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Digital neural network for managing financial risk in business due to real options in the financial and economic system[i]

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***Abstract*—The purpose of the study was to suggest and prove the hypothesis that a neural network, taking into account the dynamics of financial risk and VIX index, makes it possible to develop a profit forecast for organizations of the financial and economic system.**

For the purpose, the following tasks have been set and solved. On the basis of the OWL technology, the ontology of the financial risk concept in the financial and economic system has been created in the program Untitled-ontology-3.

The essence of the "real options" concept, their types and cost estimation procedure using the Black-Scholes and Cox-Ross-Rubinstein models has been investigated.

The theoretical foundations of risk management in the operation of the financial and economic system in terms of digitalization have been investigated.

The main trends in the development of technologies of a new technological mode (NTM) have been revealed.

The theoretical bases of artificial intelligence systems used in organizations of the real sector of the economy and other spheres have been investigated.

Based on the Deductor platform, there has been created a neural network, Kohonen Map that takes into account the dynamics of financial risk and VIX option and allows developing a profit forecast for organizations of the financial and economic system.

Based on the neural network, a profit forecast for a socio-economic system has been made.

The scientific study required monographic, design-calculation and artificial intelligence methods applied. The main factors that determine the level of financial risk in releasing innovative products in the context of market uncertainty have been identified.

The main conclusions that reflect the study results have been formulated and consist in the fact that in modern conditions of market uncertainty and risk, it is important to study the problems associated with the further development of entrepreneurship and innovation not only in the financial sector, but also in the real economy.

Keywords—financial risk, artificial intelligence, Kohonen map, VIX-index, Big Data, real option

I. INTRODUCTION

The relevance of the study is due to the need to manage risk in the operation of the domestic financial and economic system in the context of the transition to a digital innovation economy and widespread use of artificial intelligence systems.

As studies show, works of many domestic and foreign authors were devoted to this issue. So, Lomakin N.I., Korotina V.A. et al. investigated financial risk management issues based on neural networks and fuzzy algorithms [1, pp. 225-227]; Pavlov V.O. successfully conducted a study of financial risks of an organization using an artificial intelligence system [2, pp. 321-326]. In addition, in the study of factors that in one way or another determine the features of financial risk management, there is the need to consider the aspects that attract attention and require additional research. In particular, according to Krashchenko S.A., problems of developed legal and financial-economic information [3, p. 225] and analysis and evaluation of the financial stability and business activity of the organization [4, pp. 64-71] play an important role.

As evidenced in practice, the study of financial risks, regarding the ratio of business capital in a particular area of activity is of great interest. The ontology of the financial risk category is intended to reveal its essence and role in the domestic financial and economic system; it is presented in Fig. 1.

The ontology of the financial risk category is made on the basis of the OWL technology that is actively developing in the Semantic Web framework. Ontologies are developed and can be used to solve various tasks, including for joint use by people or software agents, enable the accumulation and reuse of knowledge in the subject area and create models and programs [5]. Thanks to ontologies, creating of semantic networks has become possible. The semantic network is based on three principles: aggregation, security and logic.

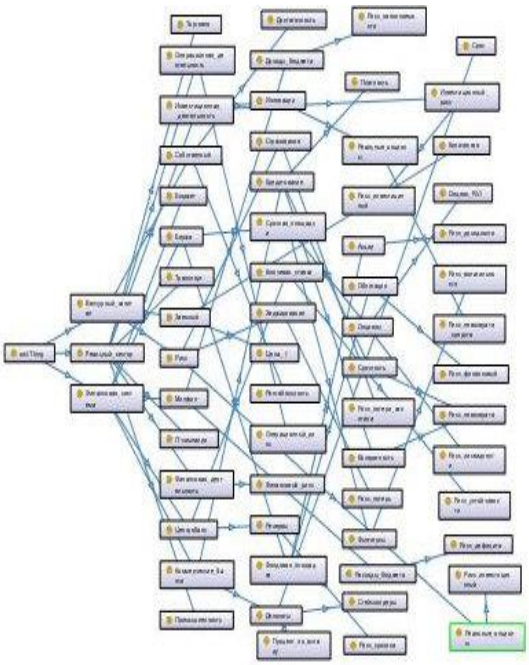


Fig. 1. Ontology of the financial risk concept in the financial and economic system

The “real option” concept occupies an important place in the ontology of financial risk. A real option (French: Option Réelle) is the right, but not obligation to make any management decision relating to the functioning of the company [6]. Unlike financial options, real options are applicable to “real” assets, for example, an enterprise, oil field etc.

Real options are usually divided into several types, i.e., reduction and withdrawal from business, development, replication of experience, switching and temporary stopping a business, a complex option that can contain more than one possibility of changes and an option to postpone the start of a project. The investment value (Vinv) of the object under investigation can be calculated using the following formula (1)

$$\varsigma\iota\nu\varpi = \varsigma\varepsilon\nu\tau + \varsigma o\pi\tau \qquad (1)$$

where Vent is the value of the enterprise without cost of the option taken into account

Vopt is the option value.

As for the value of a real option, the Black-Scholes model is usually used to estimate the fair value of an asset (2)

$$X(\Pi,\tau) = \Pi N(\delta_1) \square \Sigma\varepsilon^{-\rho\tau} N(\delta 2), \qquad (2)$$

where P is the share price, the value of the company's assets;

S is the strike price, the nominal value of the debt;

t is the time period before the option is exercised, the duration of the debt; and

r is the risk-free interest rate, corresponding to the duration.

The Cox-Ross-Rubinstein model is often called the augmented Black-Scholes model because it takes into account data that was ignored by the Black-Scholes model. The Cox-Ross-Rubinstein model is today the main discrete model in the securities market. The value of the European option of the buyer is calculated as ratio between the income expected and the option period (3)

$$C_T = \frac{MC}{(1+\frac{i}{n})^{[nT]}} = \frac{\sum_{k=0}^{[nT]} \max\{C_0\ u^k\ d^{[nT]-k};\ 0\} C_{[nT]}^{k} (1-p_{(n)})^{[nT]-k}}{(1+\frac{i}{n})^{[nT]}} \qquad (3)$$

where σ is the standard deviation of the asset value.

It seems appropriate to use a generally accepted risk assessment method. In essence, risk is a variation (dispersion) that is advisable to be present as a standard deviation. Standard deviation is determined by the formula (4)

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(r_i - \bar{r})^2}{n}}, \qquad (4)$$

where σ is the risk;

n is the number of samples;

ri is the yield in the i-period; and

$\bar{r}$ is the average yield.

Such a direction in the study of risk as fuzzy-calculations in improving risk management was quite interesting [7, p. 165].

The dynamics of the profit of the Russian financial and economic system with respect to the average value determined the risk development over the period of 2015-2018 quarterly (Fig. 2).

Many Russian scientists, such as M.Yu. Arkhipova, S.Yu. Glazyev, A.G. Granbreg, A.S. Degtyarev, V.P. Sirotin and G.A. Khmelev devoted their works to the problems of innovation-driven growth. Issues of statistical analysis of individual areas of innovation activity were considered in works by T.A. Dubrov, V.G. Minashkin, N.A. Sadovnikova and others.

Experts noted that the intensity of the technological innovations costs (i.e., their share in the total volume of products shipped) in the industrial production in 2017 was equal to 1.7%. This was the lowest value of the indicator for the last five years. Moreover, technological innovations in 2017 were carried out by 2321 organizations of industrial production, or 9.6% of their total number. Since 2013, the

innovation activity level has not changed substantially, which generally indicated a low innovation potential of the economy and insufficient rates of its development [8].

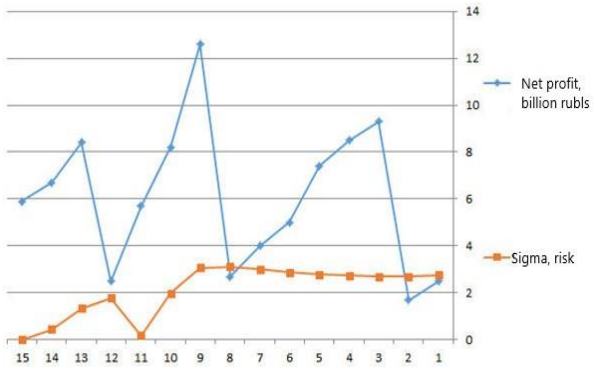


Fig. 2. Dynamics of profit parameters and risk for the period analyzed

Main trends in the development of technologies of a new technological mode (NTM) are decision-making on the basis of big data processing (BI); widespread use of robotics; implementation of artificial machine learning intelligence systems into practice; and widespread use of blockchain technology. According to experts, the speedy large-scale implementation of "Industry 4.0" technologies will contribute to the sustainable economic growth.

Many Russian and foreign scientists have dedicated their works to solving problems of sustainable economic growth based on innovation. So, Baranov E.F. and Bessonov V.A. investigated the issues of economic transformation of the Russian economy and balance of the financial and economic system [9]; exploring the issues of profitable work of the real economy enterprises, D.A. Medvedev outlined the tasks of the economic policy of Russia in order to generate a growth path for the future [10].

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 [11].

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 [12].

In the conditions of growing market uncertainty, the study of the 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 [13] and developed an artificial intelligence system to assess financial risk using the VAR method [14]; moreover, the ways of sustainable development of regional enterprises based on artificial intelligence systems were identified [15]. 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 financial forecasting [16], forecast of the e-commerce sales [17], computer vision systems for automating technological processes [18], managing the interaction between humans and robots [19], image recognition [20] and other areas.

The purpose of the study was to propose and prove the hypothesis that a neural network, taking into account the dynamics of financial risk and VIX index, enables developing a profit forecast for organizations of the financial and economic system.

To achieve the purpose, the following tasks were set and solved:

- based on the OWL technology, the ontology of the concept of financial risk in the financial and economic system was created using the Untitled-ontology-3 program;
- the essence of the "real options" concept, their types and cost estimation procedure using the Black-Scholes and Cox-Ross-Rubinstein models were considered;
- the theoretical foundations of risk management in functioning of the financial and economic system in the conditions of digitalization were investigated;
- the main trends in the development of the Industry 4.0 technologies of the new technological mode (NTM) were identified;
- the theoretical bases for the artificial intelligence systems used in organizations of the real sector of the economy and other areas were investigated;
- based on the Deductor platform, there was developed a neural network, a Kohonen map that takes into account the dynamics of financial risk and VIX option and allows creating a profit forecast for organizations of the financial and economic system; and
- a profit forecast of the socio-economic system based on the neural network was developed.

II. Materials and Methods

Based on the statistics and results of the financial system, a neural network model was evolved. A mathematical model for managing financial risk of entrepreneurship using options was developed, and a profit forecast was made. The model used the following source data (Fig.3).

1 / 15

	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.	VIX-Index	Prediction of the profit billion rubles.
Q4 2017 (Dec 18, 2017)	92037,2	7,75	1154	3403,1	848	57,61	9,3	2,7	30290,1	9,53	9,3
Q4 2016	86148,6	9,75	1113	3723,6	777,5	56,26	12,6	3,1	30796	14,04	12,6
Q4 2015	83387,2	10,5	931	3258,2	735,7	63,97	8,4	1,3	34844	18,21	8,4
Q3 2016 (September 19, 2016)	64611,5	10	991	1792,7	583,1	62,83	8,2	2	30290	15,53	8,2
Q3 2015 (from 03 Aug 2015)	62540,4	11	833	2443,6	551,7	64,28	6,7	0,4	31390	12,56	6,7
(from October 30, 2017)	61358,1	8,25	1113	2552,3	636	58,32	8,5	2,7	30694,5	10,18	8,5
Q3 2017 (September 18, 2017)	61358,1	8,5	1136	2552,3	636	56,79	7,4	2,8	30297,7	10,15	7,4
Q2 2017 (from June 19, 2017)	46018,6	9	1001	1701	424	58,94	5	2,9	29823	10,37	5
Q2 2016 (from June 14, 2016)	43074,3	10,5	931	1861,8	388,7	63,97	5,7	0,2	28864,5	20,5	5,7
Q2 2015	41693,6	11	833	1629,1	367,8	64,28	5,9	0	33565	15,39	5,9
(from 02 May 2017)	30679	9,25	1053	1701	424	56,56	4	3	29876,9	10,59	4
Q1 2016	21537,15	10,5	931	930,9	194,3	63,97	2,5	1,8	35548	13,56	2,5
Q1 2018 (from March 23, 2018)	15569,6	7,25	1261,44	852	702	57,1658	2,5	2,8	31567,6	17,86	2,5
from 12 February 2018	15569,6	7,5	1285,47	850	351	56,32	1,7	2,7	31112,1	25,61	1,7
Q1 2017 (from March 27, 2017)	15339,5	9,75	1113	850,8	212	56,26	2,7	3,1	29760,7	12,5	2,7

Fig. 3. Multidimensional Initial parameters for creating a neural network

The data after processing by the neural network (the quantization method) are presented in (Fig. 4).

The uneven dependence of a performance characteristic on factorial ones is clearly visible.

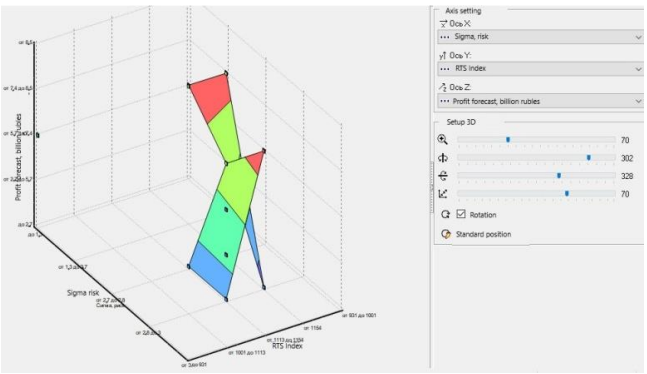


Fig. 4. Multidimensional diagram of the profit dependence of the (OY axis) on the risk (OX axis) and PTS-index (OZ axis)

III. Results and Discussion

The work resulted in the following facts obtained. The main factors affecting the release of innovative products in the conditions of market uncertainty were identified. The theoretical foundations of the artificial intelligence systems applied in various fields of activity were investigated. There was proposed and proved a hypothesis that an artificial intelligence system, using options, makes it possible to develop mathematical models for managing the financial risk of entrepreneurship to make a profit forecast.

It is important to analyze factors that determine the dynamics of financial risk and effectiveness of innovations in organizations of the real sector of the economy.

A. *Analysis of the factors determining the performance of innovations in the financial and economic system*

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 the economic growth. The Kohonen self-organizing map (SOM) is a neural network with unsupervised learning that performs tasks of visualization and clustering. The idea of the network was proposed by a 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].

B. *Formation of a neural network model*

- The Deductor platform being applied resulted in a neural network, a Kohonen Map generated (Fig.5).

The Kohonen map created by the neural network allowed managing the risk of domestic organizations 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.

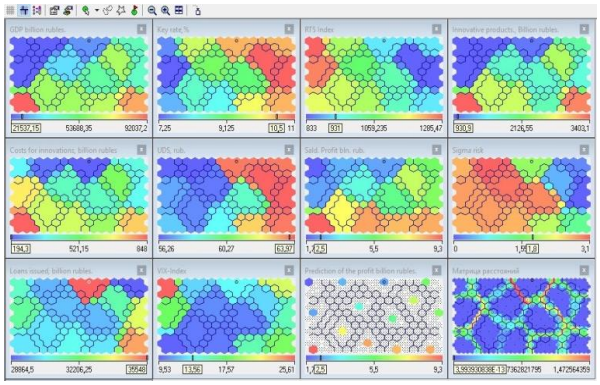
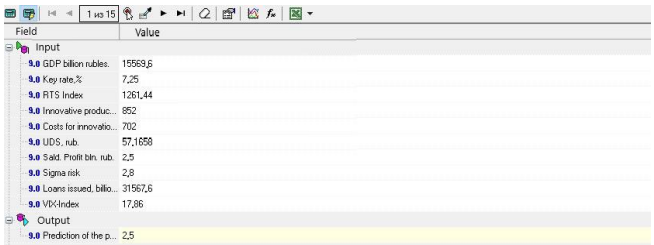


Fig. 5. Neural network, a Kohonen Map

C. *Generation of a profit forecast of a socio-economic system based on a neural network*

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



Field	Value
Input	
GDP billion rubles.	15569,6
Key rate,%	7,25
RTS Index	1261,44
Innovative produc...	852
Costs for innovatio...	702
UDS, rub.	57,1658
Sald. Profit bln. rub.	2,5
Sigma risk	2,8
Loans issued, billio...	31567,6
VIX-Index	17,86
Output	
Prediction of the p...	2,5

Fig. 6. Profit forecast based on “what-if” function

The forecast profit value for the next quarter was 2.5 billion RUB and coincided with the actual value of the current timeframe.

IV. Conclusions

On the basis of the study, we can draw certain conclusions. The study of the neural network models used in the management of financial risk in entrepreneurship is important in modern conditions.

- The main factors that determine the level and dynamics of financial risk in the conditions of market uncertainty were identified.
- The theoretical foundations of the artificial intelligence systems used in various fields of activity, including risk management, were investigated.
- There was proposed and proved a hypothesis that a neural network makes it possible to develop a profit forecast for the domestic financial and economic system in the conditions of the digital economy formation.

There was generated a neural network model, a Kohonen Map that allows to obtain the profit value predicted for the next period and makes 2.5 billion RUB.

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