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**PROGRAMMING AS A DEVELOPMENT TOOL
OF RUSSIAN SCIENCE: EVOLUTION, FEATURES
AND APPLICATION PROSPECTS**

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Abstract

Currently, the most important preconditions for efficient development of the Russian economy include improvement of production infrastructure, use of advanced technologies and scientific support of economic processes, both nationally and in certain regions.

In this connection, scientific development, the performing of fundamental and applied research, activation of innovative activity of Russian enterprises and integration of science and production have become the most relevant issues.

As it is proved in practice, programming is an efficient tools for management of sectorial processes and may be effectively applied in coordination of the development of scientific processes in a certain territory.

Aspects of programming evolution and the peculiarities and prospects of the use of this toolset under modern economic conditions are considered in this article, along with recommendations for improvement of management of Russian scientific and research activity.

The authors also designed an algorithm for a scientific and research activity development program at the regional level that produces a systemic vision of the conditions necessary for implementation of scientific and innovative potential of the development of the economy of a certain territory.

This algorithm produces a detailed understanding of the conditions necessary for implementation of the scientific and innovative potential of the development of a regional economy. Moreover, this algorithm assists in forming an efficient toolset for management of scientific and research activity and improving the competitiveness of the territorial economy.

**PROGRAMOWANIE JAKO NARZĘDZIE ROZWOJU ROSYJSKIEJ NAUKI –
EWOLUCJA, CECHY I PERSPEKTYWY ZASTOSOWANIA**

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Słowa kluczowe: programowanie, nauka, postęp naukowo-techniczny, program państwowy.

Abstrakt

Udoskonalenie infrastruktury produkcyjnej, wykorzystanie zaawansowanych technologii oraz naukowe wsparcie procesów gospodarczych, zarówno na poziomie całego państwa, jak i pewnych regionów, to obecnie najważniejsze warunki wstępne do sprawnego rozwoju rosyjskiej gospodarki. W tym kontekście rozwój nauki, realizacja badań podstawowych i stosowanych, pobudzanie działalności innowacyjnej rosyjskich przedsiębiorstw oraz integracja nauki z produkcją stają się najistotniejszymi zagadnieniami.

Jak wykazano w praktyce, programowanie jest jednym ze skutecznych narzędzi zarządzania procesami sektorowymi i może być z powodzeniem stosowane do koordynowania rozwoju postępu naukowego na pewnym terytorium. W artykule zawarto rozważania nad aspektami ewolucji programowania, szczególnie oraz perspektywami wykorzystania tego zestawu narzędziowego we współczesnych warunkach gospodarczych. Zarekomendowano propozycje poprawy zarządzania rosyjskimi działaniami naukowymi i badawczymi. Autorzy opracowali także algorytm do projektowania programu rozwoju działalności naukowo-badawczej na poziomie regionalnym, który pozwala na uzyskanie systemowej wizji warunków koniecznych do wykorzystania potencjału naukowego i innowacyjnego rozwoju gospodarki danego regionu. Ponadto algorytm ten pomaga w stworzeniu skutecznego zestawu narzędzi do zarządzania działalnością naukowo-badawczą oraz poprawy konkurencyjności gospodarki na danym obszarze.

The nature and characteristics of programming

Scientific programming involves the development and implementation of programs and is one of the most popular instruments in the world for managing research and innovation, ensuring the achievement of certain goals through the use of available resources (BILCHAK, NOSACHEVSKAYA 2011).

Traditionally, the content of the program is related to the definition of the main strategic goals, sub-goals in their chain of command, steps to achieve goals set to link actions to achieve the sub-goals, the definition of entities participating in the program, implementation mechanism, including sources of funding, methods of stimulation, responsibility, etc.

The essential features of a performance-based approach are as follows: the program is focused on the end result and is considered as a whole system, irrespective of the affiliation of its constituent elements; the program provides for certain financial, material, labour and other resources for its activities and is linked with other programs at the same level. Management of the program is carried out by the redistribution of rights, duties and responsibilities of existing organizational structures, as well as the use of different forms of coordination.

Evolution of the program and target methods in economics

In general, the beginning of the program-target method is related to the scope of state regulation and was typical of the industrialized countries in Europe from the early 1930s to the mid-1960s.

This method is relatively common, especially in the U.S., and is used to target the formation of fiscal policy and is seen as part of a continuous plan. Extensive experience in developing and implementing government programs, including science and technology, has accumulated in Russia.

National science and technology programs, developed at the state level in order to focus on the priority areas of scientific and technological progress and accelerate the development on this basis of knowledge-intensive industries, have transformed the image of the productive forces of the country, as well as for a complex perspective of basic research using competitive projects in accordance with relevant scientific advice.

The well-known and detailed shortcomings of the national science and technology policy under an administrative-command system were largely why the country has not managed to create a comprehensive system of management of scientific and technological development in collaboration with the productive sector.

In the 1990s, a variety of special programs, including those related to the development of research, were not supported by adequate financing from the federal budget.

Improving the approaches to the application of programming

In the early 2000s, a number of activities were taken at the state level to reform the procedures for implementation of federal programs and to consolidate positive trends in certain sectors and regions.

Insufficiently regulated implementation of earlier federal programs acquired during this period form a more efficient model to achieve the objectives.

In particular, to streamline the management of federal target programs at the state level, the priorities and criteria for the formation of such programs have been implemented. It is possible to give the entire set of programs a more targeted focus.

Limiting the number of federal programs and their projects will meet the funding needs of the federal budget and begin to implement the principle of full funding of programs in a timely manner.

As a result of the work done in this period, the structures of the federal target programs have been optimized and programs not meeting government priorities have been eliminated. This ensured concentration of funds and their allocation to the addressed priorities.

Personal responsibility for their conduct was also introduced in order to optimize the management structure of federal target programs.

Where specified, a state procurement coordinator has been made responsible for the preparation and implementation of federal programs, funding, coordination of state customers and reporting on the implementation of programs.

In addition, changes were made in the order of development and implementation of federal programs to adjust the program objectives and the timing of their implementation, the feasibility of further implementation of the program and to reduce the share of the program activities at the expense of the federal budget to ensure the full and timely funding for the program through non-budgetary sources and budgets of the Russian Federation.

However, there were problems which significantly reduced the effectiveness of federal programs. Part of the federal programs did not contain specific program activities, timing or evaluation of possible outcomes of their implementation. In a number of newly-approved program lists, there were no specific investment projects indicating multi-year sources of funding.

Government customers generally willingly accept the indicators which show the overall progress of financing and the expected results for the entire period of the program and do not pay much attention to the specific indicators of the progress or results of the program activities.

The absence of these indicators reduced the efficiency of the federal program as a holistic system instrument for achieving results, making it impossible for a substantive and comprehensive analysis of proposed federal programs, as well as evaluating the effectiveness of program activities and a follow up of their implementation.

Prospects for the use of a program-target approach in Russia

At present, programs are the basis of state regulation of the economy, in the world in general and particularly in Russia and they have become increasingly sophisticated. Overcoming the contradicting interests of the performance-oriented industry and the departmental management principles significantly improved methods of development and implementation.

A state program is a system of activities interrelated by task, timing and resources and public policy instruments that provide a framework of key

government functions to achieve the priorities and objectives of the state policy in the sphere of socio-economic development and security.

While implementing governmental programs, as opposed to implementation of federal programs, the problems arising with integration can be identified. It is important that when using governmental programs in financial planning it is required that uniform rules for all programs be created. Further, the diversity and specificity of branch management to integrate these policies is required.

There is now also a potential basis for the relationship between the federal, regional and municipal programs. The content of the state program of this relationship is provided and would potentially encourage greater interaction between the federal centre and the subjects of the Russian Federation.

Programming of national science and technology

In the context of the article, it is important to elaborate on the specifics of the structure and content of the draft state program of the Russian Federation, „The development of science and technology” (planned implementation period – up to 2020).

The project of the state program attempts to combine the funds intended for the development of science and technology in a policy document, which appears to strengthen their budget management.

Herewith, it is important to note that in recent years, the state budget funds of Russia are the major source of the research financial support (Fig. 1).

The draft state program has seven sub-programs. Activities for basic research in the sub-routines are present: „Basic research and development of the academic sector of science”, „Development of university research”, „Institutional development sector research and development” and „Development of international cooperation in the field of science”.

The draft state program provides for the development and adoption of policies for basic scientific research, which includes as a separate block of the program of fundamental research of the state academies of sciences, as well as plans for basic research conducted by public research foundations, national research centres, government research centres, leading industry research organizations and universities.

Thus, in our view, in the context of the solution of the modernization of the Russian economy and, in particular, extra-budgetary funds of enterprises to implement research projects and implementation of new technologies in the production process in the project of the state program, not enough attention is paid to the development of the sphere of industry research and development.

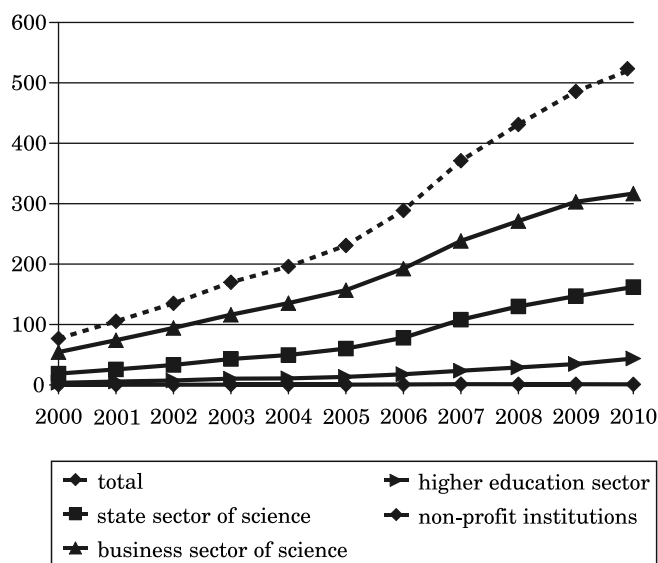


Fig. 1. Dynamics of internal expenses for research and development by sectors of science, billion rubles
Source: calculated by the author based on the data of Rosstat.

Today it is one of the most important tasks, without which the activation of the innovative activities of economic entities in Russia is difficult.

Note also that the draft state program requires the large participation of the federal executive bodies (Ministry of Education and Science of Russia, Minkonomrazvitiya Russia, Russian Finance Ministry, Rosatom, Rospatent and others) in the implementation of routines and activities. It is assumed that they will participate in setting priorities for research directions and directly conducting basic research. In this case, the Russian Ministry is the focal point of the national scientific research funded by the federal budget.

In the enlarged form of the state program is a project description of the current state of affairs in the country's science and technology with proposals to change the trends in some areas.

The total current project state program assumes research and development in eight major topic areas. Among them – IT-technology, biotechnology, medicine and health, new materials and nanotechnology, transportation and space systems, environmental management, energy efficiency and conservation and interdisciplinary research of a socio-economic nature.

As for the timing of the approval of the state program „Development of science and technology”, it is set out in the Decree of the President of the Russian Federation – of 31 December 2012 (Presidential Decree *On the long-term... 2012*).

At the present time, the coming months will see the implementation of the state program, „Development of science and technology” and a number of other related programs to identify and classify the problems and challenges in the modernization of economic processes in the country. They also offer solutions and create conditions for the widespread introduction of advanced domestic developments in production, output regions and the country as a whole for international markets of advanced technology.

It may also be advisable to allocate even more budget resources to focus on the priority areas of science and technology. One must determine not only a common approach to the implementation of these directions, but also to develop specific mechanisms in support each of them. In areas with the most obvious technological deficits, it is advisable to make appropriate institutional arrangements, for example, to generate specific technological projects implemented on the basis of federal centres of science and high technology, as well as to reorient the individual national research centres for the development of high technology in these areas.

As part of these processes, development, implementation and coordination of state programs, not only at the federal level but also regional development programs for science, can be clearly one of the most effective management tools and research and innovation activities in the country.

Mathematical approaches to the development of science programming

The application of mathematical methods within programming makes it possible to form both the current and prospective quantification of key factor transformation, ensuring effective functioning of the scientific program under various conditions. This evaluation makes it possible to predict possible changes in the development of the research and innovation activity modifying the quantitative value of various key factors.

In this connection, the key factors ensuring effective functioning and relevant results of research and innovation sectors functioning include the following:

- scientific personnel (personnel engaged in research and development; hiring and dismissal of scientific personnel);
- financial support of research and development;
- material and technical facility of science (basic means of research and development; machinery and equipment);
- efficiency of research and development at different stages of their introduction into the economy (publishing of local authors in scientific maga-

zines; application of patents and issuance of patents in Russia; creation and use of advanced production technology; volume of innovative products, works and services; expenses for technological innovation).

For evaluation of this functional dependence, various statistical indicators characterizing the process and results of the scientific activity were considered.

For the collection of these indicators, correlation and regression analysis methods were applied. This made it possible to analyse the set of indicators required for the construction of a statistically and mathematically significant model: personnel engaged in research and development; internal expenses for research and development; cost of machinery and equipment for research and development; number of mechanical patents issued in Russia.

Evaluation of the parameters significantly influencing the number of issued mechanical patents is implemented in two stages. At the first stage, the indicator of the issued mechanical patents per researcher was evaluated with the following ratio:

$$\text{patents}_{\text{lab}}(t) = F(\text{equip}_{\text{lab}}(t), \cos ts_{\text{lab}}(t), \theta)$$

when:

- $\text{patents}_{\text{lab}}(t)$ – issued mechanical patents per 1 researcher;
- $(\text{equip}_{\text{lab}}(t))$ – cost of machinery and equipment used for research and development per 1 researcher, at the time t ;
- $\cos ts_{\text{lab}}(t)$ – internal expenses for research and development per 1 researcher, at the time t ;
- θ – set of parameters to be evaluated.

At the second stage, the indicator of the issued mechanical patents per researcher was evaluated with the following ratio:

$$\text{patents}(t) = \text{patents}_{\text{lab}}(t) \times \text{labor}(t)$$

when:

- $\text{patents}(t)$ – issued mechanical patents;
- $\text{patents}_{\text{lab}}(t)$ – issued mechanical patents per 1 researcher, at the time t ;
- $\text{labor}(t)$ – personnel engaged in research and development, at the time t .

For evaluation of the type of function $F(\text{equip}_{\text{lab}}(t), \cos ts_{\text{lab}}(t), \theta)$ and the set of parameters θ , the statistical data for a certain period of retrospection for both the whole country and for individual regions were used. Methods of regression analysis were applied to these data.

The best approximation of the number $\text{patents}_{\text{lab}}(t)$ was achieved using the multiplicative function:

$$F(\text{equip}_{\text{lab}}(t), \cos t_{S_{\text{lab}}}(t), A, \alpha, \beta) = A \times (\text{equip}_{\text{lab}}(t))^\alpha (\cos t_{S_{\text{lab}}}(t))^\beta$$

when:

A, α, β – set of parameters to be evaluated.

Evaluation of the set of parameters A, α, β was achieved using the method of least squares applied to the function F in Napierian logarithms:

$$\ln F = \ln A + \alpha \times \ln(\text{equip}_{\text{lab}}(t)) + \beta \times \ln(\cos t_{S_{\text{lab}}}(t))$$

Values of the main quality characteristics of the constructed regressions indicated their importance.

The indicator of advanced manufacturing technologies was chosen as a key indicator for characterization of the functional dependence of conversion of new knowledge into new technologies and innovation, the evaluation of this indicator was implemented with the following ratio:

$$\text{tech}_{\text{new}}(t) = G(\text{patents}(t), \theta)$$

when:

$\text{tech}_{\text{new}}(t)$ – number of advanced manufacturing technologies at the time t ;

$\text{patents}(t)$ – number of issued mechanical patents, at the time t ;

θ – set of parameters to be evaluated.

For evaluation of the type of function $G(\text{patents}(t), \theta)$ and the set of parameters θ as in the previous case, the statistical data for a certain time period were used. Methods of regression analysis were applied to these data.

The best approximation of the number $\text{tech}_{\text{new}}(t)$ was achieved using the additive function:

$$G(\text{patents}(t), \theta) = a^G + b^G \times \text{patents}(t)$$

when:

$a^G + b^G$ – set of parameters to be evaluated.

Evaluation of the set of parameters $a^G + b^G$ was achieved by the least squares method.

Values of the main quality characteristics of the constructed regressions indicated their importance.

For evaluation of the functional dependence of introduction of new knowledge and technology in the real sector of economy, the application of advanced

manufacturing technologies was chosen as a key indicator and was evaluated with the following ratio:

$$\text{tech} (t + 1) - \text{tech} (t) = H (\text{tech}_{\text{new}} (t), \text{tech}_{\text{imp}} (t), \theta)$$

when:

$\text{tech} (t)$ – number of the applied advanced manufacturing technologies at the time t ;

$\text{tech}_{\text{new}} (t)$ – number of the invented advanced manufacturing technologies at the time t ;

$\text{tech}_{\text{imp}} (t)$ – number of the imported advanced manufacturing technologies at the time t ;

θ – set of parameters to be evaluated.

The best approximation of the number (t) was achieved using the additive function:

$$H(\text{tech}_{\text{new}}^{\text{3n}} (t), \text{tech}_{\text{imp}} (t), \theta) = \alpha^H \times (\text{tech}_{\text{new}} (\text{tech}_{\text{new}} (t) + \text{tech}_{\text{imp}} (t)))$$

when:

α^H – parameter to be evaluated.

Evaluation of the parameter α^H was achieved by the method of least squares. Values of the main quality characteristics of the constructed regressions indicated their importance.

Evaluation of the volume indicator for innovative goods, works and services was implemented with the following ratio:

$$\text{innov} (t) = I (\text{tech} (t), \theta)$$

when:

$\text{innov} (t)$ – volume of innovative goods, works and services at the time t ;

$\text{tech} (t)$ – number of the applied advanced manufacturing technologies at the time t ;

θ – set of parameters to be evaluated.

The best approximation of the number (t) was achieved using the additive function:

$$I (\text{tech} (t), \theta) = a^I + b^I \times \text{tech} (t)$$

when:

$a^I + b^I$ – set of parameters to be evaluated.

Evaluation of the set of parameters $a^I + b^I$ was achieved by the method of least squares.

Values of the main quality characteristics of the constructed regressions indicated their importance.

The number of indicators characterizing the scientific activity was also taken into account for the model.

Characteristics of the number of personnel engaged in research and development was implemented with the following ratio:

$$\text{labor } (t + 1) = \text{labor } (t) + \overrightarrow{\text{labor } (t)} - \overleftarrow{\text{labor } (t)}$$

when:

$\overrightarrow{\text{labor } (t)}$ – personnel engaged in research and development at the time t ;

$\overleftarrow{\text{labor } (t)}$ – hired scientific personnel for the period t ;

$\overleftarrow{\text{labor } (t)}$ – dismissed scientific personnel for the period t .

Formation of the value of machinery and equipment for research and development was implemented as follows:

$$\text{equip } (t + 1) = \text{equip } (t) - \text{equip } (t) \times \mu + \overrightarrow{\text{equip } (t)}$$

when:

$\text{equip } (t)$ – value of machinery and equipment for research and development at the time t ;

$\overrightarrow{\text{equip } (t)}$ – increase in value of machinery and equipment for research and development, for the period t .

μ – rate of depreciation of machinery and equipment for research and development.

Thus, the mathematical model reflecting the relationship of the key factors influencing the development of the research and innovation activity, can be given as the following system of equations:

$$\text{patents}_{\text{lab}} (t) = A (\text{equip}_{\text{lab}} (t))^\alpha (\cos ts_{\text{lab}} (t))^\beta, t \in \{1, \dots, nt\};$$

$$\text{patwnts } (t) = \text{patents}_{\text{lab}} (t) \times \text{labor } (t), t \in \{1, \dots, nt\};$$

$$\text{labor } (t) = \text{labor } (t - 1) + \overrightarrow{\text{labor } (t - 1)} - \overleftarrow{\text{labor } (t - 1)}, t \in \{1, \dots, nt\};$$

$$\text{equip } (t) = \text{equip } (t - 1) \times (1 - \mu) + \overrightarrow{\text{equip } (t - 1)}, t \in \{1, \dots, nt\};$$

$$\text{equip}_{\text{lab}}(t) = \frac{\text{equip}(t)}{\text{labor}(t)}, t \in \{1, \dots, nt\};$$

$$\text{cos } ts_{\text{lab}}(t) = \frac{\text{cos } ts(t)}{\text{labor}(t)}, t \in \{1, \dots, nt\};$$

$$\text{tech}_{\text{new}}(t) = a^G + b^G \times \text{patents}(t), t \in \{1, \dots, nt\};$$

$$\text{tech}(t) - \text{tech}(t-1) = a^H \times (\text{tech}_{\text{new}}(t-1) + \text{tech}_{\text{imp}}(t-1)), t \in \{1, \dots, nt\};$$

$$\text{innov}(t) = a^I + b^I \times \text{tech}(t), t \in \{1, \dots, nt\};$$

Using this mathematical model, the forecast for changes in the values of the key result indicator was prepared: the number of advanced manufacturing technologies invented in the country, with different variations of values of other indicators and, respectively, with different scenarios.

The results of approbation of this model by the example of the Russian Federation indicate that the model can be useful in the study of the scientific and innovation potential both, at the national level and at the level of individual regions.

Approbation

The following stages are suggested as the main ones for the algorithm of designing of scientific and research activity development program at the regional level:

- determination of tasks and objectives of the program;
- identifying peculiarities of development of scientific activity in the region based on opinions of academic, high-school, sectorial scientific, business community, representatives of state authorities, experts, including international ones, the public, and other interested persons;
- formulation of strategic priority lines of scientific and research activity development in the region taking into account finding out of the main sectors of regional economy in which application of the new technologies may bring significant economic effect;
- forming and implementation of the program measures (considering financial, staff-related, methodological, informational and other resources provision), purposed for achievement of the main objective of implementation of the program and the respective tasks.

In the framework of this stage, it is necessary to determine for each region the priority measures, including stock-taking and optimisation of the functioning of the scientific organizations located within the region and the creation of necessary organizational, legal and other infrastructure, etc. Special attention should be paid to the development and testing of stimulation mechanism for

off-budget financing of scientific research work, as well as to forming a system of monitoring and forecasting of needs of economic entities of the region for scientific and engineering projects. Arrangement of efficient management of the program and control of the progress of implementation will be the expected results.

Implementation of the suggested algorithm creates favourable economic, organizational, legal and other conditions for improvement of the efficiency of scientific and research activity, processes of scientific support of sectors and development of innovative activity at the regional level.

Conclusion

The main goal of optimal control of Russian science in modern conditions are as follows: efficient use of available resources and the results of research activities, with its growth corresponding to the future social and economic needs of society.

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