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NEUROMATHEMATICS AS AN EFFECTIVE TOOL FOR FORECASTING SOCIAL DEVELOPMENT OF RUSSIAN REGIONS

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Abstract

In the context of the national economic turbulence, it becomes important to forecast the social development of constituent entities of the Russian Federation. In order to provide highly accurate forecasting, neural network technologies are used in the research (a Bayesian assembly of the dynamic neural network of various configurations is formed). As a result of the forecasting, it is found, that the leading Russian regions should have a lower social development index in 2016–2017 as compared to 2014–2015. A slowdown of social development is also predicted for the leading regions of the Volga Federal District in 2016–2017, but only as compared to 2015. The obtained data show that the social development index in the Republic of Bashkortostan changes a little. Nevertheless, a significant lagging of Bashkortostan behind the leading regions of the Russian Federation and the Volga Federal District in the social sphere is predicted: Bashkortostan is a competitive region in terms of the living standards, but not in the sphere of scientific research and innovations. For this reason, measures encouraging innovative development of Russian regions as exemplified by the Republic of Bashkortostan are introduced and discussed in the paper.

Keywords: forecasting social development, Russian regions, neural simulation, Bayesian assembly of neural networks

Introduction

Nowadays, successful realization of the social potential and its innovative development is the key factor of national economy growth. Russian policy makers, scholars, and international organizations point out that Russia is not only lagging behind the economically developed countries, but it is also characterized by significant differences in the level of social development between its regions. In the report “On the strategy of Russia’s development until 2020” during the enlarged panel session of the State Council of the Russian Federation, President V.V. Putin emphasized that “a transfer to innovation-based development is related, first of all, to large-scale investments into human capital. Human development is the main aim and the required condition for the progress of the modern society. It is our absolute national priority, both today and in the long term. The future of Russia, our success depends on the education and health of people, their pursuit of self-improvement and application of their skills and talents. The future of Russia will depend on the motivation of citizens to innovative behavior and the return that the labor of every person brings. It is impossible to solve innovation development problems without an educated specialist, without a person with good health, living in good conditions. It is our strategic objective”. The purpose of this research is not only to objectively forecast and evaluate the social development of Russian regions, but to develop effective measures encouraging innovative development.

1. Research Design and Results

Under the conditions the national economy turbulence, the problem of managing the social development of Russian regions gains importance. For forecasting – a key managerial function, it is suggested to first simulate the social development of the Russian Federation constituent entities. Since the hypothesis of noisy statistical data is not rejected a priori, neuromathematical tools are used for simulating the social development of the country’s regions, thereby enabling to take into consideration the triad of “IN-factors”: incompleteness, inaccuracy, and indefiniteness.

The theorem below provides a general possibility of solving the task of finding any continuous dependence on the basis of neural network technologies [3].

Theorem. *Any continuous function $F : [0.1]^n \rightarrow [0.1]$ can be approximated by a three-layer neural network with a single hidden layer and back propagation of error algorithm with any degree of accuracy.*

Remark. An assembly of neural networks provides higher accuracy than a particular neural model [6].

Hence, the task of approximation is set, i.e., recovery of hidden functional dependencies in the source data with the help of a Bayesian assembly of neural networks. Neural network simulation is performed on the basis of NeuroSolutions for Excel (v. 6.0), a special software program. Development of neural network models involves breaking source data arrays into two groups: learning and testing samples. The learning sample consists of 320 observations (an array of social indicators for all Russian regions during the years of 2011–2014), being distributed randomly in advance. The testing sample – 80 observations – is an array of similar data for the year of 2015. A multilayer perceptron is chosen as a standard topology of neural networks. In order to prevent the neural networks overtraining, the maximum number of stages (iterations) is set according to the modification of synaptic weights as 1000. Only accurate neural networks are included into the Bayesian assembly. In this respect, a neural network is considered accurate if the following three conditions are met simultaneously:

- 1) the normalized mean-square error (NMSE) does not exceed 8 %;
- 2) the coefficient of correlation between the empirical data and the data obtained in the course of simulation ($r_{Y, \hat{Y}}$) is not lower than 0.95;
- 3) the frequency quality criterion (P_q^*) is higher than 70 %. This indicator is calculated according to the following formula [1]: $P_q^* = N^*/N_{\text{test}}$, where N^* is the number of result parameter observations explained by the neural network with the specified degree of accuracy (in this case, with the percentage error (ξ) set at 5% and 8%), N_{test} is the size of the testing sample.

It was experimentally determined that the index value of the social development of Russian Federation constituent entities is approximated by a non-linear function of the following type with the desired degree of accuracy: $\hat{Y} = f(X_{1\text{aggr}}, X_{2\text{aggr}}, x_t)$, where $X_{1\text{aggr}}$ and $X_{2\text{aggr}}$ are subindex values, correspondingly, living standards of the population, scientific research, and innovations; x_t is an additional input factor – time [2].

The values of the input and output parameters were given in our previous research [4].

An accurate Bayesian assembly of five neural networks was formed on the basis of several computational experiments. Their configuration and the results of their assessment for accuracy are given in Tables 1 and 2, correspondingly.

Not only the number of hidden layers varied, but the number neurons in them, as well. The number of neurons in hidden layers was optimized with the help of accessibility features of the software program NeuroSolutions for Excel.

Table 1. Configuration of a Bayesian assembly of neural networks

Conventional sign of neural network	Number of hidden layers	Number of neurons in hidden layers	Type of activation function in hidden layers	Type of activation function in output layer
NNM1	1	10	hyperbolic tangent	linear
NNM2	1	12	hyperbolic tangent	linear
NNM3	2	12, 8	hyperbolic tangent	linear
NNM4	2	14, 8	hyperbolic tangent	linear
NNM5	3	8, 12, 10	hyperbolic tangent	linear

Table 2. Assessment of the Bayesian assembly of neural networks accuracy

Conventional sign of neural network	r	NMSE	N^*		P^*	
			$\xi = 5\%$	$\xi = 8\%$	$\xi = 5\%$	$\xi = 8\%$
NNM1	0.979	0.043	70	78	87.5	97.5
NNM2	0.983	0.048	67	78	83.8	97.5
NNM3	0.977	0.050	67	76	83.8	95.0
NNM4	0.981	0.055	65	76	81.3	95.0
NNM5	0.976	0.048	68	77	85.0	96.3
Arithmetic mean value of the index:	0.979	0.049	67	77	84.3	96.3

Table 3. Forecasting social development of the leading Russian regions, the Volga Federal District, and the Republic of Bashkortostan for 2016–2017

The RF constituent entity	2016			2017		
	Y	X_{1aggr}	X_{2aggr}	Y	X_{1aggr}	X_{2aggr}
18. Moscow	0.581	0.682	0.610	0.562	0.687	0.616
28. St.-Petersburg	0.537	0.620	0.532	0.523	0.615	0.551
42. Republic of Bashkortostan	0.385	0.499	0.219	0.384	0.498	0.217
44. Republic of Mordovia	0.500	0.530	0.499	0.497	0.534	0.533
45. Republic of Tatarstan	0.533	0.541	0.574	0.528	0.534	0.621

The resulting Bayesian assembly of neural networks makes it possible to approximate the social development of the country’s regions with a high degree of accuracy, i.e., with a 0.979 correlation coefficient of empirical data and the data obtained in the course of the simulation, with a 4.9% normalized mean error, and to recognize correctly about 84.3% and 96.3% of observations, at 5% and 8% percentage errors, correspondingly.

Then the social development of the leading Russian regions, the Volga Federal District, and the Republic of Bashkortostan, is forecasted in the medium term (see Table 3).

In the context of a small (in terms of time) array of the source data, forecasting the values of subindices (input parameters) is performed on the basis of averaged growth rates for the years of 2011–2015. In these conditions, it is assumed that these indicators demonstrate sustained growth rates in 2016–2017.

The actual and anticipated values of the social development index of the leading Russian regions, the Volga Federal District, and the Republic of Bashkortostan, are presented in Fig. 1.

The leading Russian regions (the cities of Moscow and St.-Petersburg) are expected to have a lower social development index in 2016–2017, as compared to 2014–2015. In 2016–2017, a slowdown of the social development is predicted for the leading regions of the Volga Federal District (the Republics of Mordovia and Tatarstan), but

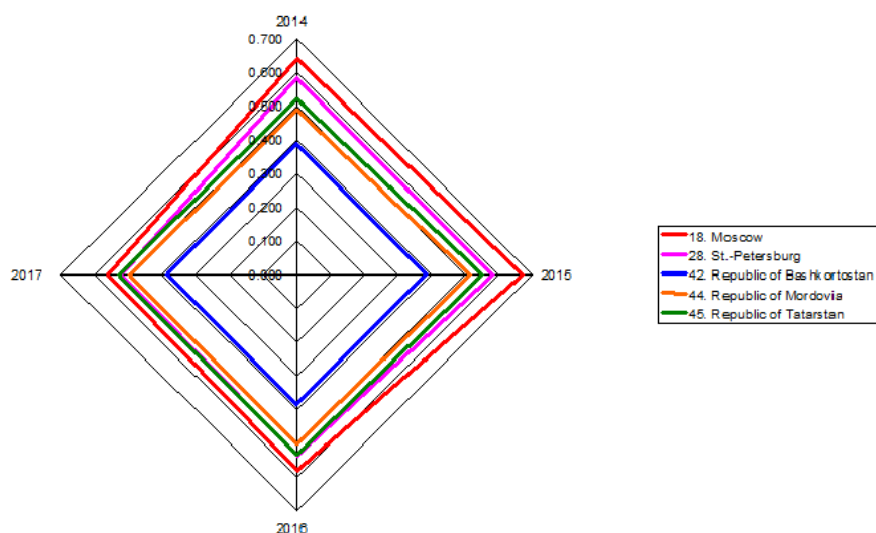


Fig. 1. Social development index of the leading Russian regions, the Volga Federal District and the Republic of Bashkortostan in 2014–2017

only as compared to 2015. The social development index in the medium term is expected to change insignificantly in the Republic of Bashkortostan, i.e., as observed for the two previous years. However, a considerable social lagging of Bashkortostan behind the leading regions of the Russian Federation and the Volga Federal District is predicted. The reason is that the Republic of Bashkortostan is a competitive region in terms of the living standards of the population, but there is a noticeable “gap” between Bashkortostan and the leading Russian regions and the Volga Federal District in the sphere of scientific research and innovations. Hence, in the current conditions, the problem of raising the efficiency of innovation activity becomes topical for the Republic of Bashkortostan. Bashkortostan has been included into the Association of Innovative Regions of Russia along with other 13 constituent entities of the Russian Federation (since 2012). Yet, the innovative infrastructure in Bashkortostan is only being formed. Innovation-oriented facilities have been created only in five (out of 64) municipalities of Bashkortostan. They are concentrated in the capital of the region (15 different facilities are functioning, including technology park, business incubators, scientific and business centers, etc.). Moreover, it should be noted that not all the created facilities of Bashkortostan’s innovative infrastructure are operating. The underdevelopment (against the leading regions) of Bashkortostan’s innovative infrastructure is aggravated by a wide range of unsolved topical problems, the basic ones of which are as follows:

1) The imperfection of the current legislation regulating innovative activities in the territories of the municipalities of the Republic of Bashkortostan. For example, among 30 regulatory legal acts applied in the territory of the Republic, there are no acts regulating the issues of venture investment. There are no unified definitions, which complicates the development of the process of financing innovative activities in the Republic of Bashkortostan;

2) A low demand for the results of scientific and innovative activities from the real sector of regional economy along with the poor future prospects of the research projects for the needs of new economic branches (five out of six technological modes) hinder the process of commercializing such results. The imbalance between patent activity of economic entities and the size of innovative products is indirectly indicative of this problem. If the Republic is classified among the leading regions in terms of the first

indicator, then, in terms of the second one (related to the GRP), it holds a median position among other constituent entities of the Russian Federation;

3) The absence of the system of independent monitoring operating efficiency of Bashkortostan's innovative infrastructure facilities;

4) Insufficient government support of small, medium, and large regional innovative business. Thus, in particular, only certain elements of cluster policy have been successfully implemented in Bashkortostan (in the form of partial backing of expenditures for manufacturing equipment and scientific research of cluster-forming business units) and occasional financial support of fundamental and applied research.

For the purpose of solving the above-listed problems, a number of measures are needed. The suggested measures can be combined into several groups [5]:

- formation of a favorable innovative climate in the territory of the republic;
- increase in the innovation activity of the population of the republic;
- financial support by the government of major innovation-related projects;
- formation of the system of scientific and production cooperation and innovation commercialization;
- development of innovative infrastructure in the territory of the republic;
- increase of innovative activity of small and medium enterprises of the republic (by means of governmental support of launching environmentally-clean manufacturing in the first instance);
- development of information support of the innovative activity.

In turn, the basic directions of implementing these measures in the territory of the republic are as follows:

- improvement of the regional law making in the sphere of regulating the innovative activity taking into account the international and federal legislation;
- financial and tax incentives for scientific and technological and innovative activities;
- formation of the system of independent monitoring efficiency of spending budgetary funds by economic entities engaged in scientific and innovative activities;
- international technological integration;
- public-private partnership in the sphere of innovative activity.

Successful implementation the discussed measures is possible in the context of updating regional the innovation policy by means of clarifying the goals and tasks on the basis of applying not only Russian, but international experiences, as well.

Conclusions

The results of the forecasting (neural network technologies are used for this purpose, i.e., a Bayesian assembly of neural networks of different configurations is formed) in the midterm are not optimistic. In particular, the leading regions of the Russian Federation (Moscow and St. Petersburg) are going to have a lower level of social development in 2016–2017, as compared to 2014–2015. Besides, the leading regions of the Volga Federal District are expected to have a slower social development in the above-mentioned period, but only as compared to the year of 2015. The Republic of Bashkortostan is assumed to have practically the same level of social development. However, a significant “gap” is still expected to maintain between the Russian leading regions (the Volga Federal District) and Bashkortostan in the sphere of social development. This “lagging” is explained not by the difference in the living standards of the population, but also by the existing “gap” in the sphere of innovations.

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Нейроматематика как эффективный инструмент прогнозирования социального развития регионов России

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Аннотация

В условиях турбулентности национальной экономики актуализировался вопрос прогнозирования социального развития субъектов Российской Федерации (РФ). С целью обеспечения высокой точности такого прогнозирования в рамках исследования используются нейросетевые технологии (формируется байесовский ансамбль динамических

нейросетей различной конфигурации). В результате прогнозирования установлено, что у регионов-лидеров РФ в 2016–2017 гг. должно ожидаться снижение индекса социального развития по сравнению с 2014–2015 гг. Для регионов-лидеров Приволжского федерального округа (ПФО) мы также прогнозируем замедление социального развития в 2016–2017 гг., но только по сравнению с 2015 г. Полученные результаты показывают, что в Республике Башкортостан индекс социального развития в среднесрочной перспективе практически не изменится. Несмотря на это, прогнозируется сохранение существенного отставания республики в социальной сфере от регионов-лидеров РФ и ПФО. Это объясняется тем, что если по уровню жизни населения РБ является конкурентоспособным регионом страны, то в сфере научных исследований и инноваций наблюдается «разрыв» между республикой и регионами-лидерами РФ и ПФО. Поэтому в рамках статьи также представлен комплекс мер, способствующих инновационному развитию российских регионов на примере РБ.

Ключевые слова: прогнозирование социального развития, регионы России, нейро-моделирование, байесовский ансамбль, нейросети

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