most numerous of all four groups, which comprises highly developed countries as well as developing countries. So, this group includes the countries of Europe and North America, the developed countries of Africa and Asia, Australia and some countries of Latin America. Among others, this group is distinguished by its high level of economic development, social life and environmental policy.

The last fourth cluster can be characterized as a transition group between the second and the third clusters. This group mainly includes countries with relatively high levels of social, technological and environmental development, but with a relatively average level of economic life. Therefore, this group is made up of some countries of Africa, South and Central Asia, Latin America, and Eastern Europe.

4. Identifying the countries similar to Ukraine. Considering Ukraine's membership of four clusters presented, a particular dynamics of the country's development can be observed. Thus, during the first period (from 1998 to 2002) Ukraine belonged to the second group of countries where third world representatives were gathered. However, over the next period, Ukraine moved to the third cluster of developed countries and maintained this position over the next decade, after which it moved to the fourth cluster during the 2013-2017 economic slowdown.

Therefore, for the further development of the model for the estimation of the migration processes in Ukraine, it is necessary to take into account the experience of quite different countries. That is why, the next stage will be the formation of a new database that combines the data of the countries that were gathered in the second cluster during 1998-2002, in the third cluster during 2003-2012 and in the fourth cluster during 2013-2017. As a result, we receive a new sample of data, which consists of 225 observations.

5. Determination of variables for fuzzy model. Given that in the literature on fuzzy modeling it is recommended to submit to the input model no more than 7±2 variables, the next stage of the model development will be the selection of the most valuable indicators. In order to identify such indicators, the interdependence between all variables is analyzed using the Pearson correlation.

It should be noted that in order to consider in the model each group of the factors influencing population migration, one indicator is chosen from every group, which characterize six spheres of society's life: the level of macroeconomic development, labor market and household income, socio-demographic situation, government activity, the level of technological development and education, and the state of the environment. At the same time, these indicators should have a significant connection not only with the initial variable but also be characterized by the closest connection with the maximum number of other explanatory variables of their group and by the minimal dependence on other factors, so the most expressed representatives of each group can be identified.

For example, the closest correlation (0.61) with the resulting indicator for a given group of countries has the variable x_2 "GDP per capita". Moreover, a moderate correlation is observed between x_2 and x_6 "FDI per capita". Given that the other variables of the corresponding group do not have a significant dependence on the output variable y, we will consider the variable x_2 "GDP per capita" as a representative of the macroeconomic indicators group.

During analyzing the indicators of the labor market and household income, the most significant link (0.53) with the variable y was observed for x_{21} "Household consumption expenditure per capita". However, this variable has a very close connection (0,95) with another factor that has already been selected for the model – x_2. Therefore, the variable x_{21} cannot be considered as a representative only of the group "Labor market and household income". Another representative of this group, which has a relatively high correlation with the resulting variable (0.23), is x_{17} "Unemployment rate, total". At the same time, for this variable there is a low degree of interdependence with the indicator x_{21} and relatively high correlation coefficients between the rest of the indicators of this group. Therefore, the variable x_{17} "Unemployment rate, total" is selected as a representative of the "Labor market and household income" group.

As a result, 6 indicators were chosen as inputs for the fuzzy model for estimation the rate of international migration: x_2 "GDP per capita", x_{11} "Life expectancy at

birth", x_{17} "Unemployment rate, total", x_{23} "Government final consumption expenditure per capita", x_{27} "Education index" and x_{32} "EPI".

6. Fuzzy model development. The realization of this task involves the development of a fuzzy inference system (FIS), which is a system that formalizes the process of obtaining fuzzy conclusions based on fuzzy preconditions using the basic concepts of fuzzy logic. The main idea of the functioning of such a system is to reproduce the decision-making process using the "IF-THEN" rules. Usually, such rules are formed directly from an expert or a training sample, through which the parameters of membership functions are defined, that determine the degree of membership of the element to a specific set, and the decision-making rules are formed.

The main components of the FIS are as follows:

– knowledge base, which includes a database (defines the membership functions) and a rule base (contains the "IF-THEN" rules);

– block of fuzzification, where the conversion of continuous input values into fuzzy sets occurs;

– decision-making block, where the value of the output variable in the form of a fuzzy set is determined based on the rule base, which corresponds to the value of the input variable;

– block of defuzzification, where the transformation of fuzzy output into a continuous variable is carried out.

Thus, the main task during FIS development is to prepare the knowledge base. For this, the first step will be the formation of fuzzy linguistic variables, defined by a set of terms that denote qualitative signs of the system's states.

In this case, three qualitative terms {L,M,H} are used for each of the variables, where L characterizes the low, M – the medium and H – the high level of the corresponding indicator. Then, based on the graphical analysis for a new sample of data with 225 observations, the parameters of the membership functions or boundary levels between linguistic terms for all variables are established.

For example, based on the analysis of the variable x_2 "GDP per capita" (see figure 3) it was set that the x_2 is considered as low or equal to the term L when its value is less than 7 thousand dollars. By contrast, the value of x_2 is considered as high or equal to the term H in case its value exceeds 23 thousand dollars. (The corresponding delimitation is indicated graphically in figure 3 by red horizontal lines).

By the same principle, the boundary levels are formed for the rest of variables. Consequently, for the output variable y, the boundary between the terms L and M is -5, and between the terms M and H is 5. Similarly, the parameters for x_{11} "Life expectancy at birth" are respectively 60 and 72, for x_{17} "Unemployment rate, total" – 5 and 12, for x_{23} "Government final consumption expenditure per capita" – 1000 and 5000, for x_{27} "Education index" – 0.55 and 0.75 and for x_{32} "EPI" – 45 and 65.

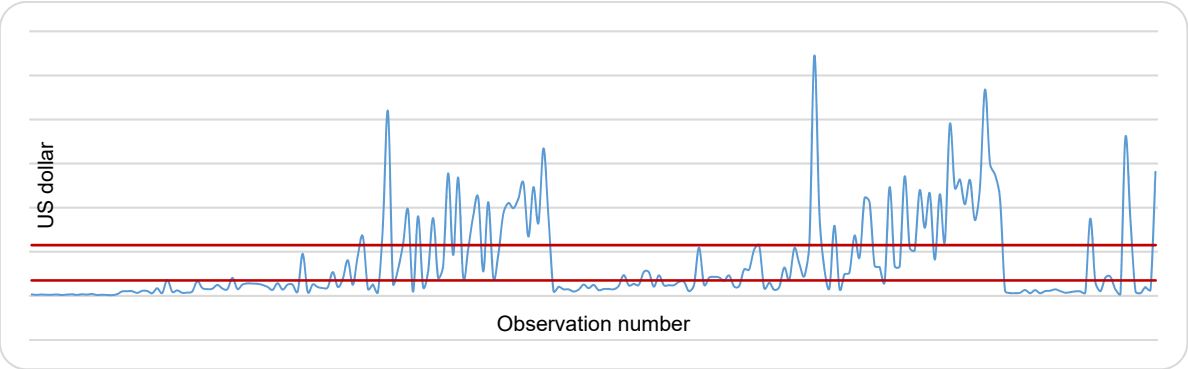

Fig. 3. Level analysis for the variable x_2 "GDP per capita" in order to determine the parameters of the membership functions

Source: output obtained in MS Excel.

Next step is the formation of decision-making rules. In order to create such rules, the quantitative values of all variables are translated into qualitative terms using defined parameters of membership functions, and its influence on the resulting variable based on statistical data is analyzed. Thus, we obtain a particular list of rules, for example:

$$\text{IF } x_2=M \text{ AND } x_{11}=H \text{ AND } x_{17}=L \text{ AND } x_{23}=M \text{ AND } x_{27}=M \text{ AND } x_{32}=M$$
$$\text{OR IF } x_2=L \text{ AND } x_{11}\neq L \text{ AND } x_{17}=M \text{ AND } x_{23}=M \text{ AND } x_{27}=M \text{ AND } x_{32}=M$$
$$\text{THEN } y=M$$

However, it should be noted that during the forming the knowledge base several ambiguous rules were discovered. For example, in the third period, there were three countries for which the same combination of input variables produced different results (see table 1).

***Table* 1. Example of ambiguous rules found during the knowledge base formation**

Country	Quantitative and relevant linguistic values of indicators						
	x_2	x_{11}	x_{17}	x_{23}	x_{27}	x_{32}	y
Poland	13031,9	76,1	8,9	2406,7	0,83	69,4	-1,9
	M	H	M	M	H	H	M
Czech Republic	20736,1	77,5	6,4	4191,8	0,86	81,7	5,7
	M	H	M	M	H	H	H
Estonia	16465,9	75,3	11,6	3175,3	0,87	73,9	-7,9
	M	H	M	M	H	H	L

Source: author's calculations.

Due to the difficulty of manual creation of the rule base because of numerous contradictions, it is decided to use the neuro-fuzzy modeling toolkit, which will allow configuring the membership functions and generating the rule base automatically.

In this study, it is suggested to use an adaptive neuro-fuzzy inference system (ANFIS) which is based on a Sugeno FIS.

In general, ANFIS is a five-layer neural network with one output and multiple inputs that automatically synthesizes the Sugeno-type knowledge base based on experimental data. In this case, the inputs of the model are described by the standard membership functions, and the terms of the output variable are expressed as linear or constant functions.

Today, this technology is one of the most common methods that integrate the principles of neural networks and fuzzy logic. In addition, ANFIS technology is supplied with high learning speed and simplicity of the algorithm, as well as implemented in many software products, including MATLAB, where the modeling will be conducted.

Therefore, 221 observations are taken as a training sample (except data for Ukraine during all four periods). During the neuro-fuzzy model's learning, the parameters of the membership functions for six input variables are determined automatically, and an appropriate rule base is generated, on which the model for the estimation the rate of international migration will be based. In this case, the mean squared error (MSE) of the built neuro-fuzzy model is 7,31.

7. Estimation the migration rate in Ukraine. At the final stage, the developed model was tested based on indicators for Ukraine. Thus, the experience of other countries let to evaluate the migration rate in Ukraine for 4 periods (1998-2002, 2003-2007, 2008-2012, and 2013-2017 years). The result of the modeling is presented in figure 4.

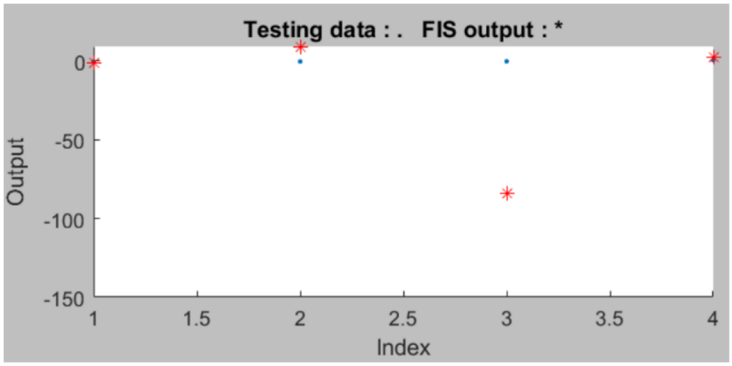

Fig. 4. Results of neuro-fuzzy modeling the international migration rate in Ukraine for 4 periods (Index – number of the period, Output – estimated migration rate)

Source: output obtained in MATLAB.

As we can see, during the three periods, the modeling results are characterized by very low errors and almost correspond to the actual values of the migration rate. However, in the third period, the result of assessing the level of international migration in Ukraine was significantly underestimated, which makes it impossible to use the developed model in order to predict the level of external migration of population in Ukraine in its pure form. However, taking into account the high predictive capacity of the model in the rest of the periods, it is worth noting the great prospect of such an approach in the context of modeling migration of the population, which creates the grounds for further development and improvement of the presented model.

Conclusions and discussions. Today, migration is one of the most characteristic manifestations of globalization, in which about 258 million people are involved. Because of the many adverse effects and possible threats, migration processes have become the subject of regulation both at the state and global levels, as well as the subject of research by many scientists whose works are devoted to the development of mathematical models for assessing and predicting potential migration scales in order to produce recommendations for state migration policies.

In this paper, in order to determine the level of international migration in Ukraine, it was proposed to combine several methods of data mining that proved the feasibility of its use in other studies and to develop the appropriate models based on the analysis of migration factors using the fuzzy logic toolkit.

In order to accomplish this task, a list of indicators that can best characterize the migration climate of each country was formed, and cluster analysis of 140 countries was conducted, which allowed selecting a group of similar to Ukraine countries in terms of economic, social, demographic, political, technological and environmental states. The resulting sample was the input data for a fuzzy model, for the development of which the most influential variables were selected that characterize the main spheres of life of citizens, the term set for all indicators was formed and parameters of membership functions were determined. However, at the stage of constructing the decision-making rule base for a fuzzy model for assessing the rate of international migration, a number of contradictory rules were found that made impossible the further development of the model manually. As a result, it was decided to use the neuro-fuzzy modeling toolkit by creating an adaptive neuro-fuzzy inference system using the MATLAB application package. The developed model was tested on an example of data on Ukraine, resulting in estimates of the migration rate for four 5-year periods from 1998 to 2017.

Despite the impossibility of using a developed neuro-fuzzy model in its pure form to predict the level of international migration due to a high error in one of the periods, the improvement of this model could be the subject of further research. At the same time, the following steps can be taken to improve the modeling results.

1. Extension of the database of input indicators. It is assumed that the inclusion of new factors to the model will allow identification of significant indicators that would unambiguously determine the motivation of the population to migrate, which would lead to overcoming the ambiguity of decision-making rules when formulating the knowledge base.

2. Changing the methodology of the choice of indicators. Given that the Pearson correlation is very sensitive to outliers, the application of such an approach in analyzing indicators for all countries may not give the optimal results.

Therefore, to assess the interdependencies between the indicators, other approaches, such as the Random Forest methodology, which is often used to select the explanatory variables, should be considered. Moreover, it is possible to improve the selection of indicators-representatives of groups of migration factors. In particular, it is possible to create an integrated indicator that would better describe the state of every sphere of the life of a particular country's society, instead of selecting only one variable from each group.

3. Extension of the timeframe of the study. At present, the migration rate at the global level is measured only every 5 years. However, after reducing the explanatory variables to such a 5-year format, sharp changes in the values of some indicators can be neutralized, so their effect is decreasing, which leads to an increase in prediction errors. Therefore, from the authors' point of view, analysis of at least annual performance will improve the quality of the model.

4. Replacement of the output variable. When applying the proposed methodology to the indicator, which is influenced by two forces, namely, the levels of immigration and emigration, we assume that the level of influence of the social life of a specific country should be the same for both emigrants and immigrants. However, in real life, this may not be true, and the speed of the reaction of immigrants and emigrants to changes in the environment within a particular country can be fundamentally different. Because of this, it would be most rational to use the proposed methodology for assessing the levels of immigration and emigration separately.

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НЕЙРО-НЕЧІТКЕ МОДЕЛЮВАННЯ РІВНЯ МІЖНАРОДНОЇ МІГРАЦІЇ В УКРАЇНІ

З огляду на важливість дослідження сучасних міжнародних міграційних процесів, в даній статті запропоновано новий методологічний підхід для оцінки рівня міжнародної міграції населення в Україні впродовж періоду з 1998 до 2017 роки. Представлений комплекс моделей дозволяє врахувати фактори, що спонукають людину до прийняття рішення про міграцію, а також досвід інших країн. На початковому етапі було виділено групи факторів впливу на міграцію населення, що можуть охарактеризувати міграційний клімат країни, та проаналізовано взаємозалежності між усіма показниками за допомогою інструментів кореляційного аналізу. Після цього на основі найвпливовіших показників було здійснено кластеризацію 140 країн та визначено групу схожих до України держав, чиї дані використовувались далі в процесі формування терм-множин для вхідних та вихідної змінних, визначенні параметрів функцій належності та побудови бази правил прийняття рішень із метою розробки системи нечіткого виведення. Проте у зв'язку з наявністю неоднозначних правил на заключному етапі дослідження для моделювання рівня міжнародної міграції в Україні запропоновано побудувати адаптивну нейро-нечітку систему виводу ANFIS. Отриману модель було протестовано на даних для України та розроблено рекомендації щодо покращення результатів моделювання у подальших дослідженнях.

Ключові слова: міжнародна міграція, моделювання міграції, кластеризація, нечітка логіка, нейро-нечітке моделювання.

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В данной статье представлен новый методологический подход к оценке уровня международной миграции в Украине на основе опыта других стран и применения нейро-нечеткого моделирования. Сперва, благодаря анализу результатов предыдущих исследований определено факторы, влияющие на принятие решения о миграции. После этого наиболее важные признаки, обнаруженные с помощью регрессионно-корреляционного анализа, использованы для группировки стран в кластеры для определения списка государств, которые схожи с Украиной в отношении миграционного климата. Основываясь на данных аналогичных стран, это исследование демонстрирует процесс разработки адаптивной системы нейро-нечеткого вывода (ANFIS) с целью моделирования уровня миграции в Украине, и дает некоторые рекомендации для дальнейших исследований.

Ключевые слова: международная миграция, моделирование миграции, кластеризация, нечеткая логика, нейро-нечеткое моделирование.

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ПРОБЛЕМИ РЕГУЛЮВАННЯ ІННОВАЦІЙНОЇ ДІЯЛЬНОСТІ НА ПІДПРИЄМСТВАХ

Проаналізовано основні проблеми, які гальмують інноваційну діяльність на підприємствах. Розкрито основні напрями вдосконалення механізму регулювання інноваційного розвитку вітчизняних підприємств. Визначено критерії підприємств, які обирають інноваційний шлях розвитку.

Ключові слова: інновації; інноваційна діяльність; підприємство; державне регулювання.

Постановка проблеми. Як у минулому, так і на сучасному етапі Україна має безліч соціально-економічних проблем, які можна вирішити, обравши курс розвитку, де пріоритетами буде інноваційна діяльність, що спрямована на структурну модернізацію підприємств та їх перехід на інноваційний шлях розвитку. В національній доповіді "Інноваційна Україна 2020" зазначено: "Інноваційність є визначальною характеристикою сучасних науково-технічних, виробничих, соціально-економічних та усіх суспільних процесів. Від оволодіння інноваційними механізмами розвитку залежить доля України: чи рухатиметься вона в напрямі входження до числа розвинених країн, чи залишиться стагнуючою країною на узбіччі науково-технічного і соціального прогресу. Це пов'язано з загальними закономірностями суспільного розвитку, згідно з якими у світі відбувається перехід від переважно відтворювального до інноваційного типу розвитку" [3]. Інноваційна політика підприємства повинна мати чіткий напрям змін. Для цього, як правило, необхідно розробити комплекс заходів, зокрема, цілі розвитку, визначити потреби ринку, ознайомитися з науковими дослідженнями, впровадити управлінські рішення, які будуть враховувати можливості та обмеженість ресурсів підприємства. Саме цим й зумовлюється актуальність теми даного дослідження. Предметом дослідження є регулювання інноваційної діяльності на підприємствах, а об'єктом – суспільні відносини, що виникають у сфері інноваційної діяльності.

Аналіз останніх досліджень і публікацій. Вагомий внесок у дослідження інноваційної діяльності підприємств зробили Гриньова В.М., Козирєва О.В. [2], які проаналізували основні соціально-економічні проблеми інноваційного розвитку підприємств, І. Чикаренко [1], яка вивчала проблеми нормативно-правової база та шляхи вирішення державного регулювання інноваційної діяльності в Україні; Лопатинський Ю.М., Водянка Л.Д. [4], які розглянули вплив зарубіжного досвіду державного регулювання інноваційної діяльності, обґрунтовували доцільність використання окремих інструментів впливу в умовах української економіки для стимулювання інноваційної діяльності підприємств, організацій та установ, сформулювали найефективніші методи державного регулювання інноваційної діяльності, які актуальні для підприємств України; Т. М. Вітренко-Хрустальова [5], яка досліджувала проблемні аспекти та напрями вдосконалення механізму державного регулювання інноваційного розвитку економіки; Скиба М.В. [6], яка структурувала процес державного регулювання інноваційної діяльності в Україні, висвітлила зарубіжний досвід щодо інструментів активізації досліджень та інновацій; Жидяк О.Р. [7], який визначив систему державної підтримки інноваційної діяльності підприємств аграрної сфери та основні джерела фінансування підприємств; Ляшевська О.І. [8], яка проаналізувала необхідність впливу органів регіональної влади на інноваційну активність регіону, запропонувала механізм фінансування інноваційної діяльності підприємств регіону із залученням Агентства регіонального розвитку та алгоритм відбору інноваційних проектів для цільового фінансування за рахунок акумульованих коштів; Федулова Л.І. [10], яка розкрила сутність впливу глобалізаційних викликів на розвиток економіки України, визначила та проаналізувала проблеми, що вимагають стратегічного підходу до розроблення державних програмних документів і запропоновано концептуальну модель інноваційної стратегії українським підприємствам, Наумовець А.Г., [9], який запропонував можливі шляхи розвитку інноваційних процесів на підприємстві, Гречан А.П. [14], яка обґрунтувала підходи до формування інноваційної стратегії транспортних підприємств з урахуванням рівня інноваційного потенціалу та виду інновацій.

Методологія. У дослідженні використано низку загальнонаукових методів, на підставі яких окреслено та встановлено основні засади розкриття проблем регулювання інноваційної діяльності на підприємствах. В роботі застосовано метод аналізу, який показує взаємозв'язок елементів, методів та інструментів регулювання інноваційної діяльності; метод порівняння, що дав змогу проаналізувати зіставлення показників за допомогою вимірювань або співставлень із відповідними показниками; статистичний метод, котрий відображає ситуацію протягом тривалого проміжку часу і вказує на можливі ризики та шляхи їх подолання; використання методів індукції та дедукції пов'язане із формулюванням найголовніших теоретичних засад вивчення управління інноваційною діяльністю для окреслення найголовніших закономірностей цього процесу на емпіричному рівні та метод узагальнення, на основі чого можна зробити висновки та дати пропозиції щодо конкретних проблем.

Мета статті. Основною метою статті є аналіз поточного стану інноваційної діяльності в Україні, джерелам фінансування, вирішенню проблем регулювання інноваційної діяльності на підприємствах. Завданнями є визначення шляхів та методів формулювання інноваційної політики, що сприятимуть здійсненню пошуків створення, провадження та поширення інновацій.

Результати. Інноваційна діяльність є складовою державної стратегії розвитку країни. Науково-технічний прогрес потребує оперативного впровадження інновацій на підприємстві, які дадуть можливість відповідати новим вимогам зовнішнього та внутрішнього середовища. Саме тому має формуватися комплекс заходів, що зможе реагувати на загрози розвитку підприємства. Інноваційна діяльність підприємства включає в себе аналіз та формулювання інновації, проектування товару чи надання нової послуги, що буде задовольняти споживачів; розгляд інновації як засобу для зміцнення своїх позицій на ринку; формування відділу, який займатиметься інноваційними розробками та мотивацією персоналу до залучення у сфері інновацій. Політика підприємства має бути спрямована на пошук та формулювання інноваційних рішень сучасних потреб соціуму.