Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 3, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

APPLICATION OF FUZZY COGNITIVE MODELS TO ASSESS THE BALANCE OF ELEMENTS OF THE SYSTEM OF SCIENTIFIC SUPPORT AND COMMERCIALIZATION OF INNOVATIONS IN THE AGRO-INDUSTRIAL COMPLEX

Ivan SANDU[1], Elena DERUNOVA[2], Anton VORONOV[2], Nikolay ZAVIVAEV[3]

[1]Federal State Budgetary Scientific Institution "Federal Research Center of Agrarian Economy and Social Development of Rural Areas - All-Russian Research Institute of Agricultural Economics, 35, kor.2 sh. Khoroshevskoe, Moscow, 123007, Phone: +7499195-60-16, Mobile:+79032382618, Email: anna_gu@mail.ru
[2]Institute ofAgrarian Problems ofthe Russian Academy of Sciences, 94, Moskovskaya St., 410012, Saratov, Russia, Phone: +78452263179, Fax:+78452264768, Mobile:+79873093797
[3]Nizhny Novgorod State University of Engineering and Economics, 22a, Oktyabr'skaya Street, 606340 Knyaginino, Russia, Mobiles: +79108796758, Emails: zavivaev_nik@bk.ru

Corresponding author: ea.derunova@yandex.ru

Abstract
Achieving technological independence from imported technologies and innovative products for the agricultural sector of the Russian economy is becoming especially relevant. The purpose of this study is to assess the balance of institutional elements of the system of scientific support and commercialization of innovations in the agricultural sector of economics and science, government, agribusiness, marketing and informatization using fuzzy cognitive models. Based on the application of cognitive modeling methods, relationships were identified between these elements for 16 different indicators included in the subsystems: educational potential, digitalization potential, human resources, science financing; research performance. Analysis and assessment of the influence of factors on each other and on the system as a whole was carried out on the basis of regression analysis using the example of 84 regions of Russia using data for 2021-2022. The greatest impact on the volume of shipped innovative goods, considered as the main concept, was exerted by the determinants "The share of organizations implementing technological innovations" and "The ratio of the salaries of scientific workers to the average salary in the region", other concepts are characterized by weak or negative dependencies. The results of cognitive modeling of the system of scientific support and commercialization of innovations in agriculture in Russia show the need to develop mechanisms for harmonizing federal and regional policies in the field of innovation implementation. The practical value of the research results lies in the possibility of applying the results in developing regional programs to accelerate the implementation of innovations in various industries and their replication.

***Key words*:** *system of scientific support and commercialization of innovations, agriculture, development institutions, cognitive modeling, factor analysis, regions, differentiation, directions of balance, development*

INTRODUCTION

In modern conditions, innovative development in all spheres of the economy is associated with accelerated intellectualization, computerization of production, and rapid rates of creation of new technologies [21]. The author's concept of the formation of regional systems of scientific support and commercialization of innovations in the agro-industrial complex is based on the concept of National Innovation Systems (NIS) and diffusion of innovations [7,11]. At the same time, increasing the efficiency of application of the results of scientific activity is associated with the creation, implementation, dissemination and commercialization of innovations taking into account the needs of the regions and the peculiarities of agricultural production in them [4, 6].

Early studies proposed a five-tier model of innovation, including science, agribusiness, government, society, information support, and representing a set of institutions and mechanisms operating on the principles of planning and coordination to search for, create, disseminate and replicate innovations and advanced production technologies [5].

The state program “Development of Science and Technology” aimed to form a competitive

research sector that would ensure breakthrough rates of economic modernization [20]. However, the process of commercialization of innovation is not developing fast enough. Insufficient level of funding of scientific research is one of the main reasons for the disunity of science and production, therefore one of the prerequisites for the integration of production, science and education is a long-term investment public-private partnership [22,23].

Global trends indicate a steady growth of knowledge and production intensity, i.e. the transformation of existing knowledge into a technological process [17,18]. As a result of the development of these processes, the task of improving human resources in the context of digital transformation and its integration into the chain of interaction between science and production when introducing innovations in agriculture is becoming more relevant [12,13]. Modern theory of decision support and adoption develops the direction of cognitive modeling based on identifying the relationships and mutual influence of statistical and evaluation indicators, as well as in modeling systems with specific cause-and-effect relationships between elements [15,16].

The global scientific community widely uses fuzzy cognitive maps for evaluation in modeling various socio-economic processes, noting as their advantage the possibility of using expert assessments and accumulated knowledge [19].

The research project presents software products for constructing cognitive maps and provides their detailed characteristics. Issues of developing methodological approaches to the use of cognitive models in various areas of the economy are presented in the works of foreign and domestic researchers [8,14,24].

Cognitive modeling takes into account the characteristics of such weakly structured systems as agriculture and rural areas, which is confirmed by the results of studies. In particular, M.E. Anokhina used cognitive strategies to develop scenarios for achieving stable economic growth in the agro-food complex of Russia [1].

Russian researchers Chernov and Shelkov applied a scenario approach to studying the possibilities of innovative development of agriculture[2].

Foreign scientists have used a cognitive approach in developing mechanisms for improving agricultural management in Scotland based on environmental regulation of agricultural production, taking into account expert assessments from farmers and the non-agricultural population [3,9].

The purpose of this study is to assess the balance of institutional elements of the system of scientific support and commercialization of innovations in the agricultural sector of economics and science, government, agribusiness, marketing and informatization using fuzzy cognitive models.

MATERIALS AND METHODS

The study is based on the study and generalization of a group of indicators and corresponding statistical data on the institutional elements of the system. During the research, such empirical methods as measurement, generalization, comparison, analysis were used. The identification or absence of relationships between institutional elements and subsystems of educational and personnel potential, as well as the potential for digitalization, financing and effectiveness of scientific research was carried out using cognitive modeling methods,using the Software For Fuzzy Cognitive Modeling software product.

RESULTS AND DISCUSSIONS

The paper develops methodological approaches to assessing the balance of elements of the system of scientific support and commercialization of innovations in Russian agriculture using the author's methodology for assessing and calculating indicators not reflected in official statistics. Despite the expansion of the database on scientific and innovative activities in agriculture, the developed author's assessment and forecasting tools predetermined the need to use additional indicators based on the adjustment of existing statistical indicators in relation to agriculture. Subsystems of educational and personnel

potential, as well as potentials for digitalization, financing and effectiveness of scientific research will be identified empirically. The study puts forward a hypothesis about the possibility of identifying cause-and-effect relationships between institutional elements for the purpose of further harmonization and achieving balance in the system as a whole.Technological transformations of the Russian agro-industrial complex are largely determined by the efficiency of the system of scientific support and commercialization of innovations. In a number of foreign countries, innovative development is modeled by strategies of scientific and technological leadership of large companies and corporations, ensuring the implementation of domestic scientific achievements in agriculture. There are various approaches to managing interregional differentiation of innovative development. One of them is smoothing out on the basis of the flow of knowledge from leading regions in scientific support to outsider regions. Other researchers propose the use of a program-targeted approach and the active involvement of outsiders in the creation of joint scientific innovative platforms [10]. To assess the balance of the institutional elements of the system, the authors developed an assessment and forecasting toolkit in their early works, including indicators from the following subsystems: educational potential, digitalization potential, human resources potential, science funding; research performance. The assessment of the mutual influence of factors was carried out on the basis of regression analysis performed on the basis of 84 regions of Russia using data for 2021-2022.

For the analysis and subsequent construction of a cognitive map, 16 indicators were selected with a preliminary construction of a matrix of paired coefficients. The following were included in these indicators:

C1 - Agricultural output, million rubles;

C2 - Share of employed population with higher education, %;

C3 - Number of students, per 10,000 people;

C4 - Share of organizations with broadband Internet access, in the total number of organizations, %;

C5 - Share of organizations using personal computers, %;

C6 - The share of active Internet users among the adult population, %;

C7 - Internal expenditure on scientific research and development, thousand rubles;

C8 - Ratio of average monthly salary of scientific workers to average monthly salary in the region, %;

C9 - Share of those engaged in research and development in the average annual number of those employed in the regional economy, %;

C10 – Inventive activity coefficient (number of domestic patent applications for inventions filed in Russia per 100 thousand people), units;

C11 – Share of organizations implementing technological innovations, %;

C12 – Share of budget funds in internal research and development, %;

C13 – Share of products of high-tech and knowledge-intensive industries in the gross regional product, %

C14 – Number of researchers in the field of agricultural sciences, people;

C15 – Number of labor force aged 15 years and older in the constituent entities of the Russian Federation, thousand people;

C16 – Volume of shipped innovative goods, million rubles. To determine the weights of the relationships, a fairly common method of paired comparisons was used. The strength of the relationship between concepts was calculated by adjusting the regression coefficients based on the normalization of each factor with an assessment of significance by the p-value of the regression model.

Positive and negative values of concepts characterize, respectively, direct and inverse dependence; zero values reflect the absence of mutual influence of factors.

Based on the processing of table data by the Software For Fuzzy Cognitive Modeling 1 program, the parameterization of the system of scientific support and commercialization of innovations in Russian agriculture was carried out in the format of a fuzzy cognitive map (Fig. 1).

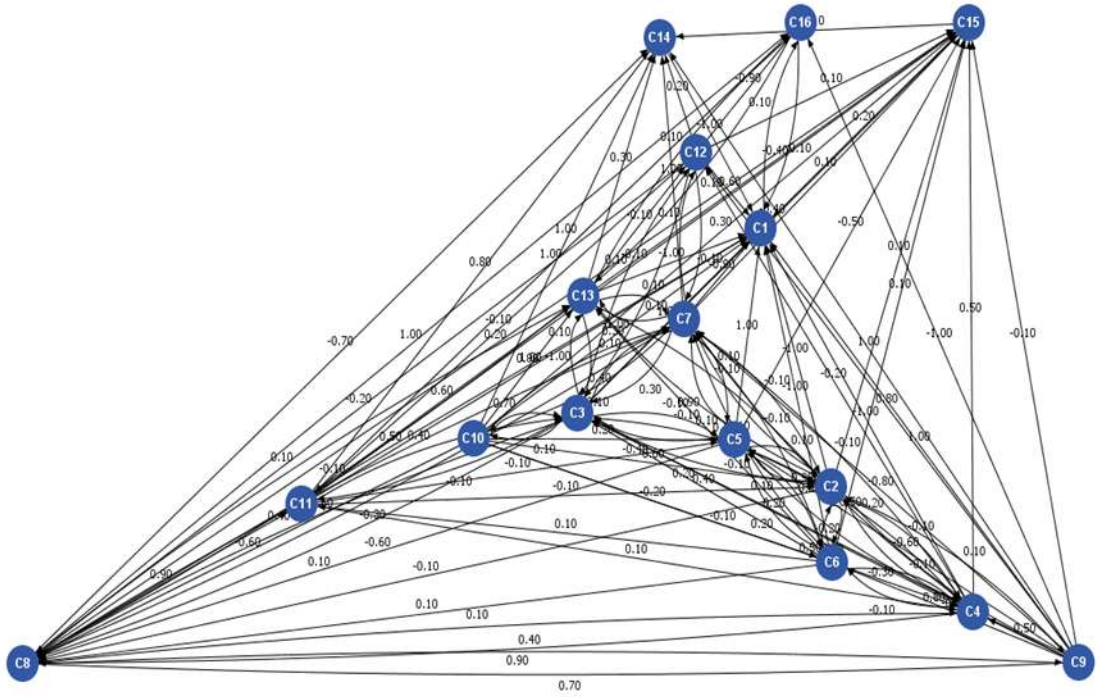

Fig. 1. Fuzzy cognitive map of the system of scientific support and commercialization of innovations in the agro-industrial complex
Source: Own calculations based on Software For Fuzzy Cognitive Modeling data.

The most important indicator of the effectiveness of the system of scientific support and commercialization of innovations in the agro-industrial complex is the volume of shipped innovative goods, defined as one of the target concepts. The greatest influence on this concept was exerted by the determinants "The share of organizations implementing technological innovations" and "The ratio of salaries of scientific workers to the average salary in the region".

The analysis showed that the above concepts are supported by the system, since their estimates are significantly higher than the estimates of the reverse effect. However, the subsystem "Efficiency of scientific research" did not reveal any impact on the production of innovative products. For example, the coefficient of inventive activity is characterized by a low value, which may indicate an insufficient level of commercialization. This fact indicates the need to develop measures to stimulate the marketing potential when introducing innovations into agricultural production. Extremely low impact of the concept "The share of products of high-tech and knowledge-intensive industries in the gross regional product", which indicates insufficient distribution of the digitalization process in agriculture. In the research financing block, a negative impact of the concept "Share of budget funds in internal research and development" on the target determinant "Internal expenditure on research and development in the field of agriculture per 1 researcher of agricultural sciences" is observed, which indicates insufficient state support for scientific research in agriculture and weak involvement of commercial organizations and other institutional units in the financing process.

The negative impact of these concepts indicates the lack of balance in the system elements.

The target concept "Number of researchers in the field of agricultural sciences" of the subsystem "Human resources" is significantly influenced by the determinants "Internal expenditure on research and development in the field of agriculture per 1 researcher of

agricultural sciences", thousand rubles; "Inventive activity coefficient". At the same time, there is no influence of the target concept on these determinants with their positive
impact on the subsystem, which indicates an unbalanced development of educational and human resources potential. The innovation sector is characterized by weak implementation of advanced technologies and innovative products, poor provision of innovative personnel, which leads to disproportions in the system of scientific support and commercialization of innovations in agriculture in Russia.
The insufficient level of coordination of the system's elements is confirmed by the parameters of assessing the system's impact on target concepts, which in most cases are lower than the assessment of the reverse impact.
The results of cognitive modeling of the system of scientific support and commercialization of innovations in agriculture in Russia indicated the need to improve the existing mechanisms for planning and coordinating its elements.

CONCLUSIONS

To improve the balance of the elements of the system of scientific support and commercialization of innovations - scientific and intellectual, investment, production and technological, marketing and information potential, an analysis was used based on the construction of fuzzy cognitive models. Cognitive modeling allows assessing weakly structured dependencies. To assess the balance of the elements of Russia, an assessment and forecasting toolkit was developed from 16 indicators included in the subsystems: educational potential, digitalization potential, human resources, science financing; research performance. The assessment of the mutual influence of factors was carried out on the basis of regression analysis performed on the basis of 84 regions of Russia using data for 2021-2022. The greatest impact on the volume of shipped innovative goods, considered as the main concept, was exerted by the determinants "The share of organizations implementing technological innovations" and "The ratio of salaries of scientific workers to the average salary in the region". Such concepts of the subsystem as "Efficiency of scientific research" did not have a significant impact on the production of innovative products from the point of view of the influence of the coefficient of inventive activity, "Share of products of high-tech and knowledge-intensive industries in the gross regional product", "Share of budget funds in internal research and development" on the target determinant "Internal costs of scientific research and development in the field of agriculture per 1 researcher of agricultural sciences", which indicates insufficient state support for scientific research in agriculture and weak involvement of commercial organizations and other institutional units in the financing process. Insufficient level of consistency of the system elements is confirmed by the parameters for assessing the impact of the system on target concepts, in most cases
lower than the estimates of the reverse impact.
The results of cognitive modeling of the system of scientific support and commercialization of innovations in agriculture in Russia indicated the need to improve the existing mechanisms for planning and coordinating its elements at the federal and regional levels.
The practical significance of the results of the conducted research lies in the possibility of assessing and forecasting the effectiveness of innovation management in the agricultural sector of the economy. The results of the research are of practical value for the development of regional programs for innovation-oriented development of the agro-industrial complex.

ACKNOWLEDGEMENTS

The reported study was funded by the Russian Science Foundation, project № 23-28- 01785 «Modeling the growth of food production taking into account the improvement of scientific support for economic entities in the agro-industrial complex ».

REFERENCES

[1]Anukhina, M.E., 2020, Modeling the strategy of managing economic growth in agriculture: monograph, M.: RUSAINS, 330 p.

[2]Chernov, I.V., Shelkov, A.B.,2020, Scenario approach to studying the possibilities of innovative development of agriculture in modern conditions.Proceedings of the 15th International Conference "Management of Large-Scale Systems Development" (MLSD'2022), Moscow: 996-1005.

[3]Christen, B., Kjeldsen, C., Dalgaard, T., Martin-Ortega, J., 2015, Can Fuzzy Cognitive Mapping Help in Agricultural Policy Design and Communication? Land Use Policy,Vol.45: 64–75.

[4]Derunova E.A., Vasilchenko,M.Ya., Shabanov, V.L., 2021, Assessing the impact of innovation and investment activity on the formation of an exportoriented agricultural economy. Economic and Social Changes: Facts, Trends, Forecast, Vol.4(5):100–115.

[5]Derunova, E., Kireeva, N., Pruschak, O., 2019, Assessment and relationships between physical and economic accessibility of food: status and forecast. Scientific Papers Series «Management, Economic Engineering in Agriculture and Rural Development», Vol.19(1):147-160.

[6]Derunova, E., Vasilchenko, M., Shabanov, V., Derunov, V., 2021, Mechanisms to stimulate the acceleration of innovative development in the agroindustrialcomplex, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. Vol.21(2):209–222.

[7]Derunova, E.A., Sandu I., 2023, Formation of a system of scientific support and commercialization of innovations in the agro-industrial complex of Russian regions in the context of innovation-oriented development. Economics of Agriculture of Russia, Vol. 11:20-28.

[8]Fitjar, R.D., Rodríguez-Pose, A., 2011, Innovating in the Periphery: Firms, Values and Innovation in Southwest Norway. European Planning Studies, Vol. 19(4): 555-574.

[9]Jetter, A. J., Kok, K., 2014, Fuzzy cognitive maps for futures studies – a methodological assessment of concepts and methods. Futures, Vol. 61: 45–57.

[10]Kobylko, A.A., 2016, Methods of promoting scientific products in the humanities "Foresight" Russia: new production for the new economy. Collection of materials of the St. Petersburg International Economic Congress (SPEK-2016). Moscow: INIR, Cultural Revolution, Vol. 3: 201-209.

[11]Lundvall, B.A.,1992, National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, Pinter Publishers, London.

[12]Machlup, F., 1962, The production and distribution of knowledge in the United States. Princeton university press, Vol. 278.

[13]Makarova I.V., Korovina G.B., 2014, Trends in neo-industrialization of the economy of an old industrial region. Digest-finances, Vol.4:32-43.

[14]Mezei, J., Sarlin, P., 2016, Aggregating expert knowledge for the measurement of systemic risk. Decision Support Systems, Vol. 88: 38–50.

[15]Nápoles, G., Espinosa, M. L., Grau, I., Vanhoof, K., 2018, FCM Expert: Software Tool for Scenario Analysis and Pattern Classification Based on Fuzzy Cognitive Maps. International Journal on Artificial Intelligence Tools, Vol. 27(07). Access mode: https://doi.org/10.1142/S0218213018600102. Accessed on July 28, 2024.

[16]Podgorskaya, S.V., Podvesovsky, A.G., Isaev, R.A., Antonova, N.I., 2019, Construction of fuzzy cognitive models of socio-economic systems on the example of the management model of integrated development of rural territories. Business Informatics, Vol. 13 (3):7–19.

[17]Popescu, A., 2014, Research on profit variation depending on marketed milk and production cost in dairy farming, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 14(2):223-230.

[18]Popescu, A., 2018, Main aspects regarding the contribution of domestic trade to the development of Romania's economy in the period 2008-2017, Scientific Papers Series Management, Economic Engineering in culture and Rural Development Vol. 18(4): 250-259.

[19]Pozharsky, N.A., Likhachev, D.A., Kislyakov, S.V.,2017, Use of cognitive maps and fuzzy logic in the development of OSS/BSS solutions for telecom operators. T-Comm-telecommunications and transport,Vol. 11 (1): 21-25.

[20]Resolution of the Government of the Russian Federation of April 15, 2014 No. 301 "On approval of the state program of the Russian Federation "Development of Science and Technology" for 2013-2020" (With amendments and additions dated: March 30, 2017, March 29, 2018). Access mode: https://base.garant.ru/70643478/. Accessed on July 15, 2024.

[21]Roco, M. C., Bainbridge, W. S., 2003, Overview converging technologies for improving human performance: Nanotechnology, biotechnology, information technology, and cognitive science (NBIC). In Converging technologies for improving human performance: Nanotechnology, biotechnology, information technology and cognitive science. Dordrecht: Springer Netherlands: 1-27.

[22]Sandu, I.S., Glagolev, S.N., Doshanova, A.I., Troshin, A.S., Lomachenko, S.N., 2015, Formation features of higher school innovation model in modern conditions. International Business Management, Vol. 9 (6): 1102-1107.

[23]Sandu, I.S., Veselovsky, M.Y., Semyonova, E.I., Fedotov A.V., Doshchanova, A.I.,2015, Methodological aspects of social and economic efficiency of the regional activities. Journal of Advanced Research in Law and Economics, Vol. 6 (3): 650-659.

[24]Solana-Gutiérrez, J., Rincón, G., García-de-Jalón Alonso, C. D., 2017, Using fuzzy cognitive maps for predicting river management responses: A case study of the Esla River basin, Spain. Ecological Modelling, Elsevier,Vol.360(C):260–269.