Simulating Development of Science in a Country with the Use of the Cognitive Approach

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Abstract. The study proposes a methodological approach to justifying the directions for reforming the scientific sphere of a country which is based on the cognitive approach. Using the proposed approach, the groups of the main problems in the development of science in Ukraine are determined and indicators for their evaluation are singled out; the cognitive model of the development of science in Ukraine is constructed. On the basis of the constructed cognitive model, impulse simulation of the influence of the main factors on development of science in a country is carried out and, according to the hypotheses on the nature of their influence, four scenarios for the development of the process under study are constructed. The analysis of the developed scenarios allowed to justify the most effective measures to stimulate the development of science in Ukraine. The practical evaluation of the proposed methodological approach has proved the feasibility of using cognitive models for analyzing and simulating development of science in a country, which allows to quickly and accurately assess a situation and identify promising measures to support it.

1 Introduction

The development of modern society is directly linked to globalization processes which imply the strengthening of integration ties among regions and countries of the world. These processes also transform the development of science which is influenced by many internal and external factors having complex interrelations and affecting each other with different strength. All this makes the problem of simulating the development of science in countries of the world extremely difficult to analyze and puts forward requirements for the choice of tools to use. Many scientists have proved the feasibility of applying the cognitive approach in analyzing and simulating complex semistructured systems and problems, including the one under study [1]. The methodological foundations of the cognitive approach were laid in the works of R. Axelrod, Vesa A. Niskanen, R. Atkin, F. Ritter, A. S. Huff and others. They were further developed in works of Z. Avdeev, S. Kovriga, V. Maximov, V. Khaustova, and others [1–7]. But insufficient attention has been paid to studying processes of scientific development with the use of the cognitive approach. At the same time, its application will contribute to a better understanding of problems in the development of domestic science, identification of contradictions and a high-quality analysis of the entire system of research

activity in Ukraine. Therefore, the aim of the article is studying the current problems in the development of the Ukrainian science and simulating its development in the context of globalization challenges by means of the cognitive approach.

2 Methodology

Cognitive simulation is based on representation of a complex system (problem) in a simplified form as a specific model and allows, based on it, to consider possible scenarios for the development of the system (problem) at certain external and internal changes.

The analysis of the existing in theory and practice approaches to diagnosing problems of functioning and development of a system (based on methods of goal-setting, strategic management, management theory, etc.) has proved the feasibility of using functional cognitive maps to represent knowledge about the development of problem situations to carry out a formal analysis of structural and dynamic features of the development of socio-economic systems in solving practical problems of reforming an economic policy [1–7]. This made it possible to form a methodological approach to justifying the directions for reforming the scientific sphere in Ukraine, the block diagram of which is present in Fig. 1.

3 Results

In order to build a cognitive model for studying problems of science development in Ukraine, in accordance with the methodological approach to justifying the directions for reforming the country's scientific sphere (Fig. 1), at the first stage, directions for reforming the scientific sphere were determined based on forming a conceptual model of the research goals, structuring the goals, and defining the goal image. This process was implemented with the involvement of a group of experts, by analyzing the peculiarities, trends and problems in the development of science during the period of Ukraine's independence, as well as studying the experience in ensuring the development of science in the leading countries of the world. As a result of the study, there was justified the need to strengthen the export potential by increasing the share of high-tech products in the context of globalization, which can be achieved by enhancing the scientific and technical potential, improving the quality of scientific staff training, bringing the R & D funding to the level of the leading countries of the world. It is these indicators that have formed the goal image of reforming the scientific sphere in the country.

At the second stage of the study, factors affecting the processes of research activity and the development of a scientific product were analyzed, which has allowed to form the problem domain, identify the main problems that are most significant as well as the main indicators for their evaluation (Table 1).

Table 1. Groups of main problems of science development in Ukraine and indicators for their assessment.

Denotation	Problem	Indicator for assessing the problem	Assessment
X_1	Low demand for science in the economy	Decrease in the share of innovatively active enterprises	Statistical assessment, calculating the growth rate
X_2	Inefficient system of state management of science	Lack of a strategy for the development of science in the country	Expert assessment, linguistic rating, determining uncertain tendencies
X_3	Low level of communication (integration processes)	Level of integration of scientific, educational institutions and business to create a scientific product	Expert assessment, linguistic rating, determining uncertain tendencies
X_4	Lack of funding and other socio-economic incentives	R & D funding	Statistical assessment, calculating the growth rate
X_5	Low level of effectiveness	Share of exports of high-tech	Statistical assessment, calculating

	of scientific results, low export potential	products	the growth rate
X_6	Staffing problem	Decrease in the number of researchers	Statistical assessment, calculating the growth rate
X_7	Low level of authority of science in the society	Level of social status of scientists	Expert assessment, linguistic rating, determining uncertain tendencies

Source: developed by the authors

Fig. 1. Structural chart of the methodological approach to justifying the directions for reforming the scientific sphere in Ukraine.
Source: developed by the authors

After identifying the main problems of the problem domain and building the primary cognitive map, the importance of the problems and connections between them was assessed based on the Analytic Hierarchy Process (AHP) developed by T. Saaty [8]. Accordingly, for this purpose, matrices of pairwise comparisons were formed and the effect of each problem which is included into another problem (or causes its occurrence) is determined.

Similarly, the matrices of pairwise comparisons for other groups of problems were formed and the effect of each problem which causes the emergence of others was determined. Based on the calculation of the weighing coefficients for problems in a group of problems, the types of problems are identified. The determination of root and nodal problems and their effect on other problems are given in Table 2.

Table 2. Determination of types of problems in the primary cognitive model

Deno- tation	Group of problems	Weighting coefficient of the problem in the group	Type of problem
X_1	Low demand for science in the economy	0.509	nodal problem
X_2	Inefficient system of state management of science	3.922	root problem
X_3	Low level of communication (integration processes)	0.235	nodal problem
X_4	Lack of funding and other socio-economic incentives	0.456	nodal problem
X_5	Low level of effectiveness of scientific results, low export potential	0	resulting problem
X_6	Staffing problem	0.502	nodal problem
X_7	Low level of authority of science in the society	0.041	nodal problem

Source: developed by the authors

At the next stage of the analysis, there were determined the values of the matrix L which includes the value of the calculated coefficients of problem importance calculated based on the data of the State Statistics Service of Ukraine for the period 2000-2018 [9].

For some problems in the development of science, the impossibility to carry out a quantitative analysis of the indicators which characterize them was determined. Such problems are described by a linguistic variable and have an uncertain tendency in the development of indicators. To assess these problems, it was proposed to apply a rating scale using the approach which takes into account the Fibonacci series and the “golden proportion” based on expert assessment [10]. According to the proposed scale, the following problems were evaluated: the inefficient system of state management of science (insignificant increase – 1.119), a low level of communication (integration processes) – 0.942, a low level of authority of science in the life of the society – 0.618.

To determine the degree of the cause-effect relations of the problems in the development of science in Ukraine and the factors which characterize them, based on the matrices of statistical data describing their dynamics, the coefficients of correlation between the quantitative parameters of the influence of the factor i on the factor j were calculated. Measuring the causal factors and their weight, taking into account the correlation described by the matrix $A \times L$, is given in Table 3.

Based on these calculations, a cognitive model for studying the problems of the development of science in Ukraine was built (Fig. 2). Based on the cognitive model, impulse simulation of the influence of factors on the development of science in Ukraine was carried out and, according to the formed hypotheses on the nature of their influence, four scenarios for the development of the studied processes were built.

Scenario 1 is based on the hypothesis that the development of science in the country will be influenced by forming and implementing an effective strategy for the development

of science. It was simulated by introducing an impulse (disturbance) into the vertex X_2 , the value of $u_1 = +1$.

Scenario 2 is based on the hypothesis that the development of science in the country will be influenced by increasing the R & D funding. It was simulated by introducing an impulse (disturbance) into the vertex X_4 the value of $u_4 = +1$. The disturbance (impulse) $U = \{u_4 = 0, 0, 0, +1, 0, 0, 0\}$ simulates the hypothesis that at increasing R & D funding a gradual increase in the share of high-tech products in the GDP is expected.

Table 3. Determining the values of the matrix $A \times L$ of measuring the causal factors and significance of the factors, taking into account their correlation.

Denotation	Group of problems	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	Low demand for science in the economy	0.000	0.000	0.000	-0.146	0.132	0.000	0.000
X_2	Inefficient system of state management of science	0.504	0.000	0.618	0.543	0.226	0.257	0.379
X_3	Low level of communication (integration processes)	0.064	0.000	0.000	0.034	0.008	0.000	0.016
X_4	Lack of funding and other socio-economic incentives	0.000	0.000	0.000	0.000	0.272	-0.018	0.000
X_5	Low level of effectiveness of scientific results, low export potential	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X_6	Staffing problem	-0.037	0.000	0.000	0.000	0.143	0.000	0.104
X_7	Low level of authority of science in the society	-0.013	0.000	0.000	0.000	0.000	0.000	0.000

Source: developed by the authors based on [9]

Fig. 2. Cognitive model for studying problems in the development of science in Ukraine
Source: developed by the authors.

Scenario 3 is based on the hypothesis that the development of science in the country will be influenced by enlarging the number of researchers due to improving the quality of

scientific staff training. It was simulated by introducing an impulse (disturbance) into the vertex X_6 , the value of $u_6 = +1$. The disturbance (impulse) $U = \{u_6 = 0, 0, 0, 0, 0, +1, 0\}$ simulates the hypothesis that at enlarging the number of researchers, due to improving of the quality of scientific staff training, a gradual increase in the share of high-tech products in the GDP is expected.

Scenario 4 is based on the hypothesis that the development of science in the country will be influenced by forming and implementing an effective strategy for the development of science along with increasing the R & D funding and enlarging the number of researchers due to improving the quality of scientific staff training. It was simulated by introducing an impulse (disturbance) into the vertex X_2 , the value of $u_1 = +1$; introducing a disturbance into the vertex x_4 , the value of $u_4 = +1$; introducing an impulse into the vertex x_6 , the value of $u_6 = +1$. The disturbance (impulse) $U = \{0, +1, 0, +1, 0, +1, 0\}$ simulates the hypothesis that at formulating an adequate policy for the development of science and elaborating a strategy for the development of science in Ukraine, enlarging the number of researchers due to improving the quality of scientific staff training, increasing R & D funding a gradual increase in the share of high-tech products in the GDP is expected.

The analysis of the scenarios for the development of science in Ukraine, built on the basis of a cognitive model of the existing problems, has made it possible to determine that at present the most effective way, which will bring the most significant results (all parameters of the goal image increase), is forming and implementing an effective strategy for the development of science. Enlarging the number of researchers by improving the quality of scientific training and increasing R&D funding under conditions which have developed in the country will not yield significant results without paying attention to strategic priorities in the development of science and relevant government support.

4 Conclusions

Thus, the proposed methodological approach has allowed to justify the most effective measures to stimulate the development of science in Ukraine. The practical evaluation of the proposed methodological approach has proved the feasibility of using cognitive models for analyzing and simulating development of science in a country, which allows to quickly and accurately assess a situation and determine promising measures to support it.

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