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Neural network model for developing innovation and investment policy of real economy organisations in conditions of modern digital transformation[i]

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***Abstract*—The purpose of the study was to suggest and prove the hypothesis that a neural network can make it possible to evolve a neural network model for developing an innovation and investment policy of real economy organizations. The model suggested includes sustainable use of capabilities of three types of artificial intelligence systems based on the Deductor platform, i.e., the Kohonen map, Big Data quantization neural network and AI decision tree system.**

The research has identified main factors determining a success and dynamic development of innovations. Theoretical foundations of artificial intelligence systems applied in the real sector of the economy and other spheres have been investigated. Theoretical bases for the development of innovation and investment policy have been considered. There has been formed a neural network family that allowed evolving a model for the development of innovative investment policy of organizations. The sales of innovative products have been forecasted.

Monographic, design-calculated and artificial intelligence methods have been mainly applied in the research presented.

The following results have been obtained. Main factors affecting the production of innovative products in the conditions of market uncertainty have been found. The theoretical foundations of artificial intelligence systems used in various fields of activity have been investigated. A hypothesis has been suggested and proved that a neural network can make it possible to evolve a neural network model for the development of an innovation and investment policy of real economy companies. The model proposed includes sustainable use of capabilities of the neural network family of three types of artificial intelligence systems based on the Deductor platform, i.e., the Kohonen map, BigData quantization neural network and the AI decision tree system.

The main conclusions that reflect the results of the study have been formulated and are of great importance for the study of the digital economy problems.

Keywords—neural network model, economy, financial sphere, market uncertainty, innovation policy, innovative products.

I. INTRODUCTION

The relevance of the study is due to the conditions of technological transformation. The theoretical foundations of artificial intelligence systems applied are important in order to evolve a neural network model for developing an innovation and investment policy of organizations in the real economy and forecasting sales of innovative products.

Experts noted that the reasons for a weak innovation activity are rooted in the current conditions of scientific research, low quality and direction of training human resources, conditions of financing research and development work (FR&DW), effectiveness of their commoditization and in the system of obtaining and protecting intellectual property, regulation of commodity, financial markets and business climate in the investment environment.

The investment policy of an enterprise is defined as a set of strategic management decisions regarding the ways to attract and expend resources for investment purposes. The feature of the main types and directions of investment strategy is based on the classification of investment sources and areas of the investment activity.

The innovation-driven development in Russia was investigated by M.Yu. Arkhipova, S.Yu. Glazyev, A.G. Granbreg, A.S. Degtyareva, V.P. Sirotin, G.A. Khmeleva, K.D. Cherpakova and others. Statistical analysis of

individual areas of innovation was considered in works by T.A. Dubrova, V.G. Minashkina, N.A. Sadovnikova, B.S. Mkhitaryan, L.M. Gokhberg and A.E. Surinov.

The cost intensity of technological innovations (i.e., their share in the total volume of products shipped) turned out to make 1.7% in the industrial production in 2017. It was the lowest value over the past five years (2.2% in 2013, 2.1% in 2014 and 1.8% in 2015–2016). Technological innovations in 2017 were carried out by 2321 industrial production organizations, or 9.6% of their total number. Since 2013, the innovation activity level has not changed substantially; in 2013–2014 it was 9.7%, then further decrease to 9.5% in 2015 and 9.2% in 2016, which generally indicated a low innovation potential of the economy and insufficient rates of its development [1]

According to the studies, the companies operating in the fields of telecommunications and information technology (3.6% in 2013, 2.4% in 2014, 3.3% in 2015 and 2.3% in 2016–2017) also exhibit a downward trend in the corresponding indicator. In agriculture, the intensity of innovation spending is minimal (1%).

Many Russian and foreign scientists have devoted their works to studying problems of sustainable economic growth based on innovations. For example, Baranov E.F. and Bessonov V.A. investigated the issues of the Russian economy transformation and balance of its financial and economic system [2]; exploring the issues of profitable work of enterprises in the real economy, D.A. Medvedev outlined the tasks of economic policy of Russia, in order to generate the growth paths for further extension [3].

Compared to 2013, the number of claims for the patents applied to Rospatent in 2014 decreased by 10.26%, and for utility models by 2.83%. Despite this, in 2014, the plan for the positive decisions made on applications for inventions was exceeded by 0.8% and for utility models by 11.8% [4].

The problem to be solved is complicated due to its versatility and complexity. Analyzing the G. B. Kleiner and M. A. Rybachuk's point of view in the book "System Balance of the Economy," R. M. Nizhegorodtsev tried to reveal the logic of a systemic paradigm in economics [5].

The innovation is a type of activity associated with the transformation of ideas into technologically new or improved products (or services) implemented on the market into new or improved technological processes or methods of production (transmission) of services used in practical activities [6].

Assessing the conditions and level of public-private collaboration projects in the constituent entities of the Russian Federation, A.N. Savrukov et al. touched upon the issues of improving the mechanism of domestic fiscal policy [7].

The influence of innovation on the balanced development of the financial and economic system was studied by many scientists. So, Stolbov M. I. et al. attempted to define the model of the Russian financial sector on the basis of cross-country analysis [8]. In the conditions of growing market uncertainty, the study of ways to reduce the risk of venture capital investments, including the risk resulting from changes in the market of modern information technologies and artificial intelligence systems, is of great importance.

For example, Lomakin N.I. proposed an artificial intelligence system to manage the financial risk of an economic entity [9] and developed an artificial intelligence system to assess financial risk, using the VAR method [10]; moreover, the ways of sustainable development of regional enterprises based on artificial intelligence systems were identified [11]. The problems of analyzing financial risk in the conditions of the digital economy formation were studied by N. Goncharova [12]. However, despite the results achieved, certain aspects of the problem require further research.

In modern conditions, neural network models and artificial intelligence systems play an increasingly important role in solving the problems involved, in particular, in forecasting the implementation of regional investment projects [13], studying the systemic impact on the economy of the monetary policy of the Russian Central Bank [14], developing the AI algorithm for trading MoEx SiH8 futures contract based on the Big Data quantization [15], intellectual data used in the evaluation of economic security [16] and study of financial risks of the neural network in a digital economy [17].

The purpose of the study presented was to suggest and prove the hypothesis that a neural network can make it possible to evolve a neural network model for developing an innovation and investment policy of real economy companies. The model suggested includes sustainable use of capabilities of three types of artificial intelligence systems based on the Deductor platform, i.e, the Kohonen map, Big Data quantization neural network and AI decision tree system.

To achieve the purpose, the following tasks were set and solved. The main factors that determine the success and dynamic development of innovation have been identified. The theoretical foundations of artificial intelligence systems used in the real economy and other spheres have been investigated. The theoretical bases for the development of innovation and investment policy have been considered. There has been formed a neural network family that allowed evolving a model for the development of innovation and investment policy of organizations. The sales of innovative products have been forecasted.

II. Materials and Methods

Based on the statistical data and results of the domestic financial system for the period of 2015-2018, neural network models were developed. A family of the digital models presented was capable of processing data to evolve a model of innovation and investment policy of organizations in the real sector of the economy. The model used the following source data (Fig.1).

COL1	GDP billion rubles.	Key rate,%	RTS Index	Innovative products., Billion rubles.	Costs for innovations., billion rubles	UDS, rub.	Sald. Profit bln. rub.	Sigma risk	Loans issued, billion rubles.	Prediction of the volume of innov.prod. billion rubles.	CO
Q1 2018 (from March 23, 2018)	15569,6	7,25	1261,44	852	702	57,1658	2,5	2,8	31567,6	852	
from 12 February 2018	15569,6	7,5	1285,47	850	351	56,32	1,7	2,7	31112,1	850	
Q4 2017 (Dec 18, 2017)	92037,2	7,75	1154	3403,1	848	57,61	9,3	2,7	30290,1	3403,1	
(from October 30, 2017)	61358,1	8,25	1113	2552,3	636	58,32	8,5	2,7	30694,5	2552,3	
Q3 2017 (September 18, 2017)	61358,1	8,5	1136	2552,3	636	56,79	7,4	2,8	30297,7	2552,3	
Q2 2017 (from June 19, 2017)	46018,6	9	1001	1701	424	58,94	5	2,9	29823	1701	
(from 02 May 2017)	30679	9,25	1053	1701	424	56,56	4	3	29876,9	1701	
Q1 2017 (from March 27, 2017)	15339,5	9,75	1113	850,8	212	56,26	2,7	3,1	29760,7	850,8	
Q4 2016	86148,6	9,75	1113	3723,6	777,5	56,26	12,6	3,1	30796	3723,6	
Q3 2016 (September 19, 2016)	64611,5	10	991	1792,7	583,1	62,83	8,2	2	30290	1792,7	
Q2 2016 (from June 14, 2016)	43074,3	10,5	931	1861,8	388,7	63,97	5,7	0,2	28864,5	1861,8	
Q1 2016	21537,15	10,5	931	930,9	194,3	63,97	2,5	1,8	35548	930,9	
Q4 2015	83387,2	10,5	931	3258,2	735,7	63,97	8,4	1,3	34844	3258,2	
Q3 2015 (from 03 Aug 2015)	62540,4	11	833	2443,6	551,7	64,28	6,7	0,4	31390	2443,6	
Q2 2015	41693,6	11	833	1629,1	367,8	64,28	5,9	0	33565	1629,1	

Fig. 1. Initial parameters for the neural networks

The work resulted in the following facts obtained.

III. Results and Discussion

The main factors influencing the release of innovative products in the conditions of market uncertainty were investigated. The theoretical foundations of artificial intelligence systems used in various fields of activity were studied. There was suggested and proved a hypothesis that a neural network can make it possible to evolve a neural network model for the development of an innovation and investment policy of organizations in the real sector of the economy.

The first part of the research results concerned the identification of the main factors influencing the output of innovative products in the conditions of market uncertainty. The sales curves of innovative products and investment in innovation for the period of from 2015 to 2018 indicated a weak innovation activity of domestic organizations.

It is important to analyze the factors determining the effectiveness of innovations in companies of the real sector of the economy.

A. *Analysis of the factors determining the performance of innovations in organizations of the real sector of the economy*

It seemed expedient to consider the dynamics of the factors reflecting the impact of the external and internal environments for the periods of time that corresponded to changes in the Central Bank's key rate and included them into the neural network model, the Kohonen Map, so that we could consider the influence patterns of innovations on the sustainability of economic growth. The Kohonen self-organizing map (SOM) is a neural network with unsupervised learning that performs the tasks of visualization and clustering. The idea of the network was proposed by the Finnish scientist T. Kohonen and is a method of projecting a multidimensional space into a space with a lower dimension, most often a two-dimensional one [18].

The Kohonen map generated by the neural network made it possible to evolve an innovation and investment policy for the development of an organization in the conditions of modern digital transformation.

The neural network contained the date (quarter); GDP (billion RUB); key rate, (KR,%); RTS-Index; innovative products, billion RUB; costs of innovative products, billion RUB; dollar exchange rate (UDS, RUB); net profit, billion RUB; sigma (risk, billion RUB); loans originated, billion RUB; and forecast for the volume of innovative products, billion RUB.

B. *Formation of a neural network model*

The Deductor platform being applied resulted in a neural network, a Kohonen Map generated (Fig.2).

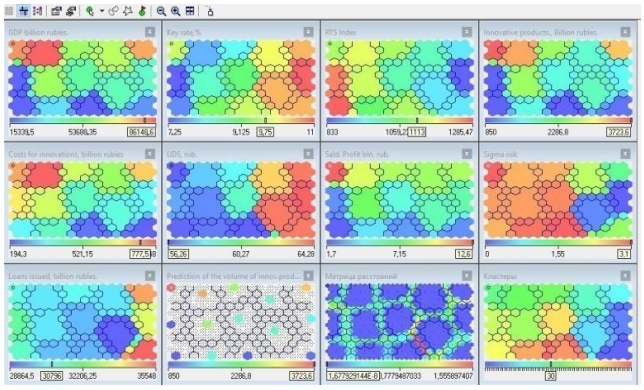

Fig. 2. Neural network, a Kohonen Map

C. *Formation of a Big Data quantization neural network*

The quantization is known to be a process of splitting a range of values of a certain variable into a finite number of levels followed by these values rounded off to the levels nearest to them.

The data quantization results are presented below (Fig.3).

	GDP billion rubles.	Key rate,%	RTS Index	Innovative products, Billion rubles.	Costs for innovations, billion rubles	UDS, rub.	Sold. Profit, bln. rub.	Sigma risk	Loans issued, billion rubles.	Prediction of the volume of innov.prod. billion rubles.
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Q4 2017 (Dec 18, 2017)	от 83387,2	7,75	1154	3403,1	948	57,61	9,3	2,7	30290,1	3403,1
(from October 30, 2017)	от 61358,1 до 83387,2	8,25	1113	2552,3	636	59,32	8,5	2,7	30694,5	2552,3
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Q2 2015	от 21537,15 до 43074,3	11	833	1629,1	367,8	64,28	5,9	0	33565	1629,1

Fig. 3. Data quantized by neural network

Spitted range of values into a finite number of levels, the data served as the source material for the work of the next neural network, “decision tree.”

D. *Developing an AI Decision Tree System*

The development of an AI “decision tree” system was essential because it allowed making logical conclusions based on the data processed, which was important for building an enterprise development policy (Fig.4).

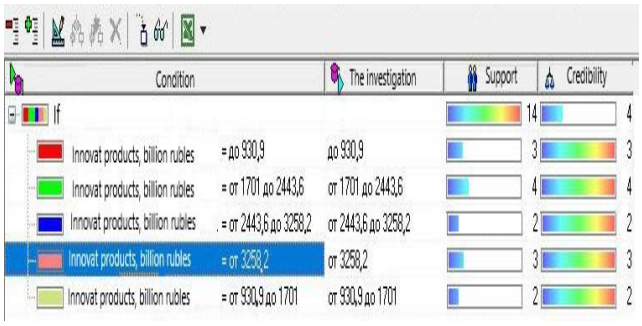

Fig. 4. “Decision tree” neural network

The research results showed the maximum output of “Innovative products, billion rubles” to be on the "tree branch" with the parameter from 3258.2.

The use of the decision tree tool allowed grouping of signs included in the neural network model of the innovation and investment policy of an enterprise in the form of a histogram (Fig.5).

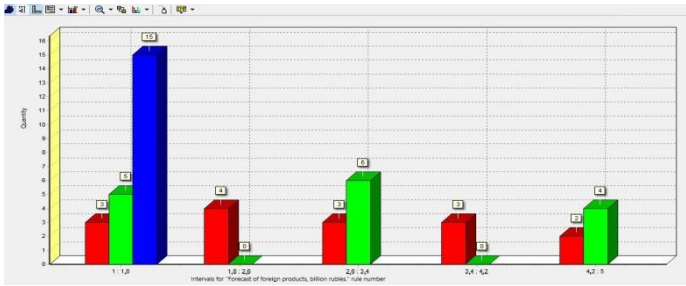

Fig. 5. Histogram of the parameters distribution in the “Decision Tree” model

For example, the four “rules” created by the neural network made it possible to determine the numerical values of the parameters (dollar rate, net profit, loans originated, sigma risk, key rate, GDP, costs for innovative products and RTS index) included into the model in the ranges required, so that the policy selected would provide access to the control numbers of the target output parameter “Innovative Products” at the appropriate levels of values, i.e., the first to 930.9; the second, from 1701 to 2443.6; the third, from 2443.6 to 3258.2; the fourth, from 3258.2; and the fifth, from 930.9 to 1.701 trillion RUB.

E. Forecasting the volume of innovative products of the neural network based organizations

Using the “what-if” function in the Deductor platform allowed obtaining calculated sales values of innovative products corresponding to the values of the input parameters predicted (Fig 6).

Input	
GDP billion rubles	21537,15
Key rate,%	10,5
RTS Index	931
Innovative products , Billion rubles	930,9
Costs for innovations, billion rubles	194,3
UDS, rub.	63,97
Sald. Profit bln. rub.	2,5
Sigma risk	1,8
Loans issued, billion rubles	35548
Output	
Prediction of the volume of innov.prod. billion rubles	930,9

Fig. 6. Sales forecast of innovative products, corresponding to the “first” variant of the innovation and investment policy

The sales forecast value of innovative products for the next quarter was 930.9 billion RUB and pointed at the “first” version of the innovation-investment policy that would be acceptable for a company in modern conditions.

IV. Conclusion

Based on the study, we can draw the following conclusions.

- The main factors that determine the innovative products output in the conditions of market uncertainty were identified.
- The theoretical foundations of artificial intelligence systems used in various fields of activity were investigated.
- There was suggested and proved the hypothesis that a neural network can make it possible to evolve a neural network model for the development of an innovation and investment policy of real economy organizations.
- There was created a neural network family of three types of artificial intelligence systems based on the Deductor platform (the Kohonen map, the Big Data quantization neural network and the AI decision tree system).

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