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HYBRID INTELLIGENT SYSTEM OF FORECASTING OF THE SOCIO-ECONOMIC DEVELOPMENT OF THE COUNTRY

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Abstract: *Implementation of the models of short- and medium-term forecasting of macroeconomic indicators for the detection of trends in the development of a whole country or a particular region is an urgent and important task in the field of macroeconomic research. The article presents the author's concept of development of scenario variant predictions based on simulation regression and factor models complemented by the author's hybrid approach to forecasting of the indicators of socio-economic development with the use of neural networks. The hybrid intellectual and economic system was developed to support the federal and regional levels of the Russian economy with means of analysis and forecasting, which implements the principles of management and decision-making on the choice of a model based on the verification of forecast calculations. The system carried out large-scale computer tests on variative forecasting of the complex of more than 600 indicators of socio-economic development of Russia based on the scenario indicator values given by experts, such as the key interest rate, international oil prices, the money supply growth rate, the change in foreign exchange reserves. After identifying a set of scenario indicators, the projected trajectory is calculates. Comparison of the reference trajectory with the perturbed trajectory (by the known scenario conditions) allows experts to obtain quantitative estimates of the differences and give their assessment. Basic forecast calculations are carried out in the framework of the econometric system and give satisfactory values for the quality and accuracy of 66-70% indicators. Neural network models are built for other indicators, which allow to improve the quality and accuracy for another 10% of the total number of indicators. The development of the system is anticipated in the area of improving the neural network models and connectivity of the forecast modules implementing decision fork algorithms.*

Keywords: *econometric models, mathematical modeling of economic systems, neural network modeling, forecasting*

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1. INTRODUCTION

Russia's transition to a market economy has laid the basis for reformation of the entire system for the collection and processing of information in the public system of statistical reporting. The transition to the system of national accounting (SNA) in Russia coincided with the reform of the SNA in the global economy (1993). In general, the transition to the SNA opened the perspective of the use of the practice of modeling of the process of forecasting of the socio-economic development, gained in market economies.

In this regard, an urgent task in the present conditions is to develop methods and instruments for forecasting of the socio-economic indicators of Russia. One of the flagship approaches to the research of relationships between economic performance in the multidimensional space of attributes is to build a system of equations of the econometric model of multiple regression (Grishin et al, 2010). This system realizes the idea of a country model, which involves disaggregation of the large socio-economic system and construction of a detailed theoretical and econometric description of each of the structural units of the system under research. The units embedded in the model are relatively small-sized and allow for a more detailed description of the factors that influence the dynamics of the development of the country (Kolmakov et al, 2012).

The first country regression models have appeared in the US in the 50s and have been successfully used to predict the development of economy (Klein and Goldberger, 1955). Further research in the field of econometrics was summarized in the famous works (Johnston and DiNardo, 1997), (Pindyck and Rubinfeld, 1999), (Hastie et al, 2009). Country systems of the forecasting models are divided by the forecast system capacity, i.e. capabilities of the system to solve in a single-pass mode the maximum allowable number of related regression equations for: systems of low capacity (up to 10 equations), medium (up to 100 equations), high (up to 1,000 equations) and extra high capacity (over 1,000 equations).

Author's team of Plekhanov RUE has developed and is developing a system of high capacity models of the short- and medium-term forecasting of the indicators of socio-economic development of Russia. The system of models includes a complex of more than 600 indicators. The developed methodology, models, software and technology tools allow a systematic coordination of macroeconomic development indicators with indicators of the financial system, foreign trade, social and other fields (Kitova et al, 2014).

However, econometric models have certain shortcomings. The frontiers of econometric models are limited with capabilities of the information base and the state of methodological tools. In recent years, an approach to forecasting based on data mining techniques has been developing, such as neural network models (Zhang, 2004). Neural network models and methods are designed to solve complex nonlinear tasks, which either exceed the capabilities of conventional algorithmic techniques or require large material and time costs for solving (Haykin, 1998).

The assumption about the qualitative improvement of the forecasting results of the unstable macroeconomic indicators using artificial neural networks is based on the fact that the simple computational elements comprising the neural network, the function of which is determined by the structure of the network and the power of reciprocal links, have the ability to parallelize processing of the information and the ability for self-learning.

The goal of this study was to create a hybrid system of models and intellectual complex of forecasting of the indicators of socio-economic development of Russia that enable the combination of different approaches that together ensure the improvement of the quality and accuracy of the forecast for most of the indicators.

2. METHODOLOGY

Methodologies and models for forecasting of the indicators of development of industries and sectors of Russian economy in the system of national accounting in relation to the scenario of Russia's economic development are based on the use of three systems: system of national accounting, system and approaches of econometric simulation modeling and expert estimates system (variant sets of the scenario indicators and the respective calculation results). The composition and structure of the data base for system of models are based on official data of the Federal State Statistics Service, the Central Bank and Ministry of Finance of the Russian Federation.

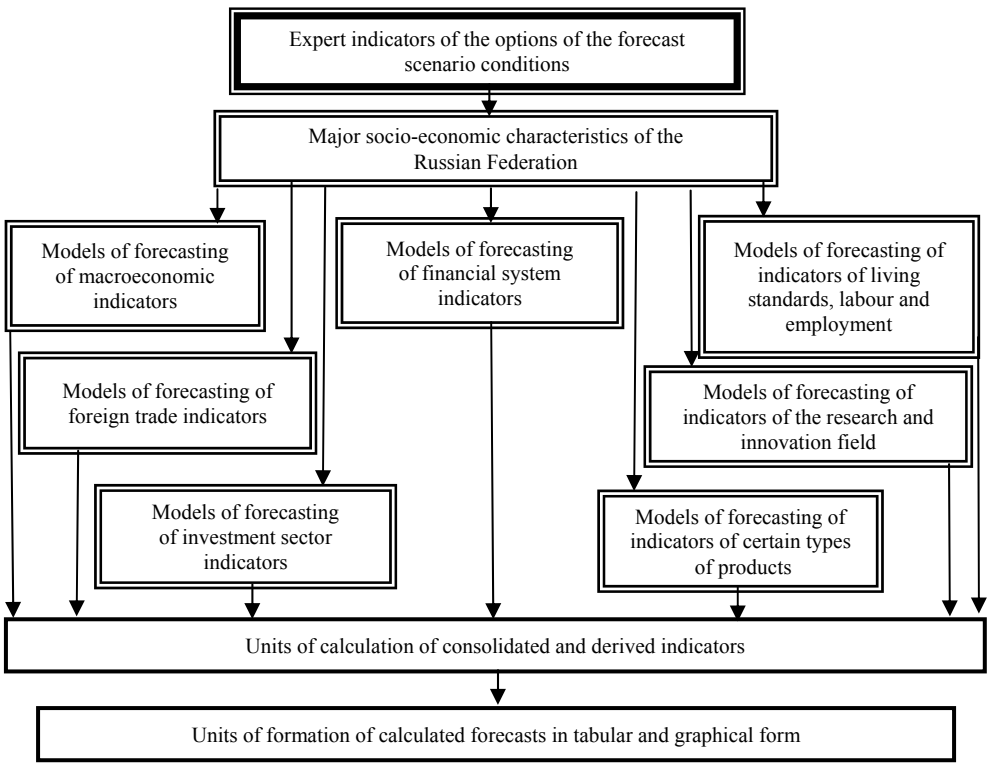
In the construction of econometric models, all the variables that describe the phase state of the economic system are linked together in the form of the system of regression and balance equations. Each indicator in the regression equations is defined as a function of other factors in accordance with the economic meaning, and the corresponding common distributed system of equations is built. After the establishment of a statistical base and selecting regressional dependencies, the regression coefficients are identified and the

script system development is designed, which reflects the behavior of the controlled variables to the entire range of the forecast.

In order to predict the dependent variable, you need to know the forecast values of all factors included in the model. They can be obtained on the basis of extrapolation methods or determined by methods of expert estimates. Since the stepwise forecast of parameters in all the equations is made in the system of models under consideration, the values of all parameters become available for use as factors by the next step.

Stepwise parallel consistent solution of equations under consideration allows to obtain interrelated forecast of indicators depending on the defined scenario conditions representing the options of development of the exogenous parameters set by experts. These indicators are the key interest rate, international oil prices, money supply growth rate and change in foreign exchange reserves of the Central Bank of the Russian Federation. The conceptual chart of the system of models of short-term forecasting of the socio-economic development of the Russian Federation is shown in Figure 1.

Figure 1: Conceptual chart of the system of models of short-term forecasting of the socio-economic development of the Russian Federation



The system of models is open both for connection of new models and the expansion of the composition of any model, and for the expansion of the service capabilities of the system as a whole.

The final stage of the forecast verification is important in forecasting the economic dynamics using regression models (Kitova et al, 2013). It is not always possible to immediately build a fairly good prediction model. Therefore, the procedures of building regression models of economic dynamics are performed iteratively until predetermined criteria are reached.

Quality and accuracy criteria used, as well as their acceptable ranges of values are given in Table 1.

Table 1
Quality and accuracy criteria

Settings of the quality evaluations		
Coefficient of determination (R^2),	> 0.4	
Fisher statistic values (F-stat).	> 5.0	
Durbin-Watson statistic (DW)	0.8 < DW< 3.2	
Settings of the accuracy evaluations (Δ)		
High	Middle	Low
<0.06	0.06< Δ <0.16	>0.16

The frontiers of econometric models are limited with capabilities of the information base and the state of methodological tools. Restrictions on the use of econometric forecasting methods appear under the following conditions:

Emergence of new indicators with short rows of reporting data.

Incomparability of reporting data of the indicator due to radical methodological changes on the reporting segment under study.

Dependence of the values of the indicator on the orders of legislative or executive power or on managerial decisions by financial agencies ("Directing" indicators).

Use of indicators with latent (unobservable) sets of influence factors.

Administrative-sensitive indicators.

These cases require the use of alternative methods of forecasting – neural networks, fuzzy modeling, etc.

In addressing the problems of forecasting based on artificial neural networks (ANN), the architecture of multilayer perceptron is the most widespread (ref. to Zhang, 2004, Haykin, 1998), where factors are input values, and the parameter under study is output signal.

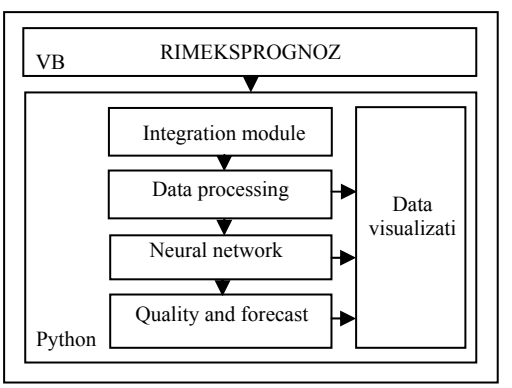
Implementation of neural network model is determined by factors and features that exist within the framework of the econometric model described as a system of regression equations. The input parameters of the neural network are presented in the form of a data set composed of values of the rows of exogenous and scenario parameters, while output or destination feature whose values are predicted by the model is an endogenous indicator. Choosing a set of arguments that affect the target indicator is an experimental task based on the understanding of the concept of economic processes and phenomena. In this regard, the quality of the forecast obtained through the model is largely determined at the stage of the input set formation. Theoretically, it is assumed that the quality of the neural network model depends on its ability to generalize. At that, the generalization error has two components. The first is related to the insufficient quality of the approximation carried out by the network function; the second is determined by incomplete information due to the limited scope of the test sample.

3. RESULTS

The constructed information forecasting system includes an integrated system of the hybrid intelligent economic models based on econometric and neural network models (Kitova, Kolmakov et al, 2015) (Kitova, Dyakonova et al, 2015).

The architecture of the hybrid intelligent economic system (HIES) is shown in Figure 2.

Figure 2; Architecture of the hybrid intelligent economic forecasting system



The HIES system includes the following functional modules:

1. Regression balance-econometric metasystem RIMEKSPROGNOZ
2. Integration module – the means of analysis and replication of data from RIMEKSPROGNOZ system into the forecasting subsystem based on neural network models.
3. Data processing module – operational preprocessing of data for further analysis.
4. Neural network forecasting module – construction of distributed neural network forecasting models.
5. Forecast quality and accuracy control module – verification of the results obtained through retroforecasting.
6. Results visualization module – output of the results obtained in accordance with the needs of the user, represents the user interface of the system.

The software product is designed in the form of a Python web application, which facilitates the work of the end expert user with the system, allows adjusting for individual needs, including configuration of predictive models, indicator choice, horizon of calculation, etc.

HIES system provides medium-term forecasting of the complex of more than 600 economic indicators in the framework of the balance-econometric metasystem RIMEKSPROGNOZ, verification of results in the forecast quality and accuracy control module, construction and implementation of neural network forecasting.

HIES-based computer experiments were conducted for the indicators of all units. The results of the construction of forecasts in HIES on the example of units of social indicators are considered below.

Equations for 31 indicators were drawn in the econometric module "RIMEKSPROGNOZ" for the social area. After receiving the calculated forecasting values of the indicators, the verification of the forecast was carried out according to the criteria of Table 1; the verification results are shown in Table 2. Evaluation of the quality was assigned by the worst of the observed values of the criteria.

Table 2.
Matrix of the results of verification of the regression forecast of the social area indicators

		Accuracy criterion		
		High	*Average*	*Low*
Quality criterion	High	12 indicators	1 indicator	1 indicator
	Low	13 indicators	3 indicators	1 indicator

12 indicators have a high level of quality and accuracy of the forecast, no changes in their equations are required. For the remaining 19 indicators, the regression equations were improved, which resulted in better quality and accuracy for 7 of 19 indicators. The remaining 12 indicators were submitted to the neural network forecasting module.

The results of the verification of the forecast of indicators on the basis of ANN are given in Table 3.

Table 3
Matrix of the results of verification of the neural network forecast of social area indicators

		Accuracy criterion		
		High	*Average*	*Low*
Quality criterion	High	3 indicators	2 indicators	2 indicators
	Low	4 indicators	1 indicator	

As a result of forecasting based on ANN, the forecasting quality of indicators "Proceeds of CHI federal fund", "Proceeds of territorial CHI funds", "Expenditure of territorial CHI funds" and "Number of leaving" has improved. Both quality and accuracy of the forecast of "Unemployed" indicator have improved.

Table 4 shows a comparison of values of criteria of the forecast quality and accuracy obtained using ANN and econometric model for the "Unemployed" indicator.

Table 4.
Evaluation of the forecast quality and accuracy

Model	*Indicator*	*Quality criteria*			*Accuracy criterion*
		R^2	f-stat	DW	*average relative error*
ANN	Unemployed	0.98	594	1.79	0.04
Econometric model	Unemployed	0.98	743	0.67	0.10

3. DISCUSSION

The constructed hybrid intellectual economic system allows for comprehensive forecasting of socio-economic indicators of development of the Russian Federation. The singularity of the study lies in the development of the concept of the hybrid system of models, combination of the balance-econometric and neural network approaches based on the embedded module of forecasts verification. At the same time, the used neural network models have some limitations. Each model is designed for a specific indicator and can be applied to others in rare cases. Neural network models require complex customization, calculations, tests and simulation calculations defined and prescribed in the modeling method (Bishop, 2006), (Russell and Norvig, 1995). A typology of neural network models and indicators based on a series of computer experiments with indicator from all areas can be worked out in the future. Another disadvantage of the constructed system is the fact that a neural network approach is exclusively used as intelligent methods. At the same time, methods on the basis of decision trees are developed and apply for time series forecasting (Quinlan, 1993), (Rokach and Maimon, 2014). It seems appropriate to develop a method of forecasting of the socio-economic indicators by means of decision trees algorithms and to embed a new unit in the system.

4. CONCLUSIONS.

The constructed hybrid intellectual economic system (HIES) allows for short-term and medium-term forecasting of a set of indicators in all areas of socio-economic activities of the Russian Federation in different scenarios (for example, at different levels of oil prices), which is extremely important in conditions of instability of the modern economy. Large-scale experiments are carried out in the system, and more than 600 indicators are forecasted. The considered system and method of forecasting allow to extend the set of indicators of socio-economic development of the Russian Federation available for the qualitative prediction, due to the hybrid approach. Application of the approach is demonstrated on social indicators.

HIES is an open developing system that requires testing of neural network models for the indicators from all units.

The constructed HIES can be used by employees of scientific institutions, expert researchers of the federal and regional ministries, departments and major corporations in their daily work. However, the system currently operates on the basis of two different subsystems. A complete HIES transition to a single modern cloud platform is planned in the future.

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