



## Forecast of Stability of the Economy of the Russian Federation with the AI-System "Decision Tree" in a Cognitive Model

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**Abstract.** Increased use of modern mathematical algorithms based on artificial intelligence determined the relevance of this study, which is important for predicting the sustainable development of the country's economy in general and its banking sector in particular. To achieve the purpose of the research, the presented work used methods such as monographic, analytical, statistical, cognitive model, and artificial intelligence system "Random Forest". The aim of the study is to prove or disprove the hypothesis that, using a cognitive model, using the Random Forest ML model, it is possible to obtain an accurate forecast of the value of the "sustainability coefficient", reflecting the stability of the domestic economy. The scientific novelty of the study is due to the fact that the author's approach is proposed for indicating the crisis state of the economy through the calculation and neural network forecasting by the machine learning model "Random Forest" of the "Stability Coefficient" of the economy, which is calculated as the quotient of dividing the profit index of the banking system to the GDP growth index. The possibility of practical application in the banking sector determines the practical significance of the conducted scientific research since the approach proposed by the authors regarding the formation of a forecast of the "sustainability coefficient" can be successfully used to support managerial decision-making at the strategic level in the banking system. A hypothesis was put forward and proven that based on the use of a digital cognitive model and the Random Forest ML system, a forecast of economic stability can be successfully generated.

**Keywords:** Cognitive modeling; DL-model Random Forest; Formation of sustainability forecast; Sustainability of the country's economy

### 1. Introduction

Increased use of modern mathematical algorithms based on artificial intelligence determined the relevance of this study, which is important for the purpose of predicting the sustainable development of the country's economy in general and its banking sector in particular. The authors proposed an AI system processing BigData to predict the financial

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risk in the real economy of Russia. A hypothesis that the neural network allows obtaining a forecast of the financial risk in Russia has been put forward and proved.

The scientific novelty of this study is the proposal to use the "Sustainability Coefficient" of the economy to determine its crisis state. The coefficient is calculated by dividing the banking system profit index by the GDP growth index. To predict this crisis state, a Random Forest machine learning model is employed. The practical significance lies in the fact that the approach proposed by the authors for forming a forecast of the "sustainability coefficient" can be used in practice to support managerial decision-making.

The aim of the study is to prove or disprove the hypothesis that, using a cognitive model, using the Random Forest ML model, it is possible to obtain an accurate forecast of the value of the "sustainability coefficient", reflecting the stability of the domestic economy. In previous studies, the authors considered issues related to identifying the main factors influencing the sustainability of an enterprise and its bankruptcy using the Connan-Golder model (Lomakin *et al.*, 2023b). Previously, the authors studied the cognitive model of financial stability of the domestic economy (Lomakin *et al.*, 2022).

Achieving the goal that was set in the study required solving a number of problems, including: 1) studying the theoretical aspects that determine the influence of the results of the banking system on changes in GDP; 2) study of trends that are associated with the development of artificial intelligence systems and their application in the financial sector, 3) formation of a neural network model dataset; 4) calculation of performance indicators and predictive value of an effective feature based on the use of the ML Random Forest model. 5) analysis of the obtained results.

Answering the question of what is new in this topic, it should be noted that the authors recently studied a correlation-regression model for analyzing overdue debts and an AI system for predicting the financial risk of Russian commercial banks; the scientific novelty of this study is to fill the gap by studying the patterns regarding the sustainability of the economy based on the Random Forest DL model (Lomakin *et al.*, 2023a).

A hypothesis was put forward and proven that, based on using a digital cognitive model and the Random Forest ML system, a forecast of economic stability was generated. The work of many scientists is devoted to the study of the problems of ensuring the sustainable development of the domestic economy. They represent the increment of scientific knowledge, the results of research presented in the works of Badvan N.L., Gasanov O.S. and Kuzminova A.N., who are devoted to the study of issues of ensuring financial market stability based on cognitive modeling (Badvan, Gasanov, and Kuzminov, 2018). Research shows that estimating the size of losses as a result of financial risk caused by volatility is important to ensure sustainable development in conditions of market uncertainty. In practice, risk calculation by the VAR method is widely used (Indah, Sari, and Wijaya, 2022).

Numerous scientists, both domestic and international, have devoted their research to addressing the presented problem. In particular, (Lomakin *et al.*, 2016) explored issues related to risk monitoring, utilizing neural networks and fuzzy algorithms. The multifaceted concept of sustainable development is influenced by various factors. According to Dianov and Isroilo (2022), sustainable development can be attained by formulating recommendations to enhance the efficiency of management systems. Furthermore, Koshelev, Dimopoulos, and Mazzucchelli, (2022) have contributed to the scientific significance by developing an innovative strategy for an industrial cluster, employing the method of complex real options.

The methodology of this study is based on the use of a cognitive model. Modeling financial and economic stability based on a cognitive model allows the development of an original approach to provide support for managerial decision-making under conditions of

uncertainty by predicting the stability of the Russian economy. The practical significance of the study is that the results of digital forecasting of the stability of the Russian economy can be recommended for practice.

## 2. Methods

### 2.1. Analysis, modeling, study and generalization

To achieve the purpose of the research, the presented work used methods such as monographic, analytical, statistical, cognitive model, artificial intelligence system "Random Forest". In the ML model, a machine learning algorithm was used, an ensemble (set) of decision trees was formed, each tree having a different architecture, generated a predictive value of the resulting feature, and the algorithm embedded in the model selected the best tree and the best forecast result. According to Accenture experts, the application of artificial intelligence systems has the potential to boost bank profits by 34%. Additionally, utilizing cloud technologies with Big Data enables banks to mitigate risks and enhance efficiency (Accenture, 2023). Notably, in the banking sector, Sberbank stands out as it employs an artificial intelligence system, enabling automated lending decisions through AI (Forbes, 2019).

To explain the method in detail, please refer to the RF Random Forest method containing an ensemble of decision trees. The tree structure includes “leaves” and “branches”, and the edges (“branches”) of the tree represent attributes on which the objective function depends. Objective function values are written in “leaves,” and attributes are written in other nodes. To classify some features, you need to move from the top of the tree to the leaves and get corresponding values. Classification decision trees are widely used in data mining because their goal is to create a model that predicts the value of a target variable based on several variables in the model's input.

In order for the works in the article to be understood and reproduced by others, it is important to also explain sample preparation. The research regarding the Random Forest DL model was carried out in the Collab cloud service (Patent, 2023). When reproducing, please first make a copy of the page and work on the copied version. The cognitive model is presented in the service (Cognitive Model, 2023). The dataset was generated using statistical data reflecting the development of the economy and banking sector of Russia for the period 2010-2022 and is presented here (Bank, 2023). Pre-processing before measurement was reduced to replacing the names of the fields of the original table with an abbreviation with a reduction in the length of names of analyzed features included in the model. The model training workflow took place using the Pandas, NumPy, Scikit-Learn and other libraries. Data collection during measurements was carried out automatically in the cloud, which is presented in the article in the form of screen forms.

### 2.2. Literature review

The study of problems related to the stability of the financial and economic system is important in modern conditions, which are characterized by the rapid development of Industry 4.0 technologies. The study of individual aspects of the problem is attracting more and more attention from domestic and foreign scientists. A substantial number of Western scientists have dedicated their studies to exploring issues related to financial stability.

The results of the studies show that This category of “economic sustainability” is a complex and multifaceted concept. Many works by Russian researchers and foreign scientists are devoted to the study of the problem of sustainability of economic systems. These problems are the focus of attention in the works of economists, for example,

[Abdrakhmanova et al. \(2019\)](#) highlight the increasing relevance and significance of studying the utilization of artificial intelligence systems and cyber-physical systems in the contemporary context. This exploration is crucial for fostering economic growth and sustainable development, particularly in mitigating financial risks amid escalating uncertainties and market volatility. [Abdalmuttaleb and Al-Sartawi \(2021\)](#) reviewed the latest research in the application of artificial intelligence for stable financing and sustainable technologies.

As practice shows, the reliable operation of the banking system is one of the key aspects of the economy's financial stability in the context of large-scale implementation of digitalization of business processes in the banking sector. Among the known problems associated with ensuring financial stability, the most pressing is preventing the growth of loan debt. It is often important to assess the creditworthiness, financial condition, and stability of businesses. A team of authors led by M. Rybyantseva reviewed various approaches to such an assessment and identified the most effective of them ([Rybyantseva et al., 2017](#)).

In the works presented by the authors Hengxu Lin, Dong Zhou, Weiqing Liu, and Jiang Bian, their own deep risk model was proposed, which made it possible to obtain a solution for deep learning and analysis of hidden risk factors. Scientists conducted experiments with data obtained from the stock market. The developed model demonstrated high efficiency since the method used made it possible to identify dispersion and reduce the risk of the total portfolio, which had minimal dispersion ([Lin et al., 2021](#)). Research by a group of authors, which included Ni Zhan, Sun, Y., Jakhar, A. and Liu, H. was aimed at solving issues in the development of graphical models of financial time series in the process of selecting an investment portfolio. The authors were various graphical models have been proposed in order to form optimal portfolios ([Zhan et al., 2021](#)) Four criteria for financial stability were proposed by Michael Foot as he came to a conclusion that it occurs when “(a) the monetary system is stable; (b) employment is close to full employment; c) there is confidence in the stability of key financial institutions and markets; (d) there are no relative fluctuations in real estate prices and financial resources within the economy that undermine (a) or (b)” ([Foot, 2022](#)).

### **3. Results and Discussion**

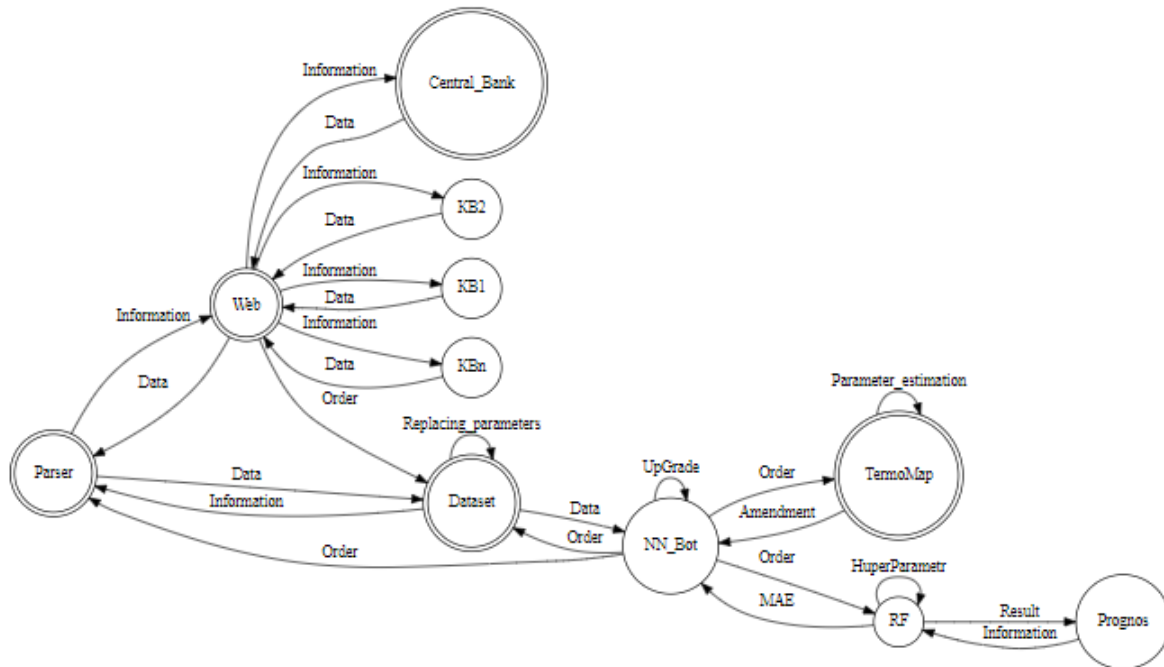
#### **3.1 Results**

The research, the results of which are presented in this article, was carried out using the Random Forest method, a cognitive model (Figure 1).

The forecast of the “stability coefficient” of the economy based on the DL model allows us to predict the level of financial and economic stability in the country and provide support for making strategic management decisions regarding achieving stability of the Russian financial system in conditions of uncertainty and risk. Forecasting the “sustainability coefficient” parameter of development is important for the development of the banking system.

The cognitive model acts as a kind of trigger, which, in turn, launches the methods as independent modular programs, in particular, the Random Forest Machine Learning Model, which makes it possible to obtain a predictive value of the stability of the economy.

The use of the Graphviz program, which is a utility package that was proposed by AT&T laboratories for automatically visualizing graphs based on their text descriptions, made it possible to provide visualization of the Digital Cognitive Model. The package developed by the companies is distributed as open source and is designed to work with Windows and other operating systems.



**Figure 1** Visualization of the cognitive model

```

digraph finite_state_machine {
    rankdir=LR;
    size="8,5"
    node [shape = doublecircle]; Parser; Web; Central_Bank; TermoMap; Dataset;
    node [shape = circle];
    Parser -> Dataset [ label = "Data" ];
    Parser -> Web [ label = "Information" ];
    Web -> Parser [ label = "Data" ];
    Web -> KB2 [ label = "Information" ];
    Web -> KB1 [ label = "Information" ];
    ...
    Prognos -> RF [ label = "Information" ]}
    
```

**Figure 2** The script for visualizing the cognitive model based on the Graphviz (fragment) The dataset for training the Random Forest model is shown below (Table 1).

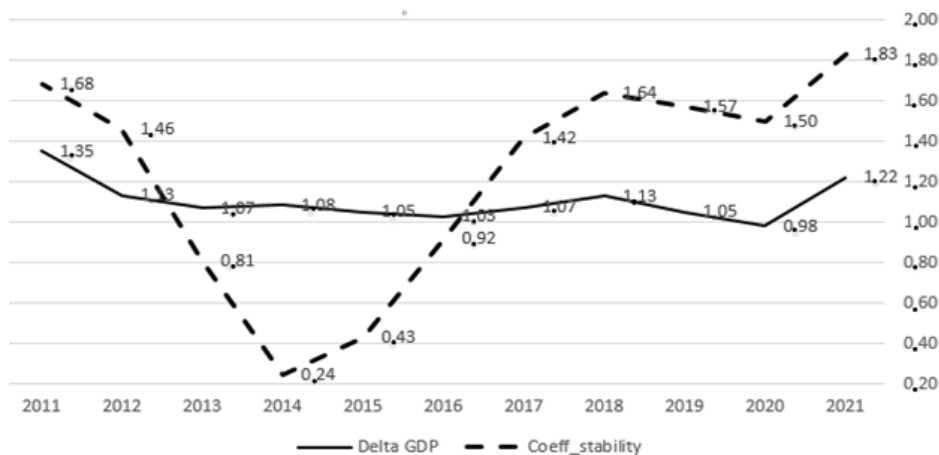
**Table 1** Dataset of the neural network model Random Forest (fragment)

Year	Key_rate	Growth_assets	Share_loans	RTS	USD	Investments	Acco-unts	Outflow	Sigma_profit	Bank_assets	GDP	Banks_profit	Coeff_stability
2021	8.50	16.0	23.5	1609.7	73.7	21.2	38300	72.0	-108.5	120.0	131015.0	2400.0	1.8318
2020	4.25	16.0	17.8	1376.4	73.8	16.5	32300	53.0	-72.7	103.7	107315.3	1608.0	1.5699
2019	7.25	10.4	5.9	1549.4	61.9	20.6	3069	25.2	-77.5	92.6	109241.5	1715.0	1.5699

In this study, the data presented in the table was obtained manually, but the process can be automated. The DL model, written in Python, was created and trained in the Google Collab cloud service. Taking into account the statistical data and the domestic financial system for the period 2010-2021, the neural network model "Random Forest" was formed. The neural network model data set includes the following parameters:

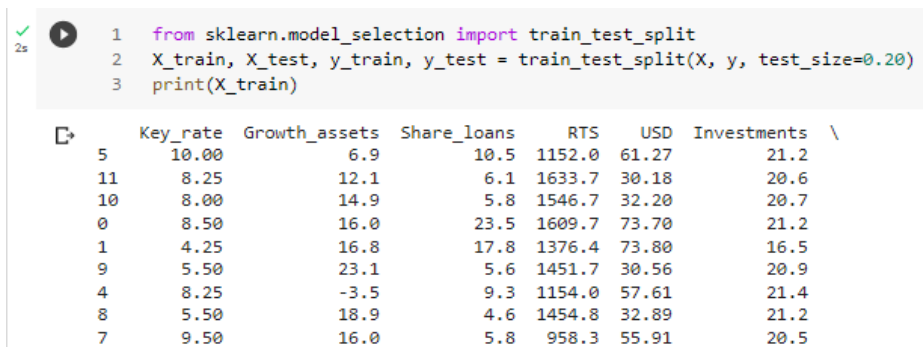
- 1) Year – Year;
- 2) Key rate at the end of the year - Key\_rate;
- 3) Growth of bank assets, % - Growth\_assets;
- 4) Share of overdue loans, % - Share\_loans;
- 5) RTS index – RTS;
- 6) Dollar exchange rate, rub. – USD;
- 7) Investments in fixed assets in GDP, % - Investments;
- 8) Number of Russians with stock exchange accounts, thousand people – Accounts;
- 9) Capital outflow, billion dollars – Outflow;
- 10) Risk (VaR), banking system, billion rubles - Sigma\_profit;
- 11) Bank assets, trine. Rub. - Bank assets;
- 12) GDP, billion rubles – GDP;
- 13) Profits of banks, billion rubles - Banks\_profit;
- 14) Stability factor (pofit /GDP) - Coeff\_stability.

Research has shown that the Central Bank's key rate, expressing the cost of money, is an important factor, representing the Central Bank's tool to ensure the stabilization of the financial system and the real sector of the economy (Figure 3).



**Figure 3** The influence of the factor’s dynamics

The proposed Economic Stability Coefficient serves as an indicator of the accumulation of crisis phenomena if its values are below the values of the GDP (Delta GDP) change index, as can be seen in the graph. Based on the use of the sklearn.model\_selection library, a model was obtained in the training set of which a training sample was randomly formed (Figure 4).



**Figure 4** Training set for the DL model “Decision Tree” (fragment)



A “decision tree” (also “classification tree” or “regression tree”) is a machine learning-based algorithm. Noteworthy is the study of G. Eason, B. Noble, and I. N. Sneddon regarding the product of Bessel functions (Eason, Noble, and Sneddon, 2022).

As a result of the work of the neural network, the algorithm selected the best decision tree from the resulting ensemble of 50 decision trees (Figure 5).

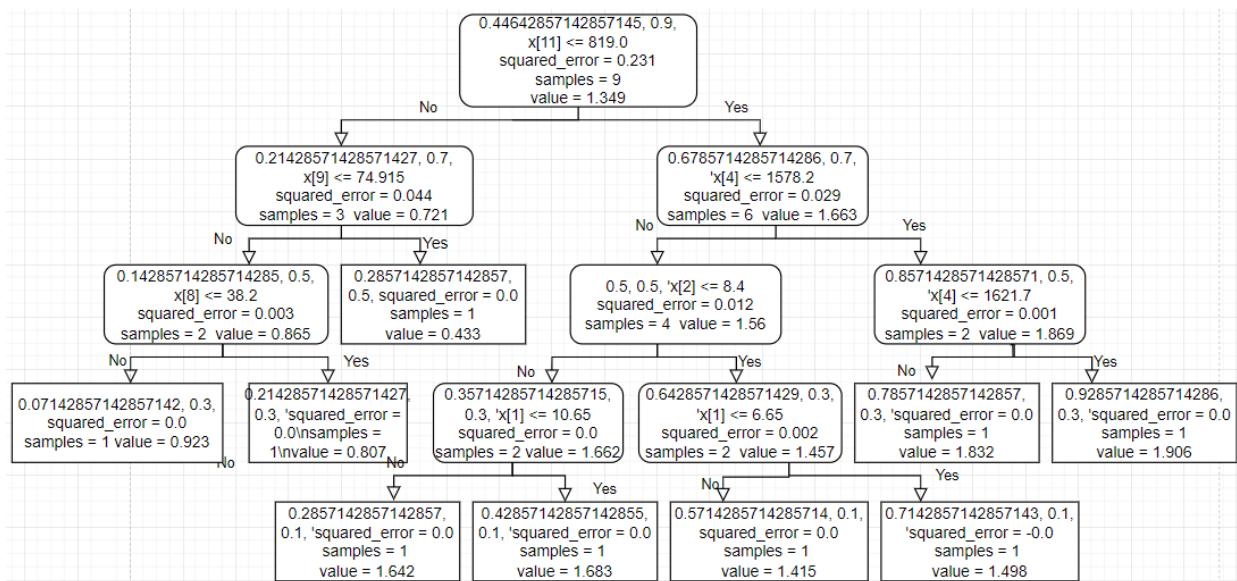


Figure 5 Schematic representation of the “decision tree”

There are two types of decision trees that can be used for both classification and regression problems. The application of random forest trees is presented in many works, including G. Louppe and others (Louppe et al., 2023).

The classic variety is the binary classification tree (respectively regression) (Breiman 2022), which is a model with a pronounced tree structure T from a random input vector (X1...Xp), taking its values in (X1\*... \* Xp) = X in the random output variable Y ∈ ε.

The tree can be constructed from an N-sized training material, with a sample taken from P(X1...Xp, Y) using a recursive procedure that identifies at each node t and has a partition st=s\*, for which the division of samples of node Nt into tL and tR ensures the maximization of some measure i(t) (for example, the Gini index, Shannon entropy or variance Y), where pL= NtL /Nt and pR = NtR / N (1).

$$\Delta_i(s, t) = i(t) - p_L i(t_L) - p_R i(t_R), \tag{1}$$

In general, for the sample under study, the accuracy of predicting the operation of the model can be estimated using coefficients, and it differs if the proportion of the test sample changes relative to the training one (Table 2).

Table 2 Forecasting quality when changing the share of the test sample

	test_size = 0.20	test_size = 0.30	Deviation
Mean Absolute Error:	0.350	0.318	-0.032
Mean Squared Error:	0.162	0.118	-0.043
Root Mean Squared Error:	0.402	0.343	-0.059

When using test\_size = 0.20, the Mean Absolute Error was 0.350555092, and when using test\_size = 0.30, the value was 0.317937701, or decreased by -0.03261739. The predicted value of the economic stability coefficient was 1.49084815, which is 18.61522068% lower than the actual value of 1.832. The obtained predictive value of the

"sustainability coefficient" indicates that next year, the stability of the economy may decrease by 0.18 points and amount to 1.49084815.

### 3.2. Discussion

Future research should use more sophisticated artificial intelligence models. The integration of cyber-physical systems with artificial intelligence enhances the promise of utilizing robo-advisors, particularly within the financial sector. Katherine D'Hondt, Rudy De Vinne, Eric Giesels, and Steve Raymond conducted research regarding the use of the AI Alter Ego system in the field of robotic investments and presented the concept "AI Alter Ego," shadow investors in robots (D'Hondt *et al.*, 2019).

Among the promising areas is the use of deep neural networks in the banking sector. For example, Rusek *et al.* proposed neural risk estimation in networks of untrusted resources (Rusek *et al.*, 2022). In addition, research into promoting green growth through innovative engineering solutions (Ramakrishna *et al.*, 2023) as well as a hybrid closed-loop supply chain approach (Xu *et al.*, 2023) appears promising.

It seems worthwhile to add limitations and future research. For example, the issue of sustainability has not been studied regarding enterprises and the entire sector of the economy, and not just the dynamics of profits in the banking sector. In future research, it is important to consider and identify patterns by identifying the contribution of groups of enterprises (clusters) to the sustainability of the economy and the dynamics of GDP. It seems advisable to sharpen your gap in existing research to increase your contribution in the future. For example, it is important to study the impact of shocks on the method of stabilizing the economy, which uses the method of increasing the key rate by the Central Bank.

## 4. Conclusions

A brief overview of the key stages of the research process includes such important phases as the formation of a cognitive model, creation of a data set, development and successful training of a random forest DL model based on selected hyperparameters. The following results were obtained during the study. A cognitive model was formed that contributed to the formation of a dataset for the Random Forest deep learning neural network algorithm. The Random Forest DL model was successfully generated. As a result of her work, a forecast of the economic stability coefficient was obtained. Correct selection of hyperparameters increases forecast accuracy. When using `test_size = 0.20`, the Mean Absolute Error was 0.350555092, and when using `test_size = 0.30`, the value was 0.317937701, or decreased by -0.03261739. That is, with an increase in the proportion of the training sample, the accuracy of the forecast increases since the Mean Absolute Error value decreased by -0.03261739. The best decision tree showed high forecast accuracy. A highly accurate forecast was obtained. The average forecast error is 0.317937701. The obtained predictive value of the "sustainability coefficient" indicates that next year, the stability of the economy may decrease by 0.18 points and amount to 1.49084815. The expectation to see the results of the model and its practical application is satisfied by the obtained predictive values of GDP, which opens up wide opportunities for applying the cognitive model in practice, for example, to provide management decision support. The model results satisfy the predicted GDP values. It will be important for future research to leverage the computational capabilities of more complex artificial intelligence models. The widespread use of cyber-physical systems based on artificial intelligence will make the use of robo-advisors even more promising. The integration of cyber-physical systems with



artificial intelligence will enhance the prospects for the use of robo-advisors, especially in the financial sector.

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