Neural Network Modeling of the Social and Economic, Investment and Innovation Policy of the State

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Abstract

The aim of the study is for a neural network modeling of changes in the main ways of the state social and economic, investment and innovation policy in Ukraine to improve the state management, and formation of the socially and innovatively oriented national economy. A numerical experiment was conducted using neural network modeling. The proposed neural network model is based on social and economic, investment and innovation development indicators of Ukraine and the leading countries of the world. Indicators describing the results of Ukraine's state policy for 2000-2021 have been utilized in the neural model. The developed model made it possible to determine the factors that can contribute to the growth of Ukraine's GDP and forecast the growth of the country's economy. The following results were obtained: public fixed investment and financing of innovative activities from the state budget has the highest influence over the economic growth of the country, equally important for the economic development is the increase of R&D funding from the state budget and government expenditure on education. The neural network model for forecasting and evaluation of the social and economic, investment and innovation policy of the state allows predicting the main directions of resource allocation and budgeting.

Keywords [1]

Neural network modeling, social, economic, investment, innovation, policy, state, socially and innovatively oriented national economy

1. Introduction

In the context of the formation of a new model of the economy, it is worth considering the question of the extent to which the influence of the state strengthens the socially and innovatively oriented national economy. To do this, it is necessary to reveal the relationship between the elements of social and economic, investment and innovation policy, and economic growth. Develop human resources, investment in growth through educational sphere, and the development of innovative ventures is a priority for Ukraine.

A socially and innovatively oriented market economy is the most promising model of the organization of social production, an innovation management system, which combines the high efficiency of the market and innovation mechanism, investment in the educational sphere, the focus on achieving justice. The basis is focused around innovative provision of economic development to achieve

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a high standard of living of the population. A certain share of GDP is redistributed through the state budget. The state is constantly searching for innovative ways to ensure social solidarity in society.

The economy of the state is founded on social sustainability and a beneficial economic climate to involve investment, growth in educational sphere and implementation of innovative processes.

The world experience of forming a developed national economy with the help of defined state social and economic, investment and innovation policy is a long-term reference point for our country. Therefore, it is important to study the social and economic, investment and innovation processes of the state. This is a prerequisite for the formation of a model of economic regulation, which will make it possible to raise the standard of living of the population.

Neural networks are a suitable tool for analyzing macroeconomic processes and determining the main directions of social and economic, investment and innovation policy of the state. Therefore, neural network modeling can contribute to the formation of a socially and innovatively oriented economy of the country.

The aim of the article is for a neural network modeling of changes in the main ways of the state social and economic, investment and innovation policy in Ukraine to improve the state management, and formation of the socially and innovatively oriented national economy.

In the process of forming a neural network model, the following tasks were set:

- analysis of the degree of influence of various elements of the state social and economic, investment and innovation policy on the formation of a socially and innovatively oriented economy of the country;
- formulation of conclusions and recommendations regarding changes in the main ways of the state social and economic, investment and innovation policy in Ukraine, which are aimed at the formation of a socially and innovatively oriented national economy;
- clarify the extent to which the characteristics of the state social and economic, investment and innovation policy for the transition to a socially and innovatively oriented national economy are changing;
- forecast of the interaction of changes in the social and economic, investment and innovation policy of the state and the degree of the socially and innovatively oriented national economy.

2. Related Works

A significant part of the existing shortcomings of the forecasting system are in the area of scientific and methodological support for the development and substantiation of forecasts and development scenarios. This prompts the deepening of attention to forecasting tools, further search for their improvement.

The forecasting system should cover the sphere of methodology and organization of forecast development, informational and organizational, economic and mathematical, econometric and technical support for forecast development and promotion of their use.

The results of the processes of forecasting the social and economic, investment and innovative development of the country should be scientifically based answers to the following questions: what opportunities exist in society to meet the needs of the population in the future; what results of social and economic, investment and innovative development can ensure a high level of meeting the needs of the population; which ways are expedient to choose to achieve needs; what resources are needed for implementation; what is the level of availability of resources in the country; what problem threatens the further development; what set of measures can ensure the expected results and others. To answer the questions, the forecasting system must have meaningful methodological and structural unity, regardless of the specifics of the objects.

A system of forecasts is used for the development of the state. Types of the country's development forecast include research, regulatory, programmatic, project, and others [1]. These forecasts have certain theoretical and practical implications, an instrumental base for their development and substantiation, and can cover all probable aspects of future development in a certain period of time. They should be accompanied by quality verification, justification of the funds spent, assessment of the quality of the results of the use, development of measures to reduce possible threats and risks of management.

The forecasting system provides for the implementation of functions and tasks, defined types of forecasts, models for forecast implementation, highlighting sources of information accumulation.

Areas of activity of forecasting the social and economic, investment and innovation development of the country should include a list of the main resulting indicators of development with a gradual increase of these indicators, taking into account the factors that affect it.

The directions of process forecasting in the country can include [2]:

- forecasting of investment and innovation development (number of innovative technologies and innovative enterprises, amount of costs for innovative activities, number of research institutions, amount of scientific and research work; investments in innovative developments);
- forecasting of economic development (volume of the labor market, products, services; volume of the capital market; GDP; gross value added; labor productivity and average salary; profit and profitability of production);
- forecasting of social development (quality of education, social protection and social security, total insurance contributions, average life expectancy of the country's population; level of education and standard of living of the country's population, purchasing power).

In recent years, forecasting methodology has been replenished with a number of effective methods of strategic analysis, information technologies and programs, and technological products. The most common methods and models used in forecasting processes [3]:

- Classic analytical and sociometric methods: (index method, reference method or method of Etalon, methods of rating assessment and ranking method; technical and economic analysis; cluster analysis; structural and logistic analysis; latent factors and classification method; discounting; expert evaluations; analysis of hierarchies, SWOT analysis of strengths and weaknesses, functional value analysis, PEST analysis (analysis of political, economic, social and technological factors)).
- Methods and models of linear and dynamic programming; multivariate correlation and regression analysis; Neural Network Modeling.
- Forecasting models based on scenarios (extrapolations based on average growth rates; extrapolations based on regression analysis; extrapolations based on average absolute growth; time series decompositions (multiplicative) and additive model; Brown models; factor models based on multidimensional ranking and correlation and regression analysis; forecast based on elasticity model; combined forecasts by a set of models).

Among the main forecasting methods, neural network forecasting methods are presumed to demonstrate consistent growth.

Currently, the real use of neural networks is developing in the following areas: stock exchange and macroeconomic forecasting; speech recognition and dialogue with the person; imitation of intellectual activity; improvement of poor-quality and noisy information; identification of suspicious persons and situations [4].

Neural networks have been advocated as an alternative to traditional statistical forecasting methods. Across monthly and quarterly time series, the neural networks did significantly better than traditional methods. As suggested by theory, the neural networks were particularly effective for discontinuous time series [5]. This approach is useful when it is necessary to overcome difficulties related to non-stationarity, incompleteness, unknown distribution of data, or when statistical methods are not completely satisfactory [6].

Neural networks have been successfully used for forecasting of financial data series [7] and future trend of the stock market that is a critical issue in investment sector [8]. Neural Networks have the advantage that can approximate any nonlinear functions without any information about the properties of the data series [7].

Over the last few recent years, there has been much research directed at predicting the future and making better decisions. This research has led to many developments in forecasting methods. Most of these methodological advances have been based on statistical techniques. Statistical methods and neural networks are commonly used for time series prediction. Empirical results have shown that neural networks outperform linear regression, especially in the case of more complex behavior of dependent variables like nonlinear, dynamic and chaotic behaviors. Neural networks are reliable for modeling nonlinear, dynamic market predictions. Neural network makes very few assumptions, as opposed to normality assumptions commonly found in statistical methods. The neural network can perform prediction after learning the underlying relationship between the input variables and outputs [9].

In this study it will be shown about the productive use of neural network modeling in forecasting problems of social and economic, investment and innovation policy of the state.

The authors offer to use the neural network for the modeling, to make a prediction about the changes in the social and economic, investment and innovation policy of the state and the degree of the socially and innovatively oriented national economy.

3. Methods

In the article, the directions and scope of changes in state intervention in the economy were clarified by neural network modeling.

We analyzed the nature of the influence of each factor of the neural network model on the result. This happened due to the successive changes of each input parameter of the model. Then, the neural network evaluated the state's performance. Graphs were constructed using the results of the calculations.

The activation value of the neuron is obtained as the difference of the weighted sum of the inputs and the threshold value. The activation signal is converted using the activation function. As a result, the output signal of the *j*-th neuron (u_j) is obtained [10]:

$$u_j = \psi_j^{(3)}\left(b_j^{(3)} + \sum_{l=1}^{p}\left[w_{lj}^{(3)} \cdot \psi_l^{(2)}\left(b_l^{(2)} + \sum_{i=1}^{n}\left[w_{il}^{(2)} \cdot \psi_i^{(1)}(x_i)\right]\right)\right]\right), \; j = \overline{1,m} \qquad (1)$$

where $\psi_i^{(1)}$ – is the activation function of the *i*-th neuron of the input layer of the neural network, $i = \overline{1,n}$;

$\psi_l^{(2)}$, $b_l^{(2)}$ – is the activation function and the offset parameter for the adder of the *l*-th neuron of the second layer of the network, $l = \overline{1,p}$;

$\psi_j^{(3)}$, $b_j^{(3)}$ – is the activation function and the offset parameter for the adder of the *j*-th neuron of the output layer of the perceptron, $j = \overline{1,m}$;

$w_{il}^{(2)}$ – is the weight of the interneuron connection between the *i*-th neuron of the first layer and the *l*-th neuron of the second layer;

$w_{lj}^{(3)}$ – is the weight of the interneuron connection between the *l*-th neuron of the second layer and the *j*-th neuron of the third layer;

x_i – *i*-th input signal of the neuron.

The formation of the neural model is carried out sequentially: first, the network type is selected to achieve the goals and objectives, then the network is trained, then the network is checked or tested, and later the network can be successfully implemented.

In the next step, the minimum and maximum number of neurons, network variants for training, selection and evaluation were determined. After that, the training and selection of neural networks are triggered.

During the construction of the neural model, a training sample was developed. StatSoft Statistica 6.0 neural network application program package was chosen as the basis for the research.

The input parameters of the model are indicators of the country's investment, innovation, social, and economic policy.

Input indicators for the neural model: paid taxes (in % of GDP, P1), corporate income tax revenue (in % of GDP, P3), revenues from the personal income tax (in % of GDP, P2), receipts from the VAT and excise duties (in % of GDP, P4), non-tax revenues of the consolidated budget (in % of GDP, B1), tax revenues of the local budgets (in % of GDP, B2), GDP, $; money supply (in % of GDP, aggregate M1), R&D funding from the state budget (in % of GDP, F1), financing of innovative activities from the state budget (in % of GDP, F2), consolidated budget expenditures (in % of GDP, B3), consolidated budget expenditure on public functions (in % of GDP, B4), government expenditure on education (in % of GDP, B5), public investments (fixed investment) (in % of GDP, Inv1).

The output parameter of the model is the pertinence or level of compliance of the state policy with the conditions of the social and innovative orientation of the economy. The expert assessment has limits, where

1 is the highest level of the social and innovative orientation of the economy, 0 is the lowest level of the social and innovative orientation of the economy.

Statistical data were collected to evaluate all factors. Statistical data characterize the investment and innovation, social and economic policies of the leading countries for 1969-2021. The sources of statistical data are the statistical materials of the IMF, OECD, State Committee of Statistics of Ukraine and other organizations. Statistics from the UK, USA, France, Germany, Sweden, Netherlands, Austria, Finland, Switzerland and others were used.

Table 1 shows indicators and statistical data for the model that evaluates the social and economic, investment and innovation policy of Ukraine.

Table 1

Indicators and statistical data for the model that evaluates the social and economic, investment and innovation policy of Ukraine [11]

Indicators	2000	2001	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021
Paid taxes (in % of GDP, P1)	29,1	27,9	29,8	30,4	30,5	31,6	30,6	29,4	33,0	34,0	33,0	32,0
Corporate income tax revenue (in % of GDP, P3)	4,5	4,1	4,9	5,3	4,8	3,6	4,2	3,7	2,0	2,5	3,0	3,0
Revenues from the personal income tax (in % of GDP, P2)	3,73	4,34	5,10	3,92	4,82	4,91	4,63	4,70	5,0	6,2	6,3	6,3
Receipts from the VAT and excise duties (in % of GDP, P4)	6,91	6,42	6,70	9,48	9,72	11,6	13,3	12,1	12,7	14,2	14,5	14,1
R&D funding from the state budget (in % of GDP, F1)	0,36	0,37	0,40	0,39	0,39	0,37	0,29	0,29	0,28	0,27	0,27	0,26
Financing of innovative activities from the state budget (in % of GDP, F2)	0,005	0,027	0,035	0,006	0,020	0,014	0,011	0,002	0,003	0,008	0,014	0,010
Non-tax revenues of the consolidated budget (in % of GDP, B1)	7,39	6,91	6,19	5,91	5,33	7,01	4,62	5,62	7,0	5,2	5,0	5,0
Consolidated budget expenditures (in % of GDP, B3)	28,28	27,19	28,42	32,12	31,41	33,61	32,00	33,61	34,2	35,0	35,8	36,0
Tax revenues of the local budgets (in % of GDP, B2)	6,89	7,21	5,70	5,22	6,13	6,41	5,61	6,10	8,0	8,8	8,4	8,4
Consolidated budget expenditure on public functions (in % of GDP, B4)	3,89	3,81	3,71	3,52	3,41	3,71	3,82	4,10	5,20	4,78	5,10	4,63
Government expenditure on education (in % of GDP, B5)	2,31	2,32	2,20	2,21	2,10	2,60	2,11	2,0	1,5	1,4	1,3	1,5
Public fixed investment (in % of GDP, Inv1)	1,29	1,51	2,13	1,89	2,52	1,23	1,41	1,31	2,01	2,20	2,88	2,15
Money supply (in % of GDP, aggregate M1)	12,2	14,6	19,3	22,3	25,2	25,6	24,0	26,4	28,9	20,2	19,37	23,5

The neural network model logically and correctly interprets the input parameters and helps clarify the scale of changes in the social and economic, investment and innovation policy of the state. The alternating change of each of the input data enables the neural network to evaluate the results of policy of the state.

4. Experiment, results and discussion

In order to form a socially and innovatively oriented national economy, policy in our country should be aimed at increasing government expenditure on education. Calculations based on the neural network model confirm the direct relationship between the volume of government expenditure on education and the degree of the socially and innovatively oriented national economy (Figures 1 and 2).

As a result of the conducted experiment, a multilayer neural network was obtained (multilayer perceptron MLP 7-6-1, activation function for hidden neurons - tanh, activation function for output neurons - logistic). This neural network has the highest performance and the lowest training error.

Figure 1 shows the dependence of "Government expenditure on education" when changing the factor P1 (Paid taxes) for certain values of the factor P2 (Revenues from the personal income tax) and fixed values of other factors (P3 = 3, P4 = 14, B1 = 5, B2 = 8, M1 = 23).

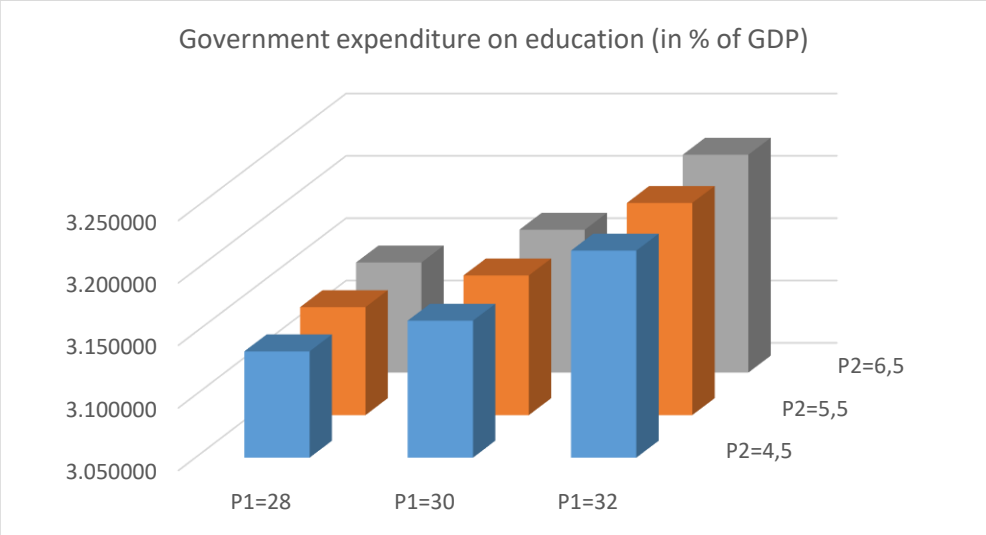

Figure 1: Forecast of government expenditure on education

Figure 2 shows the dependence of "Government expenditure on education" when changing the factor P1 (Paid taxes) for certain values of the factor P4 (Receipts from the VAT and excise duties) and fixed values of other factors (P3 = 3, P2 = 5, B1 = 5, B2 = 8, M1 = 20).

The growth of the "Paid taxes" leads to the growth of the "Government expenditure on education".

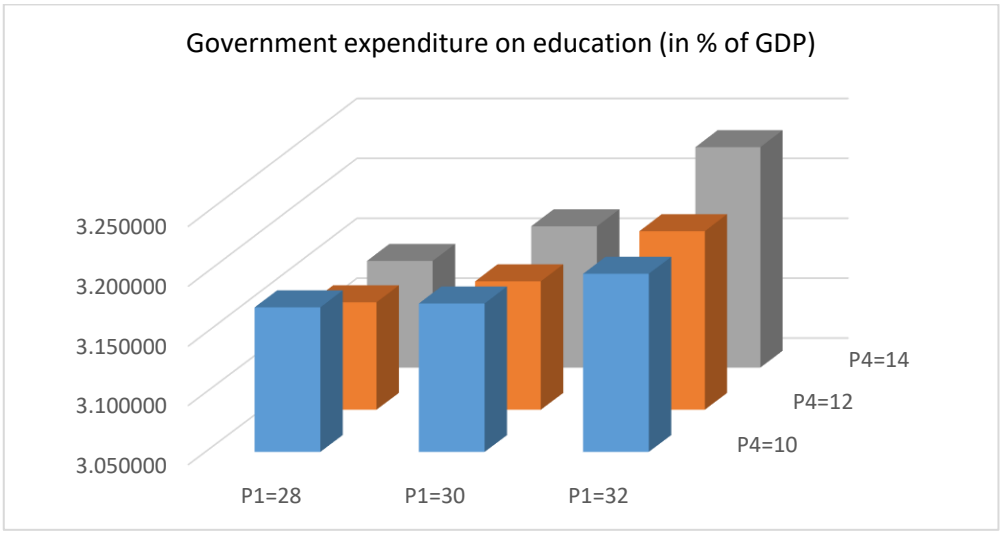

Figure 2: Forecast of government expenditure on education

C. U. Okerekeoti [12] upholds that there is a beneficial and substantial effect between GDP and government expenditure on education, almost at the 5% level of meaning. On the basis of this research, the author advised that there should be an increase in the redistribution of government spending towards education in order to enhance profits in the long run, which would cause an enhancement of welfare and social security of citizens.

Government expenditure on education are needed to support the educational and scientific sphere in Ukraine. Expenditure on education are a part of the costs necessary for the reproduction of human capital. Such expenses are important for solving social issues and obtaining a job. They are also of great importance to the financing of research and innovation activities, the formation of the country's intellectual potential. Although there was a slight increase in the absolute indicators of budget expenditures for the training of young specialists, the share of these budget expenditures is gradually decreasing.

According to the obtained results of the neural network model, in order to form a socially and innovatively oriented model of the economy, policy in Ukraine should be aimed at increasing R&D funding from the state budget. The results confirm a direct relationship between the amount of R&D funding from the state budget and the degree of social and innovative orientation of the economy (Figures 3 and 4).

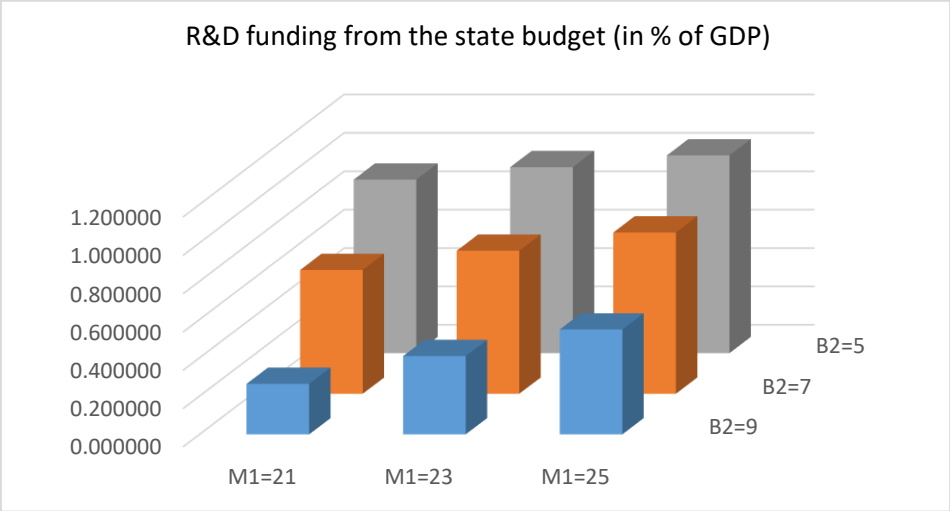

Figure 3: Forecast of R&D funding from the state budget

Figure 3 shows the dependence of "R&D funding from the state budget" when changing the factor M1 (Money supply) for certain values of the factor B2 (Tax revenues of the local budgets) and fixed values of other factors (P1 = 32, P2 = 6, P3 = 3, P4 = 14, B1 = 5). As a result of the conducted experiment, a multilayer neural network was obtained (multilayer perceptron MLP 7-7-1, activation function for hidden neurons - exponential, activation function for output neurons - tanh). This neural network has the highest performance and the lowest training error.

The growth of the "Money supply" leads to the growth of the "R&D funding from the state budget".

In Ukraine, there is a gradual reduction of government spending on research and development [13; 14]. Today, there is a need to catalyze private investments and stimulate a regular increase in R&D spending from the budget.

Despite three decades of massive R&D expenditure, economic growth levels have remained substantially lower than that of the immediate post World War II period. This raises important theoretical questions regarding R&D and its impact on growth per se. Beaudreau and Lightfoot claim that there are the physical limits to economic growth by R&D funded innovation [15].

Figure 4 shows the dependence of "R&D funding from the state budget" when changing the factor P1 (Paid taxes) for certain values of the factor B2 (Tax revenues of the local budgets) and fixed values of other factors (M1 = 21, P2 = 6, P3 = 3, P4 = 14, B1 = 5). The growth of the "Paid taxes" leads to the growth of the "R&D funding from the state budget".

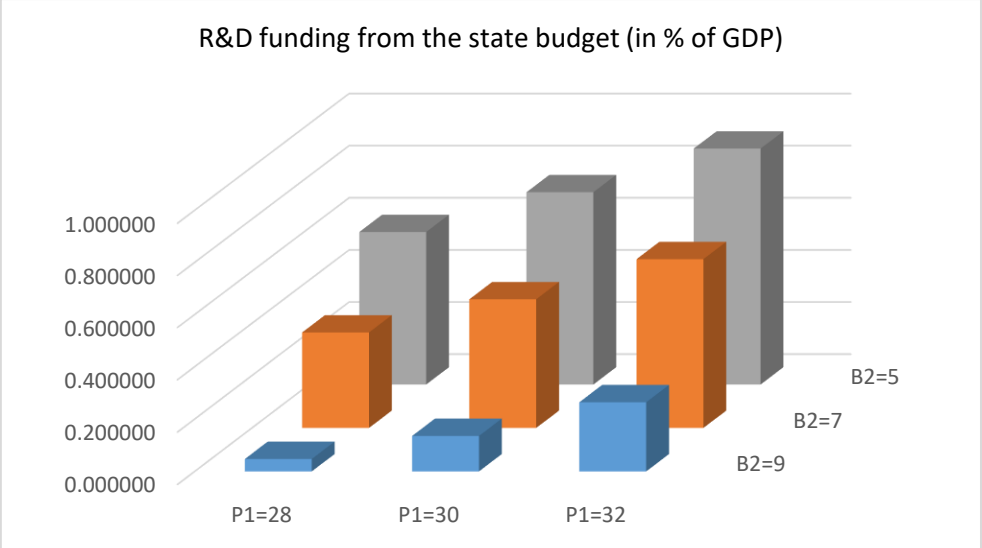

Figure 4: Forecast of R&D funding from the state budget

The current economic system in Ukraine does not provide the level of financial support for research and development that aim to achieve the most effective result in innovative activity. For this, it is necessary to improve the system of research and development in Ukraine thanks to the implementation of international experience, various available sources of attracting additional funds in this area. It is important for the state to focus its efforts on improving the quality of human capital and educational competencies. The state should take this factor into account in the process of forming strategic plans for the development of research and development.

In relation to the framework of funding of different types of scientific R&D, the share of government budget resources is one prospective sign of the level of influence of state innovative policy. It is important to develop cooperation between the private and public sectors of the national economy in funding of R&D.

Analyzing the volume of financing of innovative activities from the state budget in Ukraine, there is a decrease in government spending on innovative development of the country in GDP relative to 2003. Establishing a social and innovation-oriented model of the economy in Ukraine requires an increase in funding for innovative activities. From the figure 5, we can see that the increase in financing of innovative activities from the state budget leads to economic growth.

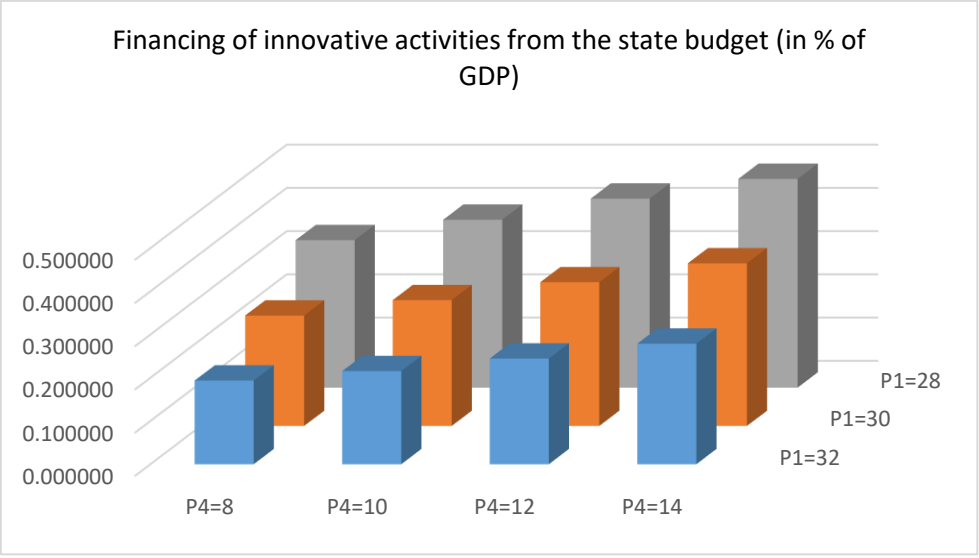

Figure 5: Forecast of financing of innovative activities from the state budget

Figure 5 shows the dependence of "Financing of innovative activities from the state budget" when changing the factor P4 (Receipts from the VAT and excise duties) for certain values of the factor P1 (Paid taxes) and fixed values of other factors (M1 = 23, P2 = 6, P3 = 3, B1 = 5, B2 = 8). As a result of the conducted experiment, a multilayer neural network was obtained (multilayer perceptron MLP 7-4-1, activation function for hidden neurons - tanh, activation function for output neurons - identity). This neural network has the highest performance and the lowest training error.

The growth of the "Receipts from the VAT and excise duties" leads to the growth of the "Financing of innovative activities from the state budget".

The obtained results characterize the existence of a direct relationship between the financing of innovative activities from the budget and the neural network assessment of the degree of assistance of state policy to the formation of a socially and innovatively oriented model of the economy [16; 17]. Such a model requires the development of state innovation programs, projects, and implementation of an innovation strategy at all levels of the national economy.

Figure 6 shows the dependence of "Public fixed investment" when changing the factor P4 (Receipts from the VAT and excise duties) for certain values of the factor B1 (Non-tax revenues of the consolidated budget) and fixed values of other factors (M1 = 23, P1 = 32, P2 = 6, P3 = 3, B2 = 8). As a result of the conducted experiment, a multilayer neural network was obtained (multilayer perceptron MLP 7-9-1, activation function for hidden neurons - exponential, activation function for output neurons - logistic). This neural network has the highest performance and the lowest training error.

The growth of the "Receipts from the VAT and excise duties" leads to the growth of the "Public fixed investment".

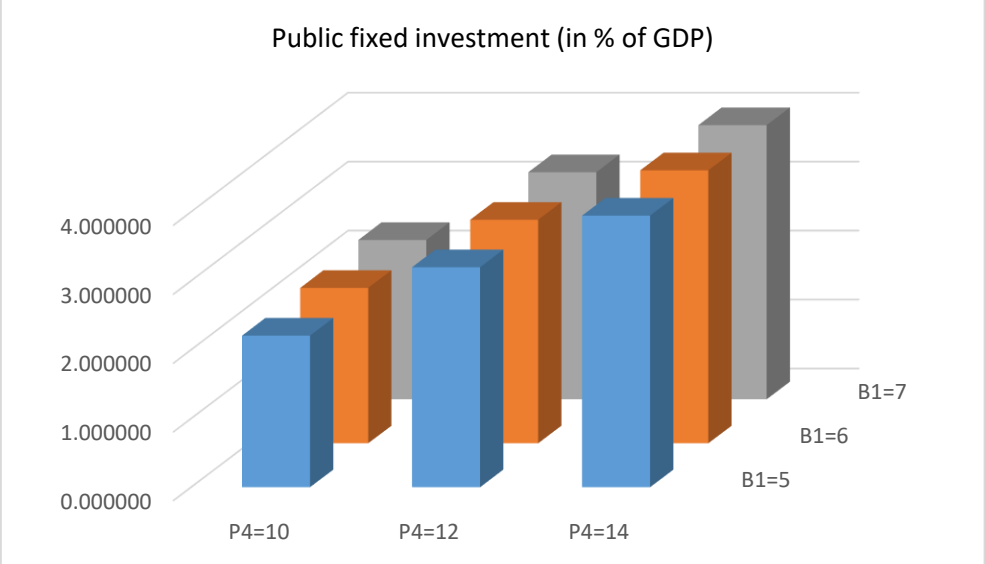

Figure 6: Forecast of public fixed investment

Investigating the trend of state capital investments in our country, it is important to note that since 2013 there has been a trend towards an increase in the share of public fixed investment in GDP. For the purpose of innovative development of the country, the volume of public fixed investment should increase.

Fixed investment stays dependent on state resources, and foreign direct investment is declining. Ukraine needs a rational distribution of foreign direct investment in renewal and modernization, investment in innovative infrastructure, and other assets, in particular private investments. There was a need for financing instruments for innovative development, implementation of state policy in innovative, industrial infrastructure projects.

5. Conclusion

Thus, the proposed neural network model for studying the action of social and economic, innovative and investment factors that determine government policy found out the understatement of state financial and resource support.

Calculations based on the neural network model confirm the direct relationship between the volume of government expenditure on education, R&D funding from the state budget, financing of innovative activities from the state budget, public fixed investment and the degree of the socially and innovatively oriented national economy.

The neural network model for forecasting and evaluation of the social and economic, investment and innovation policy of the state allows predicting the main directions of resource allocation and budgeting. The growth of innovative activity, the development of education and scientific research is possible through an effective and productive state policy.

The government needs the budgetary discipline, and monitoring to keep public expenditure at the optimal extent to cause a favorable ripple effect to various types of economic activity, sectors, industries of the economy and prevent a crowding-out effect in the country.

In that regard, it is important to make use of conclusions acquired and the results achieved through a neural network model. This may be a foundation to develop an effective strategy of the economic development of the country, strategic programs, plans, and address the social issue and Ukraine's innovative development. The forecast data may provide the basis for strategic programs, plans and budgets, social and economic and innovative projects.

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