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FORESIGHT FOR STRATEGIC FORECASTING AND PLANNING OF INNOVATION AND SCIENCE AND TECHNOLOGY DEVELOPMENT AT NATIONAL, SECTORAL AND CORPORATE LEVELS

Dissertation Summary

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1. INTRODUCTION

Research gaps, scientific problems and motivation. Investigation and administration of innovative and scientific and technological development are one of the key research objects, starting with the works of J. Schumpeter[2], who, among others, expressed the hypothesis of a positive relationship between innovation and the size of an organization, and ending with the studies of the 2018 Nobel laureate P. Romer[3] on the impact of the technological factor on economic growth.

For almost a hundred years, the academic discourse of research in this area has evolved around several scientific schools and concepts, among the most significant of which are the concept of national innovation systems, the concept of ecosystems, the theory of triple and quadruple spirals, the concept of global value chains, macroeconomic growth theories, neo-institutional economics (Table 1).

The objects of these works, first of all, were countries, regions, sectors of the economy, organizations, including science, business, universities, and society. Research questions and scientific hypotheses focused on the study of various effects from innovation and scientific and technological development, incentives and barriers to investment in innovation and R&D, the search for optimal institutional design to protect the rights to their results, ensure information, labor and financial flows between stakeholders and the development of measures to support their efforts in these areas.

Numerous empirical studies in these areas over more than half a century of their history allow us to talk about a large-scale practice-oriented base of work, demonstrating, as a rule, positive relationships between investment in innovation, science and technology with competitiveness,

[1] The wording is given in accordance with the conclusion of the Federal State Autonomous Educational Institution of Higher Education "National Research University" Higher School of Economics "dated 11.08.2022.
[2] Schumpeter J. A. 1934. *The Theory of Economic Development.* Harvard University Press: Cambridge.
[3] Romer, P. M. 1990. Endogenous technological change. *Journal of political Economy*, *98* (5, Part 2), S71-S102.

sustainable long-term growth, welfare at the national, sectoral and corporate levels (Table 1). At the same time, scientists recognize the presence of a large number of indirect and indirect effects, as well as a vast landscape of various strategies for the behavior of stakeholders in this area. Despite the relatively high level of knowledge of the area under consideration, the vast majority of studies remain an outside observer, studying stakeholders, but not trying to transform them, to influence their incentives for innovative and scientific and technological development, while recognizing the importance and necessity for these actions.

The response to the increased need for a combination of research and management approaches to the development of science, technology and innovation was the emergence of the theory of foresight as a public administration platform that unites various scientific schools (Table 2). For more than 70 years, foresight has transformed from traditional scientific and technological forecasts to a full-fledged scientific discipline which methodology combines the tools of public administration instruments, economic analysis and management, mathematical and econometric modeling, sociology and marketing[4,5,6] with their own research methods, such as the Delphi survey[7] or the development of technology roadmaps[8].

This is largely related to the difference between traditional forecasting and foresight, the task of which is not only to describe and predict the future, but also to shape it, involving stakeholders in this process, including the state, science, companies, and society. Modern foresight is based on a scientifically based basis, considers global trends and challenges that affect the shape of the future and the incentives for stakeholders to achieve their preferred position within the expected shape.

A distinctive feature of foresight is the focus on involving all key stakeholders (the so-called principle of participation) and integration into the decision-making system, first of all, research customers. To date, there are more than 3,000 projects in the world implemented using the foresight methodology, which together use over 80 different research tools[9].

[4] Miles, I. (2002). Appraisal of alternative methods and procedures for producing regional Foresight. Report prepared by CRIC for the European Commission's DG Research funded DTRATA-ETAN Expert Group Action. Manchester, UK: CRIC.
[5] Georghiou L., Cassingena H. J., Keenan M., Miles I., Popper R. (eds). 2008. *The Handbook of Technology Foresight: Concepts and Practice*. Edward Elgar: Cheltenham.
[6] Miles I., Meissner D., Vonortas N. S., Carayannis E. 2017. Technology Foresight in Transition. *Technological Forecasting & Social Change* 119: 211–218.
[7] Sokolov A. V. 2009. Results of the Delphi study. Foresight 3(11): 40–58. [In Russian].
[8] Phaal R., Farrukh C., Probert D. 2013. Technology management and roadmapping at the firm level. In: M. Moehrle, R. Isenmann, R. Phaal (eds). *Technology Roadmapping for Strategy and Innovation*. Springer.
[9] Chulok A. A. (2021). Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management, 19(2), 151–176. [In Russian].

Among the key areas of application of foresight are: *identification and verbalization of global trends and weak signals*[10,11]; *increase in innovative activity*[12,13,14]; *value creation*[15,16] *and communications within the company*[17]; *entering foreign markets*[18] and *optimizing interaction with the external environment*[19,20], *including counterparties*[21]; *competitive intelligence*[22,23]; *creation of an effective strategy*[24,25] and *integration into a decision-making system based on technology roadmaps*[26,27,28].

The complication of the requirements that foresight customers impose on it has been happening since the end of the last century - this is recorded in his works[29] by the authoritative scientist M. Keenan, noting that "the purpose of a technological forecast was to predict the future. Foresight does not predict the future, but helps to build it[30]. Along with the expansion of the range of tasks and areas of use, the definition of foresight has also been transformed: the approach of Professor

[10] Gomes L., Salerno M. S., Phaal R., Probert D. 2017. How entrepreneurs manage collective uncertainties in innovation ecosystems. *Technological Forecasting and Social Change* 128 (C): 164–185.
[11] Kaivo-oja J. R. L., Lauraeus I. T. 2018. The VUCA approach as a solution concept to corporate foresight challenges and global technological disruption. *Foresight* 20 (1): 27–49.
[12] De Moor K., Saritas O., Schuurman D., Claeys L., De Marez, L. 2014. Towards innovation foresight: two empirical case studies on future TV experiences for/by users. *Futures* 59: 39–49.
[13] Adegbile A., Sarpong D., Meissner D. 2017. Strategic foresight for innovation management: a review and research agenda. *International Journal of Innovation and Technology Management* 14 (4): 175–219.
[14] Yoon J., Kim Y., Vonortas N. S., Han S. W. 2018. Corporate Foresight and Innovation: The Effects of Integrative Capabilities and Organisational Learning. *Technology Analysis & Strategic Management* 30 (6): 633–645.
[15] Vecchiato R. 2015. Creating value through foresight: first mover advantages and strategic agility. *Technological Forecasting and Social Change* 101: 25–36.
[16] Lockwood C. 2004. Using Technology Foresight To Create Business Value. *Research-Technology Management* 47: 51–60.
[17] Reger G. 2001. Technology Foresight in Companies: From an Indicator to a Network and Process Perspective. *Technology Analysis & Strategic Management* 13 (4): 533–553.
[18] Højland J., Rohrbeck R. 2018. The Role of Corporate Foresight in Exploring New Markets– Evidence from 3 Case Studies in the BOP Markets. *Technology Analysis & Strategic Management* 30 (6): 734–746.
[19] Vecchiato R. 2012. Environmental uncertainty, foresight and strategic decision making: An integrated study. *Technological Forecasting and Social Change* 79 (3): 436–447.
[20] Calof J., Meissner D., Razheva A. 2018. Overcoming open innovation challenges: A contribution from Foresight and Foresight networks. *Technology Analysis & Strategic Management* 30 (6): 718–733.
[21] Heger T., Boman M. 2015. Networked foresight—the case of EIT ICT labs. *Technological Forecasting and Social Change*. 101: 147–164.
[22] Calof J., Richards G., Smith J. 2015. Foresight, competitive intelligence and business analytics — tools for making industrial programmes more efficient. *Foresight-Russia* 9 (1): 68–81
[23] Calof J., Rubén A., Sewdass N. 2020. Competitive intelligence practices of European firms. In: D. Sarpong, D. Meissner (eds). *Corporate Foresight and Innovation Management*. Routledge.
[24] Ruff F. 2015. The Advanced Role of Corporate Foresight in Innovation and Strategic Management — Reflections on Practical Experiences from Automotive Industry. *Technological Forecasting & Social Change* 101 (1): 37–48.
[25] Ahlqvist T., Kohl J. 2016. Constructing and mobilising futures knowledge in an organisation: foresight as a catalyst of dynamic strategic practice. *Technology Analysis & Strategic Management* 28 (10): 1138–1151.
[26] Phaal R., Farrukh C., Probert D. 2013. Technology management and roadmapping at the firm level. In: M. Moehrle, R. Isenmann, R. Phaal (eds). *Technology Roadmapping for Strategy and Innovation*. Springer.
[27] Weber C., Sailer K., Katzy D. 2015. Real-time foresight — Preparedness for dynamic networks. *Technological Forecasting and Social Change* 101: 299–313.
[28] Vishnevskiy K., Karasev O., Meissner D. 2015. Integrated roadmaps and corporate foresight as tools of innovation management: The case of Russian companies. *Technological Forecasting and Social Change* 90 (B): 433–443.
[29] Keenan M. 2009 Technological foresight: international experience. *Foresight* 3 (3): 60-68.
[30] Keenan M. 2007. Foresight comes to Russia. *Foresight* 1 (1): 6-7.

B. Martin[31] is considered canonical, according to which "foresight is a systematic attempt to assess the long-term prospects of science, technology, economics and society in order to determine strategies research areas and new technologies that can bring the greatest socio-economic benefits" [32]. R. Popper, a well-known practitioner in the field of foresight, notes that "foresight is a systemic, participatory, forward-looking and politically oriented process that is aimed at actively involving key stakeholders in a wide range of activities to anticipate the future, prepare recommendations and implementation of transformations in the technological, economic, environmental, political, social and ethical fields" [33]. Within the framework of this study, foresight is understood as a process of systematic identification and scientifically based assessment of the prospects for the future of science, economy, society and nature, taking into account global trends, internal reserves and involving all stakeholders that shape the future.

The global trends that have begun to emerge over the past 5-7 years dictate new requirements for foresight, the methodology for its implementation, the generated results and the resulting effects. Innovative and scientific and technological development of countries, sectors of the economy, companies is entering a next phase of development, facing a number of serious challenges of a transformational nature:

speeds increase: impact of global trends, reaction, decision-making, market entry, creation and commercialization of innovations, interaction of stakeholders;

research, innovation and technology, knowledge and competencies are becoming more interdisciplinary, multicultural and intersectoral, the influence of cross-effects is increasing;

the behavior, incentives and strategies of stakeholders are becoming more and more long-term and diversified;

new groups of stakeholders are included in economic and social processes that did not previously participate in them or played a passive role;

the complexity of economic, social, scientific systems increases, their structure becomes more complicated, with a simultaneous increase in the rate of obsolescence of information and knowledge, which leads to the objective need to find adequate tools not only for analyzing and studying such systems, but also for their transformation;

so-called "black swans" or "wild cards" - events which it's hard to predict with large-scale effects, which form the demand for tools for their identification and further response;

[31] Martin B. R. 1995. Foresight in science and technology. *Technology Analysis and Strategic Management* 7 (2): 139–168.
[32] Sokolov A. V. 2007. Foresight: a look into the future. Foresight 1(1): 8–15. [In Russian].
[33] Popper R. 2012. Monitoring Futures Research. Foresight 6(2): 56-75. [In Russian].

business models are being transformed, including under the influence of new technologies, such as artificial intelligence, blockchain, additive technologies;

the demand form stakeholders for economic and social institutions is growing, adequate to the ongoing changes;

the concept of evidence-based policy and economics based on data is being developed, requiring a special theoretical approach and methodological tools.

Theoretical and practical contribution

To identify the ongoing changes and manage them, it was necessary to develop an approach based on modern concepts of strategic forecasting and planning and realizing a transformational role in innovative and scientific and technological development at different levels. This major scientific problem, which is of theoretical significance, was solved as part of the implementation of this dissertation research. The scientific results obtained by the author provided a theoretical contribution to a number of modern theories and concepts, including: the concept of national innovation systems[34] (NIS) in terms of taking into account the effect of global trends and the use of foresight tools to assess the dynamic component in the strategies of its participants and connections between them; in the concept of ecosystems at the corporate level in terms of developing the author's two-loop integral ecosystem model, taking into account the impact of global trends on internal and external stakeholders of the company; in the theory of strategic management, complexity management, the concept of complex adaptive systems in terms of expanding the tools used through foresight methods, taking into account the influence of global trends and internal incentives and stakeholder strategies for innovative and scientific and technological development and integrating the results of forecasts and foresights into the decision-making system at the national level, industry and corporate levels; in foresight in terms of developing criteria for the transition from one stage of foresight to another, analysis, classification and systematization of errors that occur during foresight.

Based on the modern foresight methodology used in the world's leading foresight studies, within the framework of this dissertation, a unique foresight methodology for Russia was developed, which showed high practical significance and served as the basis for:

formation of a cycle of national foresight studies to develop a forecast for the scientific and technological development of Russia for the long term (2012-2017);

creation of the foundations of the domestic system of scientific and technological forecasting, including a network of scientific and technological forecasting centers (2013-2016);

[34] See Tab.1 and Tab 2 for more detailed information.

development of industry forecasts of scientific and technological development (2009-2017);

foresight development in the interests of research and management of national innovation systems, strategic management of the company and its ecosystem (2021-2022).

The composition of the theoretical and practical significance of the dissertation work is described in more detail below, when describing its scientific novelty, the characteristics of the main results submitted for defense, and their approbation.

The goal of the study is to develop theoretical models and methodological approaches based on modern foresight aimed at stimulating and supporting the innovative and scientific and technological development at the national, sectoral and corporate levels in Russia.

To achieve this goal, the following **tasks** were solved:

1. Systematize and conduct a comprehensive analysis of international and Russian fore-site studies at the national, industry and corporate levels, including their goals, objectives, methods used, results, integration into the decision-making system, limitations and mistakes;
2. Develop and develop methodological approaches aimed at stimulating and supporting the innovative and scientific and technological development at the national, sectoral and corporate levels;
3. Apply the developed methodological approaches in practice to conduct foresight in Russia at the national level, industry (for a sector of the economy or region) and corporate (for a company or organization) levels;
4. Conduct a sample empirical survey of stakeholders of foresight research to study their demand for foresight results (based on technological platforms);
5. To develop a qualitative forecast of possible foresight development directions in the world and in Russia, considering the results and conclusions obtained in the study.

Thus, the purpose and objectives of the study are directly related to the subject of public administration in terms of management processes, institutions and relations that arise in the preparation, adoption and implementation of the execution of decisions in public administration, as well as methodological principles, methods and tools of public administration. management.

These tasks are solved in 21 articles and chapters of monographs, representing a dissertation. Below is a timeline of the dissertation research in the context of areas of work and relevant articles (Fig. 1).

Research was conducted at 3 levels:

1) *national level*, including the development of a series of national foresights - forecasts of scientific and technological development of the Russian Federation, a system of scientific and

technological forecasting[35,36,37], networks and centers for scientific and technological forecasting[38,39], analysis of the use of foresight to manage the national innovation system (NIS) [40], development of the foresight methodology in terms of developing tools for assessing the interaction between markets and technologies in the development of technology roadmaps[41] and development of adaptive and dynamic scenarios[42], improvement of tools and methods for identifying and analyzing global trends to develop a new national foresight cycle[43];

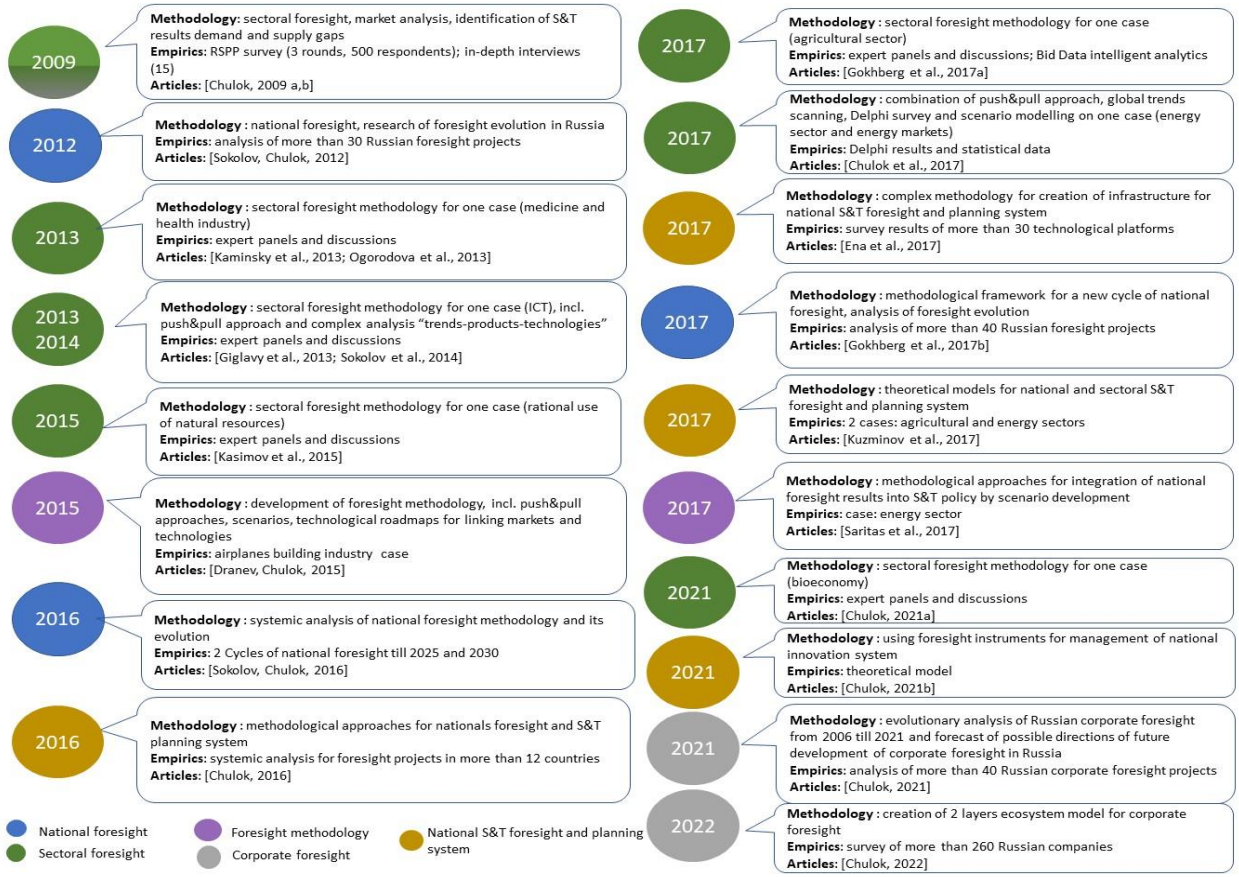

***Fig 1.* Dissertation's timeline**

Source: developed by the author.

[35] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[36] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[37] Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer.
[38] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.
[39] Kuzminov I.F., Thurner T., Chulok A. 2017. The Technology Foresight System of the Russian Federation: A Systemic View. *Foresight* 19 (3) : 291-305
[40] Chulok A. 2021 Applying blended foresight methods for revealing incentives and future strategies of key National Innovation System players. *Management of Technology and Innovation* Vol. 13. No. 4. P. 160-173
[41] Dranev Y., Chulok A. 2015. Assessing interactions of technologies and markets for technology road mapping. *Technological Forecasting & Social Change* 101 pp. 320–327
[42] Saritas O., Dranev Y., Chulok A. 2017. A dynamic and adaptive scenario approach for formulating science & technology policy. *Foresight* 19 (5) pp. 473-490
[43] Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia's agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466.

2) *sectoral level*, including the development of a forecast of scientific and technological development for certain sectors of the economy and directions[44,45], including information and communication technologies[46,47], medicine and healthcare[48,49], agricultural complex [50], bioeconomy[51], energy and energy markets[52]; rational nature management[53]. The choice of these areas and sectors of the economy is due, among other things, to their significant role in the innovative and scientific and technological development of the country, the availability of potential and opportunities for foresight and the high level of demonstration effects from the application of the methodology developed in the framework of the dissertation research, which are set out in the relevant articles of the author;

3*) corporate level*, linked with the study of incentives for Russian companies to innovate and implement the results of research and development and the creation of a two-loop integral ecosystem model for foresight at the corporate level, considering the impact of global trends on internal and external stakeholders of the company[54,55].

Information base

More than 100 foresight studies conducted in more than 10 countries (including Russia, Germany, UK, Japan, China), 400 literature sources analyzed to systematize and analyze international and Russian foresight studies at the national, industry and corporate levels;

[44] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian].
[45] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].
[46] Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian].
[47] Sokolov A., Mesropyan V., Chulok A. 2014. Supply chain cyber security: a Russian outlook. *Technovation* 34(7): 389-391
[48] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].
[49] Ogorodova L.M., Kaminsky I.P., Patrushev M.V., Chulok A.A. 2013. The role of the technology-logical platform "Medicine of the Future" in the formation of high-tech markets for products and services. ECO 9 (471): 5-14. [In Russian].
[50] Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia's agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466
[51] Chulok A. 2021. Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. In E. Koukios, A. Sacio-Szymańska (eds.), Bio#Futures, Springer.
[52] Chulok A., Slobodianik S.N., Moiseichev E. 2017. Using Foresight For Smart Policy Actions: The Case Of Russian Energy Exports. *Foresight* 19 (5) : 511-527.
[53] Kasimov N., Alekseeva N., Chulok A., Sokolov A. 2015. The Future of The Natural Resources Sector in Russia. *International Journal Of Social Ecology and Sustainable Development* 6(3) : 80-103.
[54] Chulok A. A. 2021. Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management, 19(2), 151–176. [In Russian].
[55] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

Three rounds of national foresight, 6 foresights for certain areas and sectors of the economy (information and communication technologies, medicine and healthcare, environmental management, agricultural complex, bio-economy, energy and energy markets), conducted according to the methodology developed by within the framework of this dissertation research;

Empirical surveys conducted directly according to the methodology developed by the author:

- a survey of 500 large and medium-sized companies, conducted by the dissertator jointly with the Russian Union of Industrialists and Entrepreneurs (RSPP) in 2008-2009;

- a survey of 30 technology platforms in key areas of scientific and technological development, conducted by the dissertation within the ISSEK HSE in 2016-2017;

- a survey of 260 large and medium-sized Russian companies, conducted by the dissertator together with the Association of Managers in 2021;

a survey of 33 large and medium-sized Russian companies, conducted by the dissertator together with the Association of Managers in 2022.

Brief literature review

Innovative and scientific and technological development of stakeholders is the object of research by various scientific schools. The key ones that are relevant for the goals and objectives of this study are given in Table 1.

Table 1. World research landscape of innovative and scientific and technological development

Direction	Period	Key representatives	Research object	Methods	Brief results
National innovation systems	1992 - till now	B. Lundvall, K. Freeman, R. Nelson, L. Soete, C. Adquist, B. Godin, Z. J. Acs, D.B. Audretsch, D.P. Leiden, J. Fagerberg	Interactions of stakeholders, including universities, science, companies, the state, society on issues of technology and innovation	Morphological analysis, analysis of statistical indicators, econometric models	Description of various models (from linear to complex) of interaction between actors of national innovation systems
Ecosystem conception	1993 - till now	M.G. Jacobides, D. Isenberg, E. Stam, B. Spigel, J.F. Moore	Interaction of stakeholders, including universities, science, companies, state, society within a wide class of relations, including the creation of products and services	Morphological analysis, analysis of statistical indicators, econometric models, complex adaptive models	Description of various models (from linear to complex) of the interaction of the stakeholders

Direction	Period	Key representatives	Research object	Methods	Brief results
Theory of triple and quadruple helix	2000 - till now	E.G. Carayannis E. Grigoroudis D.F. Campbell L. Leydesdorff	The role of universities Creation and dissemination of knowledge between universities, society, science, state	Theoretical modeling, analysis of statistical indicators	Description of various models of interaction of the considered stakeholders
Global value chains conception	1999 - till now	P. Gibbon, B.A. Lundvall, G. Gereffi G., R. Kaplinsky,	Accrual and distribution of cost in the process of creating a product Institutional design of chains	Econometric and statistical analysis, including according to international databases TiVA[56] and WIOD[57]	Characteristics of value chains and links, including national (sectoral) and international levels
Macroeconomic theories of growth	1956 - till now	R. Solow, G. Dosi., P. Romer, P. Aghion, D. Acemoglu, N.G. Mankiw, D. Jorgenson, K. Lee	Economic growth and its factors, S&T progress, factor productivity	Econometric models. TFP[58], KLEMS[59]	A set of economic and econometric models that demonstrate the dependence of economic growth on various factors and the relationship between them
Neoinstitutional economics	1970 - till now	O. Williamson, J. Grossman, O. Hart, J. Moore, B. Holmström, W. Nordhaus	Demand of stakeholders for R&D and innovations and incentives for their protection, including within the framework of the contract approach	Institutional analysis, econometric and mathematical models	A set of models and empirical findings that describe the demand of stakeholders for innovation and incentives to protect them

Source: developed by the author.

Based on the analysis of the studies presented above, the following gaps and gaps in existing scientific schools and concepts can be formulated:

difficulties in considering external factors (for example, global trends), interactions between them and their influence on the behavior stakeholders, leading to devaluation of the explanatory power of theories and models in a period of unstable and constantly changing external conditions;

the prevalence of the "retrospective" component over the prognostic one - as a consequence - a decrease in the value of research findings for decision-making;

the dominance of one (chosen) theoretical or empirical base, the presence of "path dependence" effects, difficulties with the rapid use of new research and analytical tools;

[56] Trade in Value-Added.
[57] World Input-Output Database.
[58] Total Factor Productivity.
[59] Capital (K), Labor (L), Energy(E), Materials (M), Services(S).

weak involvement of economic stakeholders in the formation of conclusions and the implementation of results, the view of an "outside observer from above" and, as a result, isolation from real processes and rejection (low level of perception) of conclusions by decision makers, science, companies, society, the difficulty of considering feedback from them;

low level and slow process of integrating results into the decision-making system: the path from research to action can take years;

a weak level of interaction, lack of coordination between scientific schools and concepts and, as a result, the absence of a synergistic effect, "fatigue" of the sample for empirical analysis.

Partially, these restrictions were removed within the framework of foresight studies, the world landscape of which was formed in the following scientific areas: foresight for countries, sectors of the economy, areas of science and technology; corporate foresight; theory and methodology of foresight, policy measures, evidence-based policy (Table 2).

Table 2. World research landscape of foresight studies

Direction	**Period**	**Key representatives**	**Research object**	**Methods**	**Brief results**	**Direction**
Foresight for countries, economic sectors, S&T areas and technologies	1950 – till now	I. Miles M. Keenan Kaivo-oja J. R A.V. Sokolov	Countries, regions, cities, economic sectors, areas of science and technology	Combined methods, including quantitative, qualitative and specialized (Delphi, critical technologies, Big Data analysis)	Global and national challenges, development priorities, including science, technology, innovation, recommendations for action policies	A system of documents at various levels (decrees of the president, government decrees, programs of ministries and departments)
Corporate foresight	1970 – till now	R. Rohrbeck R. Phall F. Ruff D. Meissner J. Calof	Trends, markets, products, competitors, society, technologies	Expert methods, quantitative, specialized (trend scanning, roadmaps, scenarios, audit and benchmarking, competitive intelligence)	Innovative development directions, lists of global trends and weak signals, recommendations for increasing innovative activity, value creation, business ecosystems	Methodological recommendations, guides, seminars and trainings for decision makers. Laboratories, observatories and foresight portals, networks of specialized organizations

Direction	Period	Key representatives	Research object	Methods	Brief results	Direction
Foresight theory, STI policy and instruments, evidence-based policy	1970 – till now	I. Miles L. Georghiou R. Popper O.Saritas N. Vonortas L. Gokhberg	Foresight tools, policy measures and their effectiveness	Expert methods, mathematical modeling, empirical, scenario and narrative analysis	Recommendations on optimal sets of foresight methods, policy tools and their combination ("policy mix"), development and application of the concept of evidence-based policy	Methodological recommendations, guides, seminars and trainings for decision makers. Laboratories, observatories and foresight portals, networks of specialized organizations

Source: developed by the author.

An important feature of the presented research agenda is that foresight is a broader evidence-based approach that combines both quantitative and qualitative methods. A forecast is a more traditional tool, often based on quantitative models, and subject to limitations associated with the determinism of forecasting processes, the difficulty of integrating results into management routines, and the high costs of adapting models to rapidly changing external factors. Within the framework of the works presenting this dissertation, an attempt was made to remove these limitations of traditional forecasting by supplementing quantitative methods, such as scenario modeling, statistical, bibliometric and patent analysis, with qualitative tools, including a wide range of methods of working with experts, such as surveys. , in-depth interviews, Delphi surveys, development of high-quality planning, programming and management models based on the application of foresight tools to the concept of national innovation systems and ecosystems.

At the time of publication of the articles included in this dissertation, the Russian literature did not provide a detailed description of theoretical models and methodological approaches to conducting foresight at the national and sectoral levels in relation to Russia; accordingly, in the world literature, the description of the results of Russian foresights of scientific and technological development and foresights was present in a rather truncated, overview form.

None of the scientific papers, either in Russia or in the world, by the time the dissertation author's articles were published, presented methodological approaches to the implementation of Russian foresight at the national and sectoral levels (due to the fact that the foresights themselves had not yet been developed). The articles constituting this thesis for the first time presented the periodization and systematization of Russian foresight studies, proposed methodological approaches to the development of the Russian system of scientific and technological forecasting and planning.

The world academic literature in the field of foresight research has rather superficially touched upon the possibilities of applying foresight, considering the incentives and strategies of stakeholders, not only in the theoretical aspect, but also in practice; Russian discourse lacked such studies.

However, the landscape of international foresight research over the past 5-10 years has begun to dynamically transform towards a combination of "pure" economic theories and concepts and practical foresight tools to enable the transformation of incentives for innovative and scientific -technological development, including through the information and communication functions of foresight: part of this trend in changing the agenda of academic work is this dissertation research and research carried out by the author together with colleagues.

A special part of the world research agenda in recent years is devoted to the search for adequate methods for analyzing potential strategies for the behavior of stakeholders, united in the concept of a national innovation system or ecosystems. A number of works by the author of the dissertation develop these areas through the prism of foresight, demonstrating the possibility of using a new methodological tool for this area - foresight - to analyze and potentially transform participants in the national innovation system, the company's ecosystem. There were no such works on the Russian research agenda at the time of publication of the dissertation articles.

Thus, the corpus of articles by the author of the dissertation solves a major scientific problem and fills a theoretical gap in the scientific literature devoted to Russian foresight research and a comprehensive description of the possibility of using foresight for the innovative and scientific and technological development at the national, sectoral and corporate levels.

The scientific novelty of the dissertation research includes:

creation of a set of interrelated theoretical models and methodological approaches, including the adaptation and improvement of the world's existing approaches and research practices, which made it possible to develop foresights in Russia at the national, sectoral and corporate levels, including a long-term forecast of scientific and technological development of Russia, to form the foundations of the scientific and technological forecasting systems and analyze the concept of the national innovation system from the standpoint of foresight;

removing the limitations of traditional forecasting in terms of the methods used, taking into account global trends, involving stakeholders and transforming their strategies through integration based on foresight for quantitative and qualitative methods, including scenario modeling, statistical, bibliometric and patent analysis, a wide range of methods of working with experts - surveys, in-depth interviews, Delphi surveys, qualitative models of planning, programming and management in relation to the concept of national innovation systems and ecosystems;

developing a long-term forecast of scientific and technological development of Russia for the long term by sectors of the economy, internal and individual areas and solving emerging methodological problems related to the specifics of the behavior of Russian stakeholders; external criteria for the development of foresight, classification of the stages of foresight development in modern Russia for the period from 2006 to 2021;

systematization of typical errors in foresight research and their classification into three groups: methodological errors associated with the definition of foresight goals and objectives, the combination of methods used, and their scientific validity; organizational, relating to the processes of foresight implementation and its individual procedures; communication, reflecting the quality of interaction with foresight customers and stakeholders;

conducting a sample empirical survey of foresight study stakeholders to study their demand for foresight results (based on technology platforms) in 2015-2016;

development of a qualitative forecast of possible directions of foresight development in Russia.

Main author's original scientific results include the following:

1. Methodological models and approaches have been developed that allow:

conduct selection, involvement and communication with experts in the framework of foresight research[60,61,62,63];

conduct a national foresight aimed at identifying promising areas of scientific and technological development of the country for the medium and long term[64];

conduct sectoral foresights aimed at determining the prospects for the development of a sector of the economy, a separate area[65,66,67,68,69];

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[60] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian]..

[61] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].

[62] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].

[63] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.

[64] Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456.

[65] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].

[66] Ogorodova L.M., Kaminsky I.P., Patrushev M.V., Chulok A.A. 2013. The role of the technology-logical platform "Medicine of the Future" in the formation of high-tech markets for products and services. ECO 9 (471): 5-14. [In Russian].

[67]Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian].

[68] Kasimov N., Alekseeva N., Chulok A., Sokolov A. 2015. The Future of The Natural Resources Sector in Russia. *International Journal Of Social Ecology and Sustainable Development* 6(3) : 80-103.

[69] Chulok A. 2021a. Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. In E. Koukios, A. Sacio-Szymańska (eds.), Bio#Futures, Springer.

to form an integrated system of scientific and technological forecasting in Russia[70,71];

analyze the development of the national innovation system using foresight tools[72], including the use of a scenario approach and the development of roadmaps[73]. The personal contribution of the author as part of the team of forecast developers was to create a research methodology and its direct implementation in practice, including solving emerging methodological problems related to the specifics of the behavior of Russian stakeholders, including their low readiness to be involved in collective expert events, low demand for advanced technologies, short planning and forecasting horizon. A forecast of the scientific and technological development of Russia for the period up to 2030 has been developed[74,75]. The forecast[76] was approved by the Russian Government in 2014 and performed an indicative role for stakeholders, transforming their expectations about the future and increasing incentives for cooperation. It was used to develop more than 20 national-level strategic documents, including the Strategy for Scientific and Technological Development of Russia[77], regional programs and tools, including the Moscow Innovation Cluster[78], became the basis for developing innovative development plans for companies with state participation[79]. Foresights and visions of the future of certain areas and sectors[80] of the economy have been developed, including: information and communication technologies[81,82]; medicine and

[70] Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer.
[71] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.
[72] Chulok A. 2021 Applying blended foresight methods for revealing incentives and future strategies of key National Innovation System players. Engineering Management in Production and Services Vol. 13. No. 4. P. 160-173
[73] Dranev Y., Chulok A. 2015. Assessing interactions of technologies and markets for technology road mapping. *Technological Forecasting & Social Change* 101 pp. 320–327
[74] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[75] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[76] The forecast is the largest Russian study in this area and was developed by a wide range of Russian and foreign experts. Among the key ones are the dissertation candidate and his co-authors. The role of the dissertator was, among others, in the development of the research methodology and its direct implementation in practice.
[77] Approved by Decree of the President "On the strategy of scientific and technological development of the Russian Federation" No. 642 of December 1, 2016.
[78] Created by Decree of the President of the Russian Federation No. 672 dated November 26, 2018 “On the Creation of an Innovation Cluster on the Territory of Moscow”.
[79] See, for example, the minutes of the meeting of the Interdepartmental Commission for Technological Development under the Government Commission for the Modernization of the Economy and Innovative Development of Russia dated October 25, 2019 No. 34-D01.
[80] These foresights and visions of the future are the largest Russian research in the respective fields and were developed by a wide range of Russian and foreign experts. Among the key ones are the dissertation student and his co-authors. The role of the dissertator was, among others, in the development of the research methodology and its direct implementation in practice.
[81] Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian].
[82] Sokolov A., Mesropyan V., Chulok A. 2014. Supply chain cyber security: a Russian outlook. *Technovation* 34(7): 389-391.

healthcare[83,84]; rational nature management[85]; agricultural complex[86]; bioeconomy[87]; energy and energy markets[88] for the period up to 2030 and beyond, including new knowledge about global trends, promising markets and technologies. The results obtained were used by specialized technological platforms (including TP "Medicine for the Future", TP "Biotech2030"), industry universities, companies to develop and adjust their own strategies and plans for innovative development in the medium and long term. The author's personal contribution as part of the foresight development team was to create a research methodology and its direct implementation in practice, including the solution of emerging methodological problems related to the specifics of the behavior of Russian stakeholders.

2. A two-loop integral ecosystem model of foresight at the corporate level has been developed, considering the impact of global trends on internal and external stakeholders of the company[89], including on the basis of an empirical survey conducted by the author jointly with the Association of Managers on more than 260 Russian companies in 2021 . The scientific novelty of the model is represented by several components. First, in one model, the most significant internal and external stakeholders of the company are considered. Secondly, the effect of global trends that can affect internal and external stakeholders, as well as the connections between them, is taken into account. In addition, a number of stakeholders (for example, large or transnational companies) themselves can set trends or influence already formed ones. Thirdly, in the above model, the company is considered not from the standpoint of an "outside observer", but as an active participant, for which the author formulated recommendations on the use of foresight tools in the interests of forming an internal ecosystem and interacting with an external one.

3. New qualitative results have been obtained:

[83] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].
[84] Ogorodova L.M., Kaminsky I.P., Patrushev M.V., Chulok A.A. 2013. The role of the technology-logical platform "Medicine of the Future" in the formation of high-tech markets for products and services. ECO 9 (471): 5-14. [In Russian].
[85] Kasimov N., Alekseeva N., Chulok A., Sokolov A. 2015. The Future of The Natural Resources Sector in Russia. *International Journal Of Social Ecology and Sustainable Development* 6(3) : 80-103.
[86] Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia's agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466.
[87] Chulok A. 2021a. Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. In E. Koukios, A. Sacio-Szymańska (eds.), Bio#Futures, Springer.
[88] Chulok A., Slobodianik S.N., Moiseichev E. 2017. Using Foresight For Smart Policy Actions: The Case Of Russian Energy Exports. *Foresight* 19 (5) : 511-527.
[89] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

the systematization and comprehensive analysis of the results of international and Russian foresight studies at the national, sectoral and corporate levels was carried out[90,91];

identified and systematized the key effects of foresight at the national, sectoral and corporate levels[92];

a classification of foresight development stages in Russia for the period from 2006 to 2021 has been developed[93,94] using external and internal criteria;

a systematization of typical errors in foresight studies was carried out and their classification was carried out;

external and internal factors that affect the efficiency of foresight application in Russian conditions, including those related to the willingness of stakeholders to change[95,96,97];

directions for integrating foresight results into the decision-making system at the level of the country, region, industry, and organization have been identified and systematized[98,99].

4. An empirical survey was conducted - a survey of stakeholders of foresight research to study their demand for foresight results based on 30 technology platforms[100];

5. A qualitative forecast of possible directions for the development of foresight in Russia has been developed, including possible forks and further steps to form a system of scientific and technological forecasting and planning in the country[101,102,103] in the context of a new reality and the transformation of national priorities, including in the direction of ensuring food and economic

[90] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[91] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].
[92] Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456.
[93] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[94] Chulok A. A. 2021. Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management, 19(2), 151–176. [In Russian].
[95] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian].
[96] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].
[97] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.
[98] Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer.
[99] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].
[100] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279
[101] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[102] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[103] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

security, accelerated digitalization of economic sectors, and the achievement of technological sovereignty.

Brief methodology description

The concept of methodology within the framework of this dissertation research corresponds to the tradition and definitions set within the cycle of works of Academician A.M. Novikov and co-authors[104], who note that "methodology is the doctrine of the organization of activities." The term "organization" scientists, referring to the philosophical encyclopedic dictionary[105], are considered in three sections: a) internal order, consistency in the interaction of more or less differentiated and autonomous parts of the whole, due to its structure; b) a set of processes or actions leading to the formation and improvement of relationships between parts of the whole; c) an association of people jointly implementing a program or goal and acting on the basis of certain procedures and rules. The proposed definitions can be used in the development of the foresight methodology, as they are close in their meaning to its main principles and characteristics.

Despite the fact that certain methods and tools of foresight are well studied in the world literature, there are no special "canonical" standards for conducting foresight research. Separate guides, formed as a result of major foresight initiatives of the late 20th century and early 21st century, provide only a general idea of the possible methods and combinations of various tools and describe an extensive set of national and sectoral cases[106,107].

The reasons for this lie in the specifics of the foresight itself: in contrast to the classical macroeconomic or scientific and technological forecasting, which can be “repeated in laboratory conditions”, it is focused not only and not so much on the development of the actual forecast of the future in terms of individual values of indicators, but on its formation through informing stakeholders about possible trends and development scenarios, developing a consensus, consolidated position on the desired future and integrating it into the decision-making systems.

At the same time, it is the development of a foresight research methodology that works in practice, considering country specifics, the characteristics of formal and informal institutions, incentives and restrictions of foresight stakeholders - is a major scientific problem that the world's leading researchers in the field of foresight are working to solve.

In developing the methodology of this dissertation research, the experience of leading countries in foresight research was used, including Japan, Great Britain, Canada, the USA, as well

[104] Novikov A.M., Novikov D.A. Methodology. – M.: SYNTEG. – 668 p.
[105] Philosophical Encyclopedic Dictionary. – M.: Sov. Encyclopedia, 1983.
[106] UNIDO Technology Foresight Manual Technology - Foresight in Actio, UNIDO, Vienna, 2005
[107] Georghiou L., Cassingena H. J., Keenan M., Miles I., Popper R. (eds). 2008. *The Handbook of Technology Foresight: Concepts and Practice*. Edward Elgar: Cheltenham.

as guides of international organizations, including the EU, UNIDO, UNESCO, theoretical models and methodological approaches formed by the world's leading scientific schools and researchers in the field of foresight (Table 2).

This dissertation research, including methodology, was closely related to the stages of the formation of an innovative and foresight culture in Russia, the goals and objectives facing at the national, sectoral and corporate levels, and the cycles of developing a national forecast of scientific and technological development for a long-term period.

At the initial stage, when performing the first cycle of work on the development of a long-term forecast of scientific and technological development of Russia for the period up to 2030 in 2008-2010, the key task was to restore the culture of long-term forecasting of science and technology after an almost 20-year break and stimulate transition of the country's economy to an innovative path of development.

In articles[108,109] one can find methodological approaches to the development of the so-called. "sectoral block" of the national foresight, which was initiated by order of the Russian Ministry of Education and Science in 2008-2010 as well as a comprehensive methodology for determining the future shape of the sectors of the economy, taking into account the analysis of global trends, taking into account macroeconomic scenarios, including those developed by the Ministry of Economic Development of Russia in the framework of the Concept for the long-term socio-economic development of the Russian Federation for the period up to 2020[110] and sectoral strategies.

An important element of the methodology was an empirical survey of 500 Russian companies, conducted jointly with the Russian Union of Industrialists and Entrepreneurs (RSPP), according to the methodology and questionnaire directly developed by the author of the dissertation. This kind of survey was one of the pioneers in Russia in terms of its novelty and scale, since empirical research in this area of that time mainly concentrated on the analysis of the current situation, and for the most part among one circle of stakeholders (mostly companies).

However, the key problem hindering the innovative development of Russia at that time was the gap between the demand for research and development results from companies in the real sector of the economy and the supply of science. In order to eliminate the errors of "one-sidedness" of surveys and to transfer the dialogue from the format of "mutual claims" into the mainstream of

[108] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian].
[109] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].
[110] Approved by Order of the Government of the Russian Federation of November 17, 2008 No. 1662-r

shaping the future, the study used the method of "mirror" survey using a specially designed questionnaire, which was used as part of a business survey together with RSPP, and when conducting Delphi on a sample representing the scientific field. An enlarged diagram is shown in Fig.2.

In 2022, according to an extensive questionnaire developed by the author of the dissertation research, a survey was conducted of 33 large and medium-sized companies - members of the RSPP about their demand for foresight and its results, the level of trust in various foresight tools and potential areas for using its results. The data obtained make it possible to better understand the strategies and incentives of Russian business for long-term forecasting and planning and to further "fine tune" the foresight methodology to take them into account.

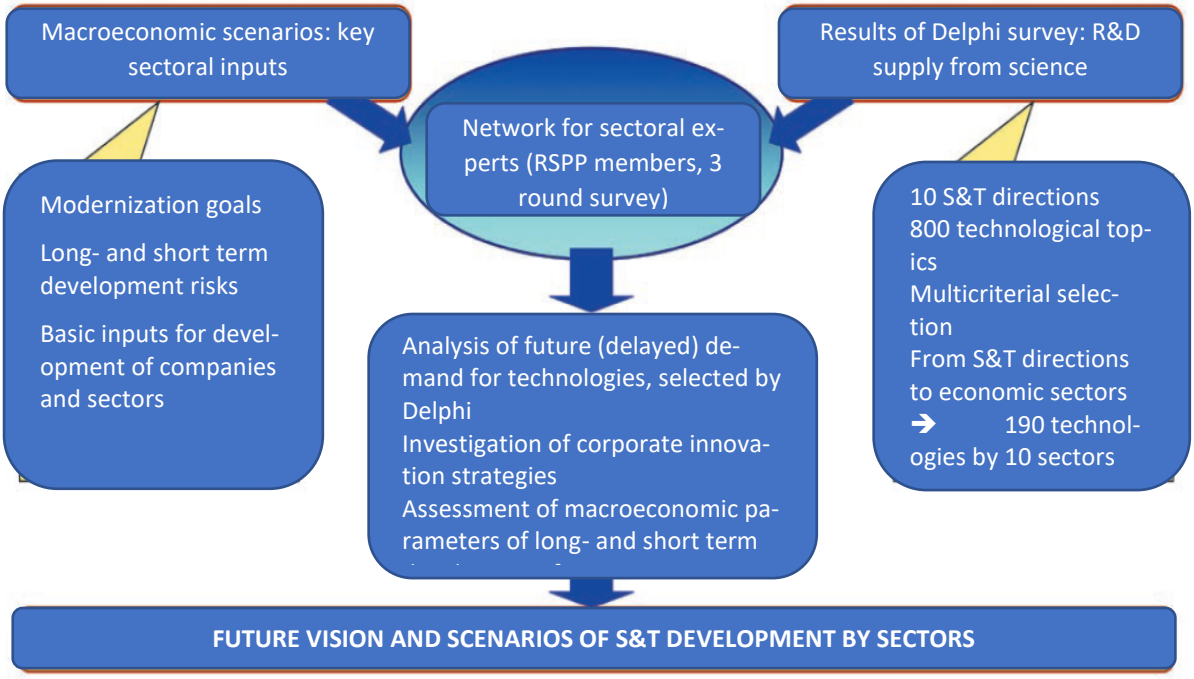

***Fig 2*. Sectoral foresight methodology within the 1st Cycle of National foresight**

Source: developed by the author.

The article[111] continues the description of the content model for conducting an sectoral foresight, demonstrating how the combination of quantitative and qualitative methods was carried out within the framework of the study, including for two areas: the aviation industry and information and communication technologies. The portfolio of methods used to conduct foresight at that time was dominated by expert-oriented ones, such as in-depth interviews, seminars, focus groups, within which the patterns of the future development of sectors were determined and a common consensus vision was formed.

[111] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].

The next stage of the dissertation research was closely connected with the development of the second and third cycles of the forecast of scientific and technological development of Russia for the period up to 2030, which took place from 2011 to 2014. The key task of that time was to determine the most promising areas for the development of science and technology for Russia for the period up to 2030, ensuring the implementation of the country's competitive advantages[112].

To implement it, the research methodology was significantly expanded by methods such as bibliometric and patent analysis, the identification of wildcards - events which it's hard to predict, but they have large-scale effects, the formation of road maps, and the development of high-quality sectoral models[113]. In addition, the research methodology has been significantly strengthened by the development of a separate methodological unit related to expertise.

The development of methodological approaches to the formation of expert pools, the verbalization of their knowledge and the formation of communication platforms for their interaction - these major scientific tasks at the national level faced the Russian research community 10 years ago. A significant contribution to their solution was made by the works of the dissertation.

An enlarged diagram is shown in Fig.3.

The scientific novelty of the presented methodology lies in the combination of studies at the global and national levels, and not in general terms, as was the case in most works of that time, but in accordance with clear logical connections: from global trends to an assessment of their effects for Russia and identifying relevant challenges and windows of opportunity; from world markets - to product groups and product groups and promising areas of demand; from the global scientific agenda to assessing the positioning of domestic research on the global scientific landscape. The implementation of these tasks required a combination of different foresight tools - such an abundance of methods used in one study was unique for the works of that time.

During the implementation of the forecast, on the basis of the sectoral centers for scientific and technical forecasting created in leading universities, an expert network was formed, covering more than 200 organizations (research centers, universities, companies in the real sector, etc.) and more than 2 thousands of experts, the selection of which was carried out on the basis of specially developed procedures and criteria (Fig.4, Fig.8). Strict qualification requirements were imposed on experts: publications with a high citation index, patents, participation in major scientific events, fame in a professional environment, etc.

[112] Forecast of scientific and technological development of the Russian Federation for the period up to 2030. 2014. M.: NRU HSE. [In Russian].
[113] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].

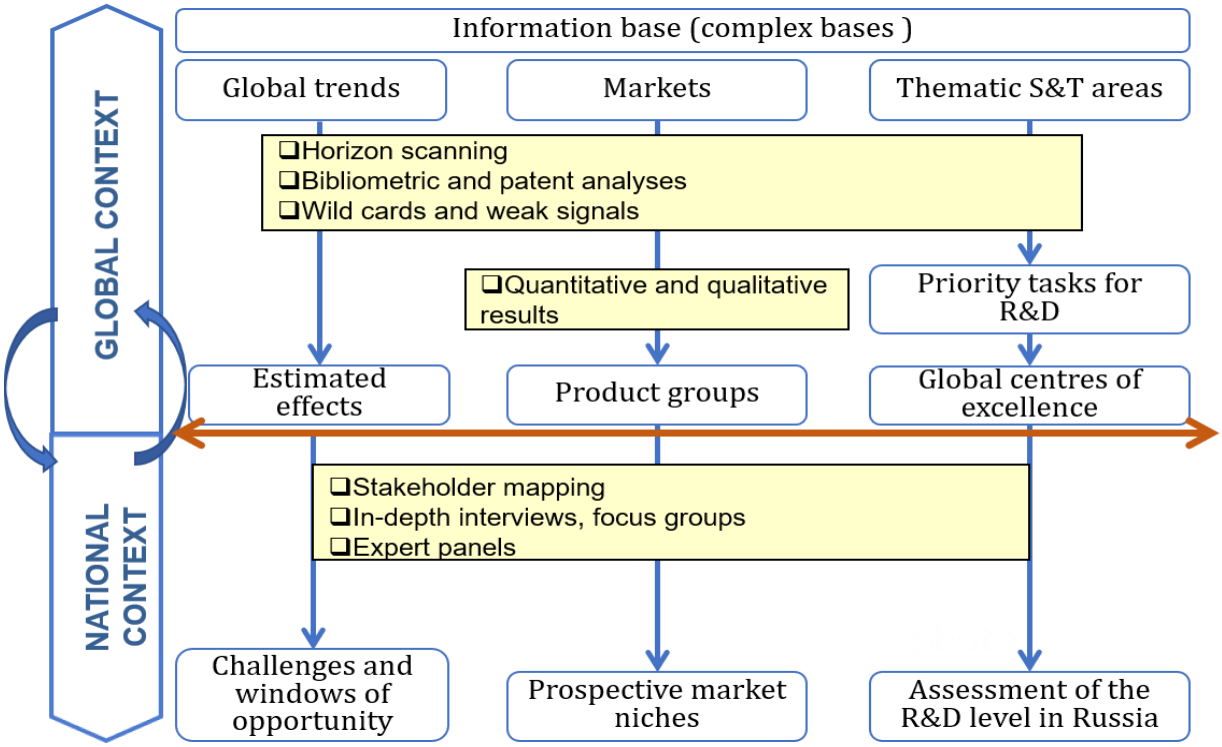

***Fig 3*. Methodology of National foresight**

Source: developed by the author.

The application of this methodology in practice made it possible to form the image of the future in key areas of scientific and technological development of Russia. The works of the dissertator and co-authors[114, 115] , , describe in detail its characteristics in terms of the following parameters: global trends, including an assessment of their positive or negative impact on the direction, innovative markets, promising products and services, including a description of consumer characteristics, which will determine their competitiveness in the future and technologies, including those for which the country has significant groundwork in comparison with the world level, "white spots" - areas where the backlog is critical. Below is an example of visualization of the results of the forecast in the direction of "products and services" (Fig. 4).

In 2021, when the first predictive five-year period passed - from 2015 to 2020, an assessment was made of the "marketability" of the results of the study[116]. According to the estimates obtained, it ranged from 85% to 90%, which seems to be a very high indicator and positively characterizes the quality of the forecast methodology and the level of its implementation.

[114] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[115] Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456.
[116] See https://trends.rbc.ru/trends/futurology/602bc7e69a7947338022ea96 [In Russian]

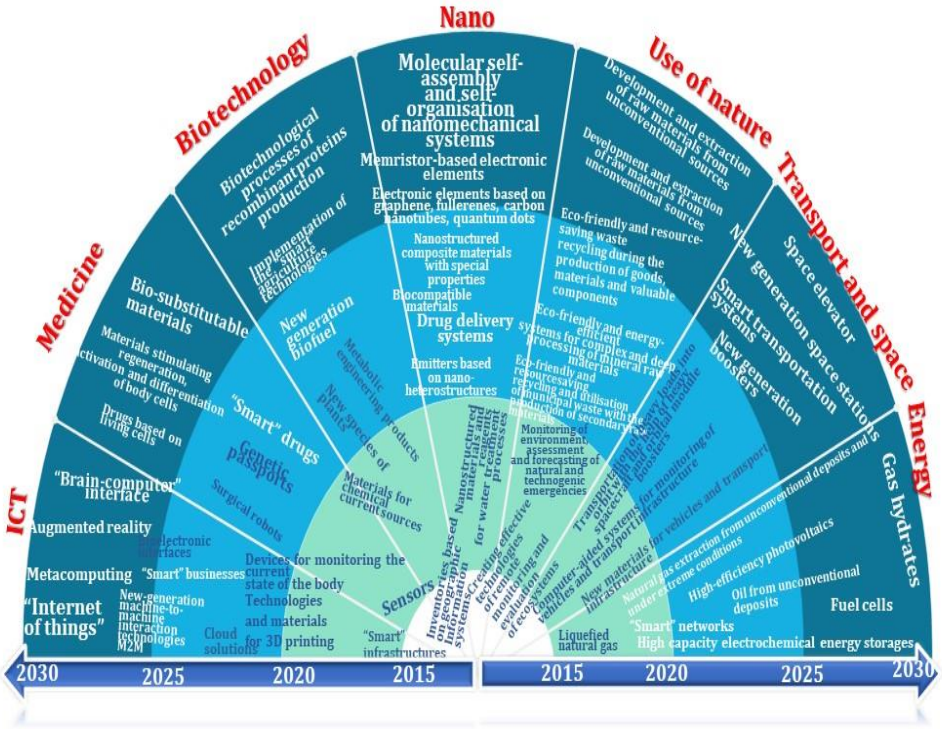

***Fig 4*. Perspective products and services: radar 2030**

Source: developed by the author.

As expert practitioners, representatives of innovative companies, engineering centers, marketing organizations, consumer and supplier (distributor) organizations of innovative products, etc. were involved in the development of the forecast. trends and assessment of their impact on Russia, the formation of lists of promising products and services, as well as areas of scientific and technological development with a "depth" of the hierarchy equal to 4: priority areas (1) - thematic areas (2) - areas of background research (3) - research and development priorities (4) [117,118]. According to the methodological recommendations developed by the dissertator and co-authors, working groups of top-level experts in the most important areas of science and technology development (more than 120 major Russian and foreign scientists) and extended working groups were formed, including representatives of science, government, business, expert community, with a total number of over 800 people. The organizational and methodological scheme of the network of sectoral centers for scientific and technological forecasting is shown in Fig. 4.

[117] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[118] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.

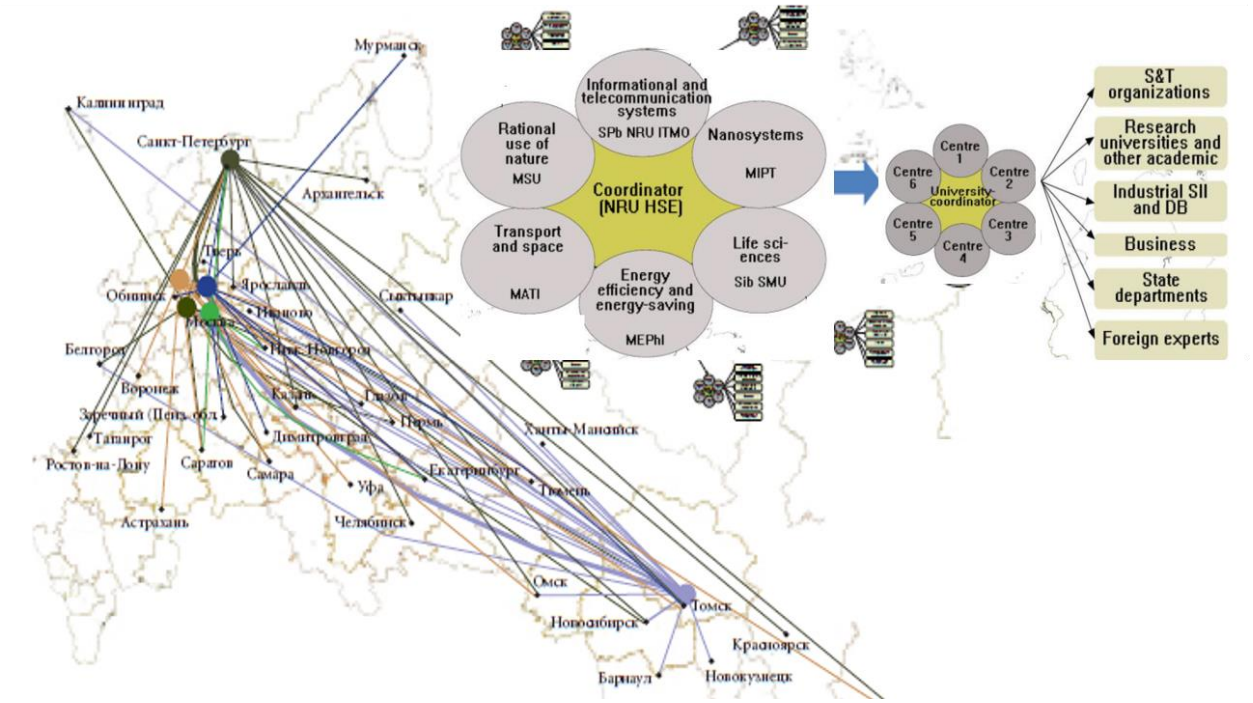

***Fig 5*. Organizational chart for network S&T Foresight centres and regional expert's distribution**

Source: developed by the author.

The article[119] provides a methodology for developing a forecast of scientific and technological development of Russia for the period up to 2030, a systematic analysis of the evolution of foresight in modern Russia at the national, sectoral, corporate and regional levels, and a methodological approach to integrating the results foresight into the decision-making system of stakeholders - NIS participants and their use in innovative and scientific and technical development.

Thus, the forecast became not only a research or final document of a strategic level[120], but also acted as a permanent research interactive iterative process that formed the basis for the development of an innovative and foresight culture in Russia on a national, sectoral and corporate levels.

The article[121] provides a critical analysis of the stages of development of the methodology for the national forecast of the scientific and technological development of Russia, their differences from each other. A systematic analysis of the forecast of scientific and technological development of Russia until 2030 is also presented according to the methodology proposed by the well-known

[119] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[120] The results of this part of the study were included in the "Forecast of scientific and technological development of Russia for the period up to 2030", approved by the Chairman of the Government of the Russian Federation on January 3, 2014 (No. DM-P8-5).
[121] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.

international researcher in the field of foresight I. Miles[122]. Following the so-called. The "foresight stages" that he proposed made it possible to consider the stages of development of Russian foresight through the prism of an international approach to foresight analysis.

On the world academic agenda, there are several approaches to the classification of foresight stages and generations, most fully described in the work of Turkish researchers from the Middle East Technical University, highlighting social and public factors, the stages of globalization in the world, chronological criteria and assessing the context - foresight activities. research. The generally accepted approach is the definition of foresight generations, based on the level of stakeholder involvement and ongoing activities, proposed by the classics of foresight research.

L. Georgiou and M. Keenan[123], J. Miles, and R Popper[124], in which they divided 5 generations of foresight. The first is related to the dominance of forecasting technologies and attempts to get the most accurate forecast possible, in order to then present it to a wide audience. The beginning of the second generation dates back to the 90s of the last century, when, in addition to the technological component, a market component appeared, designed to promote the unification of the efforts of science and business.

The third generation is associated with the addition of a social component to the foresight research agenda and the expansion of the circle of involved stakeholders. Fourth, an emphasis on consistency, including national innovation systems, and the development of corporate foresights. The fifth generation is marked by structural changes in foresight research - integration into the decision-making system and scientific, technical and innovation policy.

An important methodological feature of the considered works is the dominance of qualitative, expert and the almost complete absence of quantitative, clearly verifiable criteria for dividing the history of foresight into stages, which can largely be explained by its complex, interdisciplinary nature as a scientific discipline and the prevalence of qualitative, descriptive or informal results over calculated, quantitative. Moreover, most authors do not present a classification of the criteria themselves and do not provide a clear justification for the transition from one stage to another, acting rather in the logic of a narrative description of the foresight history.

Based on the research conducted within the framework of this dissertation, two groups of criteria were proposed (see Appendix 1), in accordance with which three stages in the development

[122] Miles, I. (2002). Appraisal of alternative methods and procedures for producing regional Foresight. Report prepared by CRIC for the European Commission's DG Research funded DTRATA-ETAN Expert Group Action. Manchester, UK: CRIC.
[123] L. Georghiou, M. Keenan. 2006. Evaluation of national foresight activities: Assessing rationale, process and impact," Technological Forecast and Social Change, vol. 73, no. 7, pp. 761–777.
[124] Popper R., Georghiou L., Miles I., Keenan M. 2010, *Evaluating Foresight: Fully-fledged evaluation of the Colombian Technology Foresight Programme*. 1 edn, University of Valle, Santiago de Cali, Colombia.

of foresight research in Russia were identified and the author's forecast of the key characteristics of the following , the fourth stage.

Internal criteria characterize the maturity, depth and scope of the foresight studies themselves. For example, at the very beginning of the formation of foresight in the 90s in perestroika Russia, the term itself was unusual for the professional community, there were practically no scientific schools conducting foresights and considering it as an object of study, the tasks solved with the help of foresight were point and rather but-force experimental.

As part of the second stage (2005-2014), a significant number of foresight studies appeared at the corporate, industry, regional and national levels, which marked the development in 2011-2013 of a pioneering for modern Russia Forecast of scientific and technological development of Russia for the period up to 2030 , which marked a new for that time paradigm of tasks to be solved within the framework of the "push & pull" concept: from global challenges to national opportunities, from markets to technologies, from scientific backlogs to the identification of "white spots".

During this period, the number of publications of Russian researchers devoted to foresight in domestic and foreign scientific journals increased significantly, reflective studies appeared, devoted to describing the results and assessing the success of domestic foresights. Foresight centers have been institutionalized in a number of leading Russian universities and are closely integrated into the global research agenda and expert networks.

The third stage (2015 - 2021) showed how the foresight research landscape can be expanded to include an interdisciplinary agenda that requires the use of combined foresight tools such as technology roadmaps, scenarios and big data analysis. The results of foresight studies themselves have become more complex and systemic, having gone from simple hierarchical lists, ratings or descriptions within the first and second stages to semantic maps, full-fledged passports-characteristics or special databases - downloads from analytical systems that analyze big data.

The number of Russian foresight studies exceeded the threshold of 100 projects[125], and among foresight customers, in addition to large companies, medium-sized ones began to appear more and more often, in addition to federal executive authorities - regional and municipal, in addition to "individual" - "collective" in the form technological platforms or associations that bring together professional market players. Foresight began to be institutionalized in economic and social processes, for example, separate foresight centers within companies, specialized foresight courses and trainings began to appear.

The fourth stage in the development of Russian foresight, which began to unfold in 2022, is most likely to be associated with the development of combined methods, in which big data

[125] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.

analysis can become a single platform for combining quantitative and qualitative tools. One of the milestone events of the fourth stage may be the consolidation of foresight scientific schools that carry out not only research, but also educational activities, including within the framework of MBA and EMBA programs.

External criteria - associated with the action of trends external to foresight, changes in strategies, incentives and demand of key stakeholders, including foresight research, characteristics of the national innovation system and institutions that affect strategic forecasting at the national, sectoral, regional and corporate levels.

Macroeconomic instability that dominated the first stage, short forecasting horizons for key stakeholders, and the general negative connotation of the term “planning” determined the position of foresight far from the mainstream in the constellation of studies of that time. Temporary stabilization of basic geopolitical, macroeconomic and sectoral parameters, the gradual development of a culture of foresight research, the consolidation of the priority of the “innovative development path” at the national level, the entry of many Russian companies into international markets and an increase in their perception of the level of competition created a favorable foundation for the emergence of various experiments with foresight stimulated the attempts of stakeholders to explore its possibilities for innovative and scientific and technological development, to assess its boundaries and prospects. The transformation of "quantity into quality" marked the third stage, which clearly demonstrated the fragility of the formed world and national value chains, the non-linearity and incomprehensibility of global trends and set a new format for demand from stakeholders at the national, industry, regional and corporate levels at such foresight opportunities as the unification and involvement of various economic agents in the process of shaping the future, relying on a combined methodology that complies with the principles of scientific validity, combining different types of results within the framework of a single concept of "trends-markets-products-technologies" and vice versa, from the possibilities of science and technology to demand from world and national markets.

The fourth stage of foresight research in Russia, most likely, will be directly related to the response to those external challenges and national tasks that have been identified in the 2022 agenda, primarily related to ensuring technological sovereignty and security in a broad context, maintaining the pace innovative development and digitalization, entering new markets and searching for promising niches.

At the same time, the methodology proposed in the framework of this dissertation research can be successfully used as a basis for taking into account the features of a new stage of fore-site research, since it meets the principles of scientific validity, adaptability and was formed taking into account numerous empirical surveys of key stakeholders , which made it possible to take into

account not only their current needs in forecasting and planning innovative and scientific and technological development, but also future, promising ones.

The article[126] continues a retrospective analysis of Russian foresight at the national level, taking into account new global trends and drivers, such as the technological revolution, the strengthening of the green agenda, the transition to energy-saving technologies and the circular economy. The article presents a critical analysis of the results of the forecast of scientific and technological development of Russia for the period up to 2030 and a methodological framework for the further formation of a new cycle of national foresight and expansion of the national system of scientific and technological forecasting and planning, including, considering the action of the adopted in 2014 Federal Law No. 172 "On Strategic Planning".

The article[127] continues this line of research in terms of developing methodological approaches for closer integration of the results of the national foresight into science and technology policy through a scenario tool developed on the principles of dynamism and adaptability. As an example, a case on the forecast of scientific and technological development of Russia for the period up to 2030 is given.

As part of the second stage of the dissertation, a block of studies related to determining the shape of the future in key areas of scientific and technological development of Russia and individual sectors of the economy was significantly strengthened, including: information and communication technologies, medicine and healthcare, environmental management, agricultural complex, bioeconomy, energy and energy markets. The article[128] presents the implementation of the combined push&pull approach, the selection of global trends based on the Delphi survey and scenario modeling on the example of a single area – energy and energy markets.

Below is a typical methodology for conducting foresight at the sectoral level for the direction of "medicine and healthcare" (Fig. 6). It is linked to the general research methodology presented in Fig. 2 and Fig. 3, and considers the specifics of the direction in terms of global trends, incentives and restrictions of key players, their strategies for innovative and scientific and technological development. The study was carried out jointly with the technology platform "Medicine of the Future", which acted as an information and communication platform.

[126] Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456.
[127] Saritas O., Dranev Y., Chulok A. 2017. A dynamic and adaptive scenario approach for formulating science & technology policy. *Foresight* 19 (5) pp. 473-490
[128] Chulok A., Slobodianik S.N., Moiseichev E. 2017. Using Foresight For Smart Policy Actions: The Case Of Russian Energy Exports. *Foresight* 19 (5) : 511-527.

As a result, more than 1,500 specialists were selected to work in this area - representatives of science, the state, universities, companies, of which about 300 are directly involved in the study[129,130].

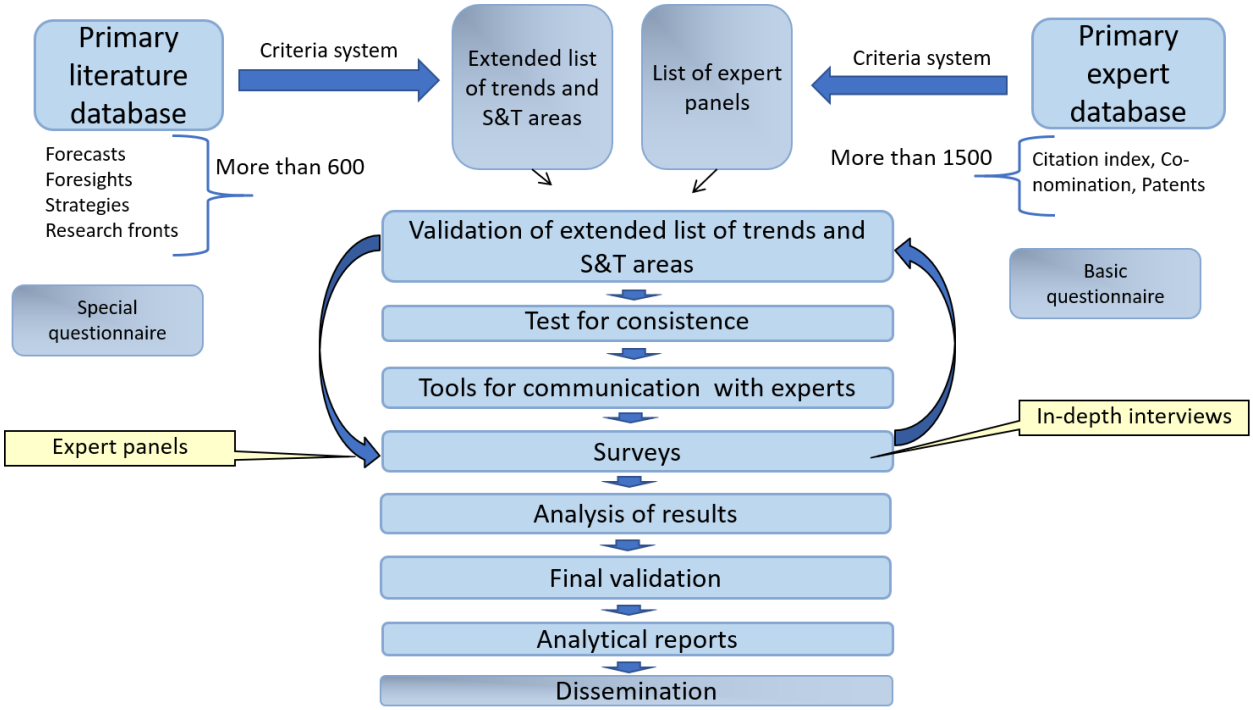

Fig 6. **Typical model for sectoral foresight within 2nd and 3rd National foresight Cycles**

Source: developed by the author.

Summarizing the methodological approaches to conducting foresight at the national, sectoral and corporate levels, developed in the framework of this dissertation research, it is possible to form the following methodology-algorithm suitable for a typical foresight research (Fig. 7).

[129] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].
[130] Ogorodova L.M., Kaminsky I.P., Patrushev M.V., Chulok A.A. 2013. The role of the technology-logical platform "Medicine of the Future" in the formation of high-tech markets for products and services. ECO 9 (471): 5-14. [In Russian].

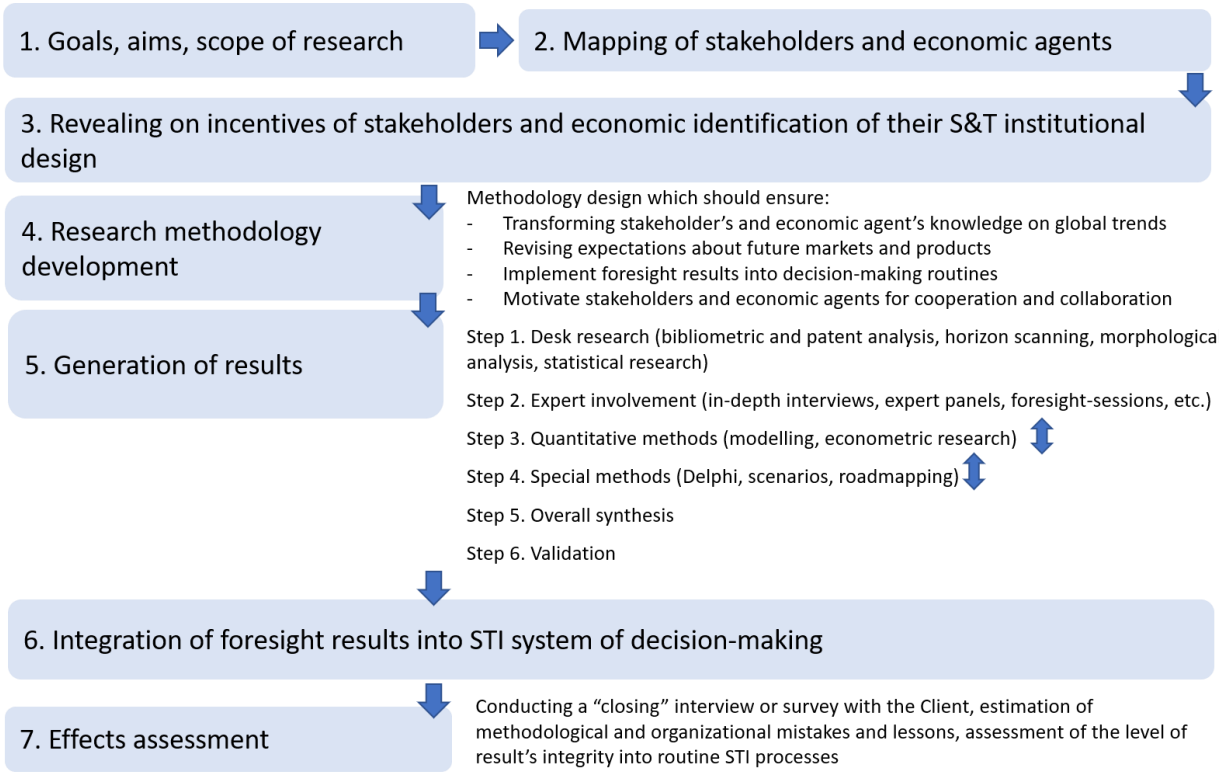

***Fig 7*. Typical methodological scheme for a foresight research**

Source: developed by the author.

The methodological results obtained as part of the dissertation research at the national and sectoral levels served as the basis for the formation of theoretical models that systematize and generalize the knowledge accumulated by the dissertation within the framework of the national system of scientific and technological forecasting and planning[131,132,133].

The chapter[134] presents methodological approaches to the formation of a national system of scientific and technological forecasting and planning, including an analysis of the factors and determinants influencing its institutional design, an analysis of the evolution of its key elements since 2006, and proposals for its in- institutional design. This direction of the dissertation research was finalized in the article[135], which presents theoretical models of the functioning of the national and sectoral systems of scientific and technological forecasting and planning, considering the con-

[131] Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer.
[132] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.
[133] Kuzminov I.F., Thurner T., Chulok A. 2017. The Technology Foresight System of the Russian Federation: A Systemic View. *Foresight* 19 (3) : 291-305.
[134] Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer.
[135] Kuzminov I.F., Thurner T., Chulok A. 2017. The Technology Foresight System of the Russian Federation: A Systemic View. *Foresight* 19 (3) : 291-305.

straints and incentives at different levels, including corporate, as well as methodological approaches for implementation on the example of the energy sector and the agricultural complex. The methodological model summarizing the above results is shown in Fig.8.

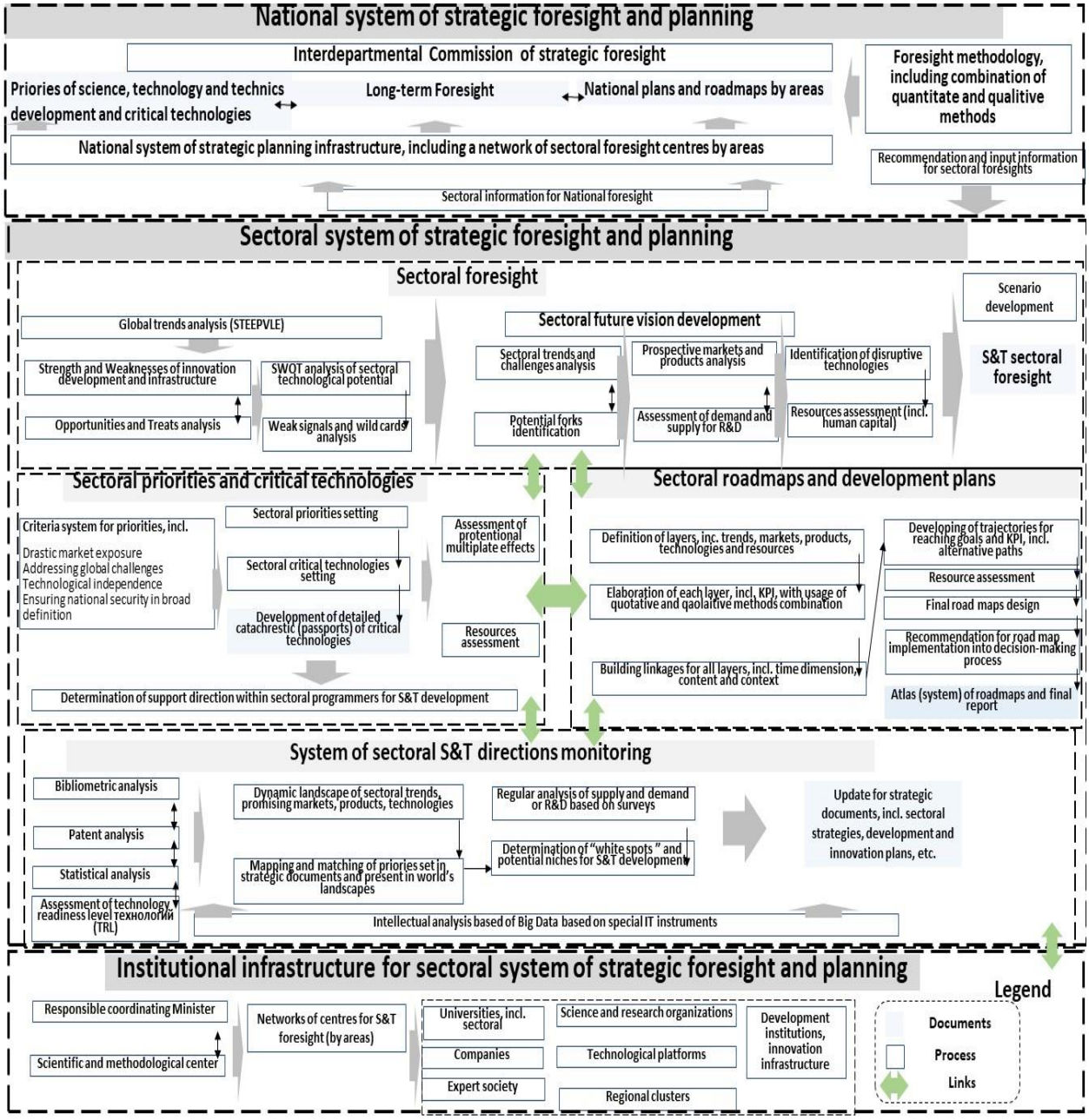

Fig 8. **National and sectoral S&T foresight and planning system model**

Source: developed by the author.

The article[136] provides a comprehensive methodology for the formation of the infrastructure component of the system of scientific and technological forecasting and planning in Russia, including on the basis of the so-called sectoral centers for scientific and technological forecasting, which were created on the initiative of the Russian Ministry of Education and Science in 2011.

[136] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.

The scientific novelty of this approach lies in the combination of the analytical component used to analyze the operation of the network (including bibliometric and cluster methods for analyzing mutual publications), and the practical orientation, expressed in the creation of a scientific and technological forecasting infrastructure in the country that has been functioning for more than 10 years (at the time of writing the dissertation summary).

A separate methodological block representing the scientific novelty of the dissertation was an empirical survey of stakeholders to study their demand for foresight results (based on technological platforms). The uniqueness of this survey consisted both in the choice of the object of the survey itself (at that time, technological platforms were active communication platforms for science, business, the expert community and

acted as good aggregators - "proxies" for assessing demand), as well as the very fact of a survey aimed at identifying potential demand for the results of research activities of a network of sectoral centers. At the time of the dissertation and co-authors of this study, there were practically no similar works in Russia.

The obtained results of this survey made it possible to identify imbalances in supply and demand for the results of research and development in the country and later served as the basis for fine-tuning the instruments of scientific, technical and innovation policy implemented in Russia.

Thus, within the framework of the second stage of the dissertation, the expansion of the research methodology took place in the following areas:

- development of methods for assessing the interaction of markets and technologies, including within the framework of the "push & pull" concept and in the development of technological roadmaps, trend analysis and scenario development;

- identification of drivers of economic and innovative development for the development of a new cycle of national foresight;

- assessment of network effects from foresight and development of approaches to the formation of a system of scientific and technological forecasting and planning;

- analysis and systematization of foresight effects at the level of economic sectors;

- development of approaches to integrating foresight results into the decision-making system of stakeholders participating in the NIS and their use in innovative and scientific and technological development.

A separate major scientific task, which was solved within the framework of this dissertation research, was the development and practical testing of a theoretical model for selection, involvement and communication with foresight research experts. The organizational and methodological scheme of work within the framework of sectoral centers for scientific and technological forecasting was presented in Fig. 5.

Below (in Fig. 9) is an enlarged architecture of the model, the description, characteristics of the elements and the evolution of the design of which were outlined in the works of the author and co-authors[137,138,139,140].

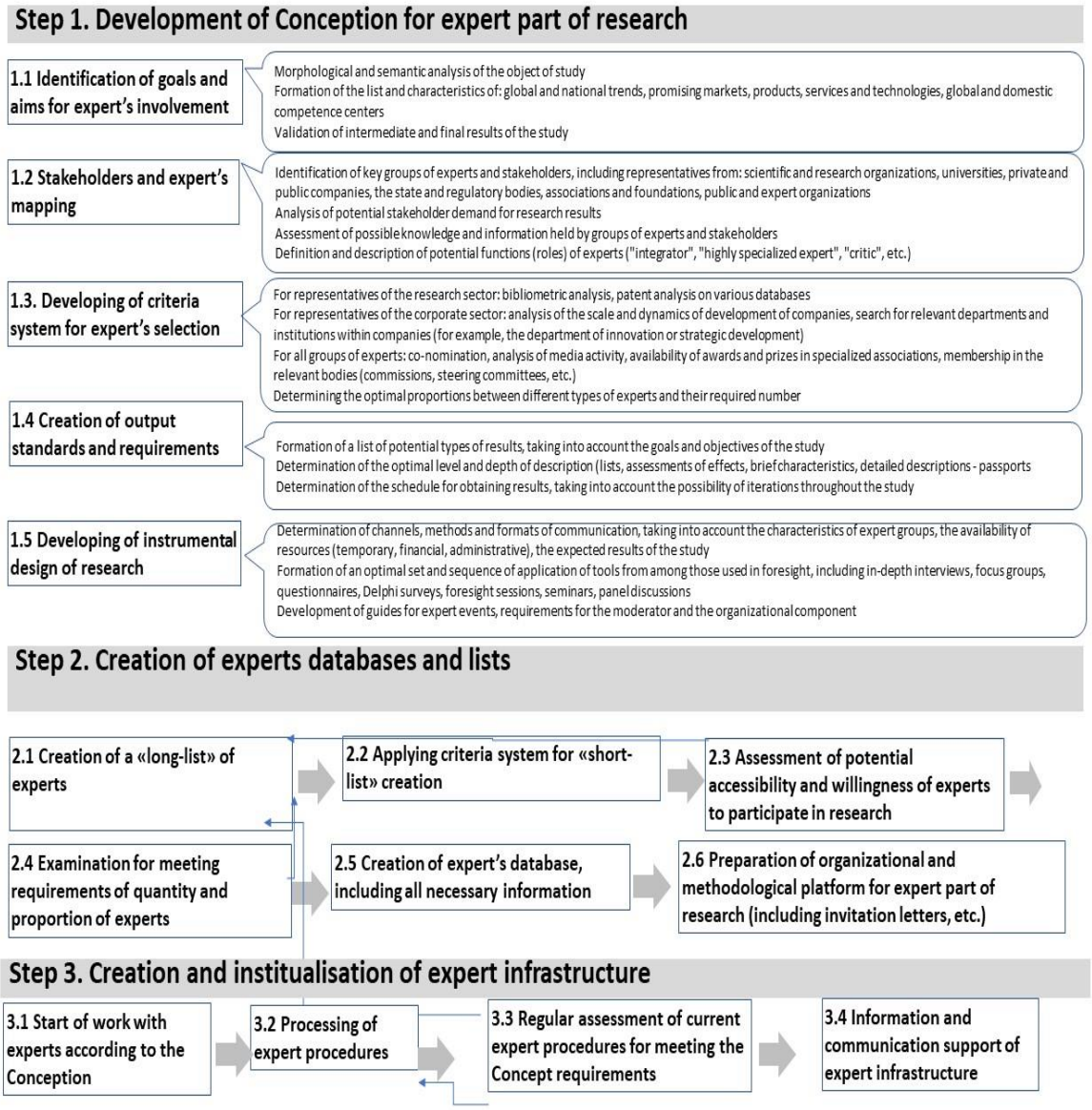

Fig 9. **Architecture of expert part of typical foresight**

Source: developed by the author.

[137] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian].
[138] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].
[139] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[140] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.

The third stage of the dissertation research is connected with the consolidation of previously developed methodological approaches and the analysis of the concept of the national innovation system to determine the optimal sets of foresight research tools, depending on its participant; development of a qualitative forecast of possible directions of foresight development in Russia and development of a two-loop integrated ecosystem model for foresight at the corporate level.

It is the company that is one of the central stakeholders of transformations. Over the past thirty years, the company and its environment have been the subject of a lively academic discussion of the major world schools discussed earlier. However, despite a significant number of theoretical and empirical publications, the research landscape is still highly fragmented and is characterized by the presence of several extensive gaps associated with an integrated approach to studying the company, considering the action of global trends, incentives and behavior patterns of its key stakeholders.

The article[141] presents the results of a study that combines various theoretical approaches on the foresight: the author's two-loop integral ecosystem model is proposed that considers the impact of global trends on the company's internal and external stakeholders, including on the basis of an empirical survey conducted by the author together with the Association of Managers on more than 260 Russian companies in 2021.

A set of practical recommendations on the use of modern foresight tools for the formation, management and transformation of the company's ecosystem is presented, an expert forecast is made of possible directions for the development of the proposed model for the next 10 years.

Below is the indicated two-loop integral ecosystem model (Fig. 10).

Model development algorithm

1. Analysis and selection of trends (global and Russian)
2. Formation of a list of participants in the internal ecosystem (based on the analysis of other models)
3. Formation of the list of participants in the external ecosystem (based on the analysis of other models)
4. Assessing the impact of trends on internal and external participants in the ecosystem
5. Assessment of foresight opportunities for the formation of an internal and interaction with an external ecosystem

[141] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

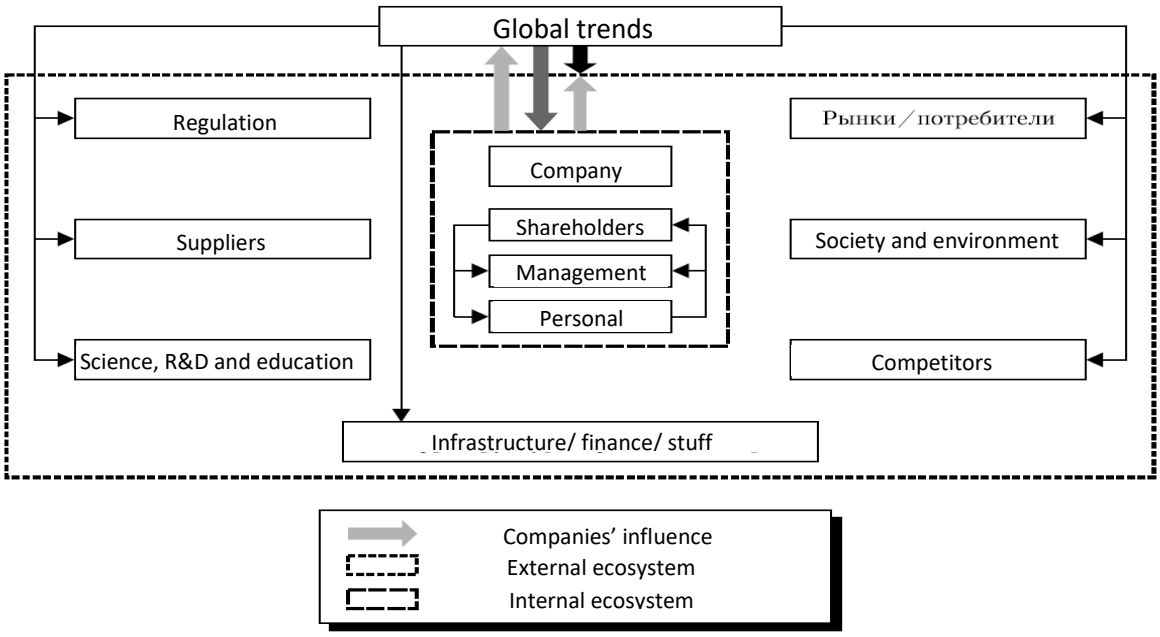

Fig 10. **Two layers ecosystem model for corporate foresight**

Source: developed by the author.

The influence of trends in this model is considered in the following areas: goals and objectives of stakeholders, their incentives, institutional design, demand for foresight methods. To assess the impact of global trends, as a "starting point", materials from a number of key works were analyzed that describe the results of systematic, comprehensive national forecasts and foresights, including those with Russian specifics. Then, with the direct participation of the dissertation student in developing the methodology, including the questionnaire, in June-August 2021, a survey was conducted of 260 managers of Russian large and medium-sized companies in conjunction with the Association of Managers, including to assess the impact of global trends on the incentives and strategies of companies for innovative and scientific and technological development. The final list of trends included more than 20 items[142].

In order to fully take into account the peculiarities of working with each type of stakeholder in the company's ecosystem, the widest possible range of foresight methods was used as the initial toolkit, including quantitative methods, such as mathematical models or bibliometric analysis, expert, for example, foresight sessions or empirical surveys, creative, including analysis of jokers, combined - roadmaps and scenarios, etc.

In Russian and most foreign studies on ecosystems and foresight, these elements of the model are often studied separately: for example, in the framework of innovation or business systems, much attention is paid to external stakeholders, sectoral or national foresights are guided by

[142] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

lists of global trends, etc. .d. However, there are no concepts or models that carry out a full-fledged “assembly” in the totality of the above factors.

Further, the effect of global trends on the inner and outer contours of the model and the corresponding foresight opportunities are considered in sequence. Depending on the specifics of stakeholders and the impact of global trends on them, four functional foresight groups were identified: group 1 “studying the future”; group 2 "providing evidence and justification"; group 3 "communication and participation"; group 4 "integration into the decision-making system".

The article provides a brief description of the changes taking place with the stakeholder under the influence of global trends, the transformation of their institutional design and incentives for innovation; the following are foresight tools that a company can effectively use to work in the appropriate conditions.

Thus, the systemic distinctive features of the methodology of this dissertation research, which represent scientific novelty and significance, are:

considering and systematic assessment of a wide range of global trends, including social, economic, scientific and technological, political, value and environmental ones: in most Russian studies, either individual groups of the listed trends were emphasized, or their number was insignificant;

involvement of a large number of experts, representatives of science, business, the state on a systematic basis: forecasts developed according to the methodology proposed in the framework of the dissertation included a significant number of experts (from 100 to 2000) selected in accordance with a scientifically based system of criteria (including bibliometric methods); work with them was carried out using various tools - from individual (in-depth interviews and polls) to group (focus groups, seminars, expert panels, foresight sessions);

considering the incentives and restrictions of interested stakeholders for their innovative and scientific and technological development and the use of this information to optimally adjust the foresight methodology and develop further recommendations to increase the level of applied application of the results;

a combination of quantitative and qualitative methods, such as expert interviews and scenario analysis methods: Russian futures research practice tends to focus on a particular class of methods or tools;

focus on transforming the system of incentives for stakeholders through the integration of foresight results into the decision-making system, organizational routines and internal institutions of research customers: most domestic research on the future is limited only to informing foresight participants.

2. MAIN FINDINGS AND RESULTS PRESENTED FOR DEFENCE

2.1 Systematization and comprehensive analysis of international and Russian foresight studies at the national, sectoral and corporate levels was carried out

2.1.1 It is shown that foresight can act as a unifying methodology for ensuring innovative and scientific and technological development and its public administration, as it is based on advanced scientific approaches, allows flexible adaptation of tools and is aimed at informing and transforming stakeholders[143,144].

2.1.2 The key effects of the foresight at the national, sectoral and corporate levels are identified, including expanding the horizons of vision, improving the efficiency of innovation and scientific and technological activities, the formation of planning and forecasting systems and their institutionalization[145,146].

2.1.3 Taking into account the world experience in classifying foresight stages and generations, two groups of criteria were developed (internal criteria - characterize the maturity, depth and scope of foresight research inside and external criteria related to the action of trends external to foresight, changes in strategies, incentives and demand of key stakeholders), on the basis of which the classification of foresight development stages in Russia was carried out. A classification of foresight development stages in Russia has been made, it is shown that at the current stage, the key tasks are to expand and improve the scientific validity of research tools, integrate foresight into management routines, and increase stakeholder confidence in the results of forecasts and foresight studies[147].

2.1.4 Identified external and internal factors affecting the efficiency of foresight, including those related to the readiness of stakeholders to change[148]. External factors largely consist in the scale and regularity of the development and updating of forecasts and foresights, the depth of their use at the national and sectoral levels, the existence of appropriate legislative conditions and stimulating regulatory and legal acts. The key internal factors are the presence of a competent team,

[143] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian].
[144] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].
[145] Chulok A. 2021b Applying blended foresight methods for revealing incentives and future strategies of key National Innovation System players. *Engineering Management in Production and Services* Vol. 13. No. 4. P. 160-173
[146] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].
[147] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32
[148] Chulok A. A. 2021. Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management, 19(2), 151–176. [In Russian].

the scientifically sound base of the study itself, and the institutionalization of foresight into managerial routines. Knowledge about the Russian specifics in this area is summarized, related to the limited methods used, the low level of demand for innovations, and the gaps in the national innovation system that have been preserved since 90s of the last century. The motives and incentives of Russian stakeholders to participate in foresight research and readiness to transform their strategies based on their results largely depend on the level of maturity of the innovation and predictive culture at the national, regional, industry and corporate levels, the strength of competition in the main markets products and services, the presence of external incentives in the form of trends or legislative restrictions and horizons of individual strategies and plans of direct foresight customers.

2.1.5 The results of foreign foresights were systematized in such areas as global trends, promising market niches; priorities of innovative and scientific and technological development, methods used. At the time of writing the scientific articles included in this doctoral thesis, there were no such assessments in the Russian research agenda[149].

2.1.6 Directions for integrating foresight results into the decision-making system at the country, sectoral, and organization levels have been identified and systematized150.

At the national level, these are primarily long-term forecasts (including the forecast of scientific and technological and socio-economic development), the strategy of scientific and technological development, the state program of scientific and technological development. At the sectoral level - forecasts of scientific and technological development, strategies and programs for innovative and scientific and technological development of individual sectors of the economy for the long term, road maps developed by sectoral ministries and departments. At the corporate level - plans and strategies for the innovative development of companies, forecasts of promising markets, products and technologies, priority areas for innovative and scientific and technological development and road maps. It is shown that such integration should consider the incentives for innovative and scientific and technological development, their current level (status) of innovative and scientific and technological activity and strategies for its implementation, the impact and effects of global trends, such as social economic, scientific and technological, environmental, value and political.

2.1.7. Considering foresight as a technology for managing innovative and scientific and technological development at the national, industry and corporate levels, three groups of typical mistakes were identified that were made during its formation and functioning in Russia[151]: methodological errors associated with the definition the goals and objectives of the foresight, the com-

[149] Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456.
[150] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[151] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32

bination of methods used, their scientific validity; organizational, relating to the processes of foresight implementation, its separate procedures, for example, expert ones; and communication, reflecting the quality of interaction with foresight customers and stakeholders (for details, see Appendix 2). It was revealed that at the initial stages of foresight development in Russia, when many stakeholders - representatives of state-owned companies, large private enterprises, individual ministries and departments, regions, were just starting to use foresight, assess its capabilities and effects, frequent methodological errors were associated with a shift in the set of applied tools towards less resource-intensive and more "visual" ones, such as expert panels, foresight sessions, foresight marathons, etc.

In the same period, a largely one-sided idea was formed about foresight as an exclusively "expert" method based on identifying and systematizing the positions of individual specialists, who often were not even selected according to transparent and scientifically based criteria. It is shown that individual attempts to import foresight as a technology without adaptation to Russian realities – peculiarities of incentives, strategies, behavior and culture of stakeholders or "shortening the path", replacing a full-fledged foresight cycle with a "quick", truncated version, led to the devaluation of its results and the attitude of the professional community towards it.

On the other hand, communication errors in interactions with the customers themselves, experts or stakeholders represented by professional communities or the public were also characteristic of the initial stages of foresight formation in Russia. With its development, some of the errors were corrected, primarily related to the perception of foresight by customers - the lessons of past projects made it possible to clearly demonstrate that work with the future should be carried out on a systematic and regular basis, this was also facilitated by the legislative formation of the scientific and technological forecasting system within the framework of which important institutional foundations for forecasting and planning in the country were fixed, for example, in the Federal Law No. 172 "On Strategic Planning" adopted in 2014. At the same time, a significant increase in the number of foresight projects and the popularity of the term "foresight" in Russia led to the emergence of a new class of errors, manifested in the use of the term "foresight" in relation to any event related to the discussion of the future.

The development of the foresight methodology at the present stage has brought to the fore the question of the sequence and combination of various methods in the interests of ensuring their synergistic effect. A separate group of mistakes and lessons associated with the use of foresight is related to the horizons of forecasting and planning of stakeholders: starting from the basics of the formation of innovative and scientific and technological development in modern Russia, the planning horizons of companies and the state diverged greatly: Thus, according to a survey by the Russian Union of Industrialists and Entrepreneurs, the timing of plans and strategies differed at

least twice. At the same time, not taking into account the factors influencing the characteristics of the time horizons of stakeholders led to the emergence of either futurological projects that are very far removed from reality, or, conversely, purely short-term ones, without even covering the medium-term planning horizon.

2.2. Methodological approaches and theoretical model have been developed aimed at stimulating and supporting the innovative and scientific and technological development at the national, sectoral and corporate levels

2.2.1 Methodological approaches have been developed that make it possible to conduct a full-fledged national foresight focused on identifying promising areas of scientific and technological development of the country for the medium and long term[152]. It is shown[153] that a necessary condition for the effective implementation of the national foresight is the availability of a methodology that provides a combination of quantitative and qualitative methods, allowing the involvement of stakeholders at all stages of the study: from setting goals to validating the results; formation of a structured pool of experts selected according to a transparent system of criteria (including based on bibliometric analysis data) and including specialists with different functions: narrowly focused on certain thematic areas or areas, system-oriented (integration) and information and communication, providing a comprehensive discussion and discussion of foresight results.

2.2.2 Methodological approaches have been developed for the formation of an integrated system of scientific and technological forecasting in Russia[154,155]. It is shown that the system should develop along three key "layers": national, sectoral and infrastructural. Corresponding structural elements have been developed for each of the "layers", including standard methods, expected results and systems of internal and external relationships. The developed methodological models and concepts served as the basis for the formation and development in Russia of a system of sectoral centers for scientific and technological forecasting, created at the initiative of the Ministry of Education and Science of Russia, and a system of sectoral centers for scientific and technological forecasting in the agricultural complex, created at the initiative of the Ministry of Agriculture of Russia[156].

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[152] Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian].
[153] Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32.
[154] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279.
[155] Kuzminov I.F., Thurner T., Chulok A. 2017. The Technology Foresight System of the Russian Federation: A Systemic View. *Foresight* 19 (3) : 291-305.
[156] Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia's agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466.

2.2.3. Methodological approaches have been developed to analyze the development of the national innovation system through the prism of 19 global trends using more than 30 foresight tools grouped into four groups: group 1 “studying the future”; group 2 "providing evidence and validity"; group 3 "communication and participation"; group 4 “integration into the decision-making system[157]. It is shown which combinations of foresight methods are best used to work with the main participants of the NIS, including science, society, business, infrastructure and institutions, education and the state. For example, for business it is a combination of tools for identifying and analyzing global trends, statistical and econometric analysis, competitive intelligence, foresight sessions, technological and integrated roadmaps.

2.2.4 For the sectoral level, methodological approaches have been developed that allow conducting sectoral foresight, focused on determining the prospects for the development of the economy sector and individual areas: including information and communication technologies[158,159], medicine and healthcare[160], agricultural complex [161], bioeconomy[162], energy and energy markets[163]; rational nature management[164]. It is shown how information about global trends, promising markets, products, services and technologies can change the behavioral strategies of stakeholders within the studied sectors of the economy, for example, by stimulating them to revise and expand their strategic plans, including additional products in them, services and technologies, including those of an interdisciplinary nature. Methodological approaches and mechanisms for the institutionalization of foresight into the management routines of stakeholders are proposed, including on the basis of sectoral technological roadmaps.

2.2.5 For the corporate level, a two-loop integrated ecosystem model[165] has been developed that considers the impact of global trends on internal and external stakeholders of the company. Methodological approaches and mechanisms have been proposed to institutionalize foresight into

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[157] Chulok A. 2021b Applying blended foresight methods for revealing incentives and future strategies of key National Innovation System players. *Engineering Management in Production and Services* Vol. 13. No. 4. P. 160-173

[158] Sokolov A., Mesropyan V., Chulok A. 2014. Supply chain cyber security: a Russian outlook. *Technovation* 34(7): 389-391.

[159] Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian].

[160] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].

[161] Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia’s agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466.

[162] Chulok A. 2021a. Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. In E. Koukios, A. Sacio-Szymańska (eds.), Bio#Futures, Springer

[163] Chulok A., Slobodianik S.N., Moiseichev E. 2017. Using Foresight For Smart Policy Actions: The Case Of Russian Energy Exports. *Foresight* 19 (5) : 511-527.

[164] Kasimov N., Alekseeva N., Chulok A., Sokolov A. 2015. The Future of The Natural Resources Sector in Russia. *International Journal Of Social Ecology and Sustainable Development* 6(3) : 80-103.

[165] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

the management and planning routines, including on the basis of corporate technological road maps.

2.3. The developed methodological approaches are applied in practice to conduct foresight at the national, sectoral and corporate levels. The following new qualitative and quantitative results have been obtained:

2.3.1 For the national level, based on a methodology developed by the author a forecast of scientific and technological development of Russia for the period up to 2030 has been developed[166], in which more than 150 global and national trends, more than 80 promising markets, 250 product groups, more than 1000 technologies are identified in 6 areas. The forecast performed an indicative role for stakeholders, transforming their expectations regarding the future and increasing incentives for cooperation. The results obtained, communicated to stakeholders, allowed them to adjust their expectations and strategies for innovative and scientific and technological development [Sokolov, Chulok, 2012; Gokhberg et al., 2017b]. The scientific results of this dissertation research made it possible to significantly expand the horizons of the strategic vision of the relevant ministries and departments, companies with state participation. They led to a revision of their own plans and forecasts, stimulated the creation of an Interdepartmental Commission on Technological Forecasting to develop joint decisions on issues of scientific, technological and innovative development. The developed methodological approaches made it possible to start the institutionalization of prognostic activity in the country, served as the basis for creating a system of technological forecasting and planning.

2.3.2 For the sectoral level[167] based on a methodology developed by the author visions of the future of certain areas and sectors of the economy, including information and communication technologies, have been, medicine and healthcare, environmental management, agricultural complex, bioeconomy, energy and energy markets. In total, more than 60 global trends were identified in these areas, their effects were assessed in the form of a positive or negative impact on Russia, more than 50 promising products and services, more than 100 research and development priorities were identified. The results obtained were used by specialized technological platforms (including TP "Medicine of the Future", TP "Biotech2030"), sectoral universities, companies to develop and adjust their own strategies and plans for innovative development in the medium and long term. The article[168] shows the example of the information and communication technology sector to show

[166] The Forecast itself is a large-scale national study. The author of the dissertation research was one of the key developers, responsible for the development of the forecast methodology and its practical implementation.
[167] The industry foresights themselves are large-scale national studies. The author of the dissertation research was one of the key developers, responsible for the development of the methodology and its practical implementation.
[168] Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian].

the results of applying an end-to-end methodology to identify a wide range of global trends (including social, economic, scientific and technological, environmental), assess their impact on Russia, determine promising products and services, developing under the influence of these trends and priority areas of research and development. A demonstration of the interrelationships of global trains and responses to them from science and technology is also presented in the article[169], in which the results of an expert assessment of the importance of thematic areas in the field of medicine and healthcare for responding to key challenges in the period up to 2030 are presented. The scientific results of this dissertation research made it possible to consolidate disparate players, including those representing different value chains, demonstrating to them the landscapes of global trends, markets, products and technologies, and the challenges and opportunities they generate, and thereby, influencing expectations about the future and stimulating awareness and consideration by stakeholders of each other's mutual constraints, supply and demand on the results of R&D, technology, and innovation.

2.3.3. For the corporate level, separate elements of foresight were applied, aimed primarily at scanning global trends and promising markets, developing a system of measures to integrate results into strategies and development roadmaps. For a number of universities, proposals were developed on the research agenda, which formed the basis for the creation of interdisciplinary scientific platforms, research centers, the functioning of international laboratories, areas and centers of international cooperation, the development of new educational programs and courses in the areas identified as part of the foresight research. A comparative analysis of the planning horizons laid down in the basic Russian strategic documents and the responses of survey 500 RSPP respondents was carried out: strategic development plans of 70% of the largest companies surveyed do not exceed 7 years, and only every eighth company plans with a horizon of 12-15 years[170], presents the results of an empirical survey of science and business using a “mirror questionnaire” in order to identify gaps in potential supply and demand for research and development results in such areas as energy and information and communication technologies. As a result of the study, three groups of technological areas were identified[171]: a) those for which there is a current business demand, but science is ready to offer them with a time lag (depending on the direction - from 20-30% of the entire sample); b) technologies that scientists are ready to offer companies, but there is

[169] Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian].
[170] Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian]
[171] Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian].

no demand for them yet (10-15%); c) areas of "coincidence" of interests of science and business (20-30%).

In addition, the study made it possible to identify directions for the implementation of these technologies: through their purchase on the open market, public-private partnerships or independent development. The scientific results obtained were pioneering for their time in Russia and became part of the foundation for the development of evidence-based research to analyze the strategies of innovative development of companies and the features of the proposals from scientific organizations.

The scientific results of the dissertation research in this area have led to positive effects: expanding the horizons of vision of internal stakeholders and external shareholders of companies, developing and revising development strategies, clarifying business and risk models, consolidating stakeholders within companies around achieving the future, creating separate departments, research departments that carry out foresight or based on its results, the formation of an external ecosystem of the organization.

2.3.4. The developed foresights contributed to positive changes in economic development, acceleration of innovation and scientific and technological development. The developed methodological approaches, which, among other things, involve immersing the key stakeholders of the study in its results, have made it possible to increase the level of self-enforcement of stakeholders, to stimulate their independent actions in planning and forecasting the inclusion of results in their business models.

2.4. An empirical survey of stakeholders of foresight research was carried out to assess their demand for foresight results (based on technological platforms). Its uniqueness and scientific novelty lie in the very sample of organizations covering the key sectors of the Russian economy, the composition and structure of the questionnaire, and the results obtained, which are pioneering in the landscape of empirical surveys of that time. The article[172] provides data from a survey of technology platforms on their demand for potential results of work on the part of sectoral forecasting centers, which made it possible to further adjust the work of the centers themselves and the network as an institutional platform. It is shown that 5 groups were identified among the most requested results: a) global trends and drivers; b) promising markets; c) promising products and services; d) technologies and areas of technology leadership; e) global and national centers of excellence. These results made it possible to further refine the design and format of foresight studies conducted by sectoral centers for scientific and technological forecasting and served as the

[172] Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279

basis for transforming the strategies for innovative and scientific and technological development at the sectoral and corporate levels.

2.5. A qualitative forecast of possible directions of foresight development has been developed, considering the results and conclusions obtained in the dissertation research.

2.5.1 It is shown that further development of foresight research will be carried out in the following areas[173,174]:

immersion and integration - further transformation of foresight into an institutional routine, a tool for the formation and management of ecosystems;

scientific validity - development of tools, combination of various methods, including big data analysis;

integration of different levels of foresight - national, sectoral, corporate and regional, interconnection with systems of strategic forecasting and planning;

elongation of horizons associated with the action of external factors (trends) and changes in the expectations of stakeholders.

2.5.2. Possible foresight development paths are identified, including: maintaining the dominance of scientific and technological topics or focusing on social, ethical and environmental priorities; "soft" institutionalization through informal institutions and practices or centralized (state) management through relevant laws and regulations; reliance on expert knowledge and stakeholder opinions or mathematical analysis tools based on artificial intelligence technologies.

2.5.3. The following steps are proposed for the development of foresight in Russia: raising the level of innovation and foresight culture, developing tools both in terms of individual methods and searching for their optimal combinations, stimulating foresight research practices and sharing results, including standards for the quality of foresight, creating a network of sectoral foresight centers and a scientific and methodological center (observatory) for foresight research.

The presented results in different areas of this dissertation research give a comprehensive picture of the formation and functioning of the system of scientific and technological forecasting in Russia at the national, sectoral and corporate levels.

3. APPROBATION AND PRACTICAL TESTING

Practical testing of the research results was carried out in the period from 2009 to 2022 as part of the formation in Russia of a system of scientific and technological forecasting and planning at the national, sectoral and corporate levels, in the formation of author's lecture courses at leading

[173] Chulok A. A. 2021. Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management, 19(2), 151–176. [In Russian].
[174] Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian].

Russian universities and discussion of preliminary and final results at key international and Russian conferences and other academic events.

3.1 The results of the study were used:

at the national level (by the Government of Russia, the Ministry of Education and Science of Russia, the Ministry of Economic Development of Russia) to form the Russian system of technological forecasting and planning, universities (including MISIS, Tyumen State University, National Research University Higher School of Economics) to determine the strategic agenda and development strategies, specialized industry associations, including RSPP and the Association of Managers to inform participants about global global trends and scientific frontiers;

at the sectoral level (by sectoral ministries and departments, including the Ministry of Agriculture of Russia, the Ministry of Digital Development of Russia and the Ministry of Energy of Russia, specialized technology platforms, including TP "Medicine of the Future", TP "Biotech 2030") when forming sectoral policies - developing sectoral forecasts and programs scientific and technological development at the corporate level (private and public companies);

at the corporate level by Russian public and private companies from various sectors of the economy and areas (including banking, energy, agro-industrial complex, metallurgy, mechanical engineering, IT) to develop and adjust strategies and plans for innovative development for the medium and long term.

3.2 The results of the study formed the basis for the development of a series of author's lectures read, among other things, within the framework of:

master's program of ISSEK HSE "Governance in the field of science, technology and innovation";

master's program of the Faculty of World Economy and World Politics of the National Research University Higher School of Economics "Scientific and technological forecasting in the digital economy";

MGIMO master's program "World Agricultural Markets";

MBA program MGIMO "International oil and gas business"

the professional retraining program of the National Research University Higher School of Economics "Executive Master in Marketing".

3.3 The results of the study were tested in numerous scientific and scientific-practical events, including[175]:

[175] For more details see personal page: https://www.hse.ru/staff/Alexander.Chulok#__tab2. Date of access – 05.09.2022.

more than 30 international and Russian events, including those included in the top 10 most authoritative foresight topics and methods of forecasting and planning. Below are the key activities:

1. "Foresight and science, technology and innovation policy", Russia, Moscow, 2012-2020 (held annually):

1.1 October 19, 2012, report "Designing Future S&T Agenda for Russia";

1.2 October 30, 2013, report "Building a technology forecasting system in Russia";

1.3 November 6, 2014, report “Industry Foresight Research: Integration into National Science and Technology Forecasts”;

1.4 November 7, 2014, report “National Technology Forecasting System: Opportunities for Innovation Clusters”;

1.5 October 19, 2016, report "Forecast of scientific and technological development of Russia: 2030";

1.6 November 19, 2015, report "Long-term forecast of scientific and technological development of Russia until 2040: questions of methodology";

1.7 November 1, 2017, report “Global challenges of foresight research: a look through the prism of Russian experience”;

1.8 November 15, 2018, Skills and Competencies Foresight: A New Agenda in the Global Digital Age;

1.9 November 21, 2019, report “Combined foresight methods for studying the strategic development of corporations: the case of Russian companies”;

1.10 November 11, 2020, report "Bioeconomy 2.0 - a key priority for a post-COVID society";

2. “FTA conference”, Belgium, Brussels, June 5, 2018, report “Changing the role of Foresight in 21 Century: a look through the prism of Russian S&T Foresight 2030”;

3. “Foresight for Strategic Planning”, Japan, Tokyo, November 27, 2017, report “Foresight for Smart Science Technology and Innovation Policy: Insights from Russia”;

4. “4th International Seville Conference on Future-Oriented Technology Analysis (FTA)”, Seville, Spain, May 12, 2011, report “Forecasting of long-term innovation development in Russian economy sectors: main results, lessons and policy conclusions”;

5. BRICS Seminar "Systems of Innovation and Development" (Brazilia, Brazil, March 25, 2014, report "Russia S&T Foresight: methodology, results, evaluation and effects"

6. International scientific seminar "Assessing the effects of foresight studies in Russia and the European Union", Russia, Moscow, January 30, 2014, report "S&T Foresight studies in Russia: current status and future goals";

7. International seminar "The Future of Agriculture: Global Challenges and Technological Changes", Russia, Moscow, March 3, 2016, report "Scientific and technological foresight of the agro-industrial complex";

8. Moscow International Salon of Education, Russia, Moscow, April 13, 2016, report “Forecast of scientific and technological development of Russia until 2030: what actions can be taken now”;

9. "VUZPROMEXPO", Russia, Moscow:

9.1. September 29, 2014, round table “Technological forecasting system: the role of leading universities”, report “Interaction between universities and companies: problems and prospects in the context of the formation of a national technology forecasting system”;

9.2 December 14, 2016, report “Forecast of scientific and technological development of the Russian Federation for the period up to 2030: opportunities for the accelerated development of the national economy”;

10. Methodological seminar HSE Laboratory of Economic and Sociological Research, Moscow, Russia, February 8, 2022, report "Modern foresight tools in the study of innovative and scientific and technological development of economic agents at the national, sectoral and corporate levels";

11. V Russian Forum of Small and Medium Enterprises within the framework of the St. Petersburg International Economic Forum, Russia, St. Petersburg, June 5, 2019, report "Global Trends in Small Business 2036"

12. Meeting of the Presidium and Board of the Scientific and Technical Council of the Ministry of Agriculture of the Russian Federation, Russia, Moscow, March 30, 2016, report "On the main provisions of the Forecast of scientific and technological development of the agro-industrial complex of the Russian Federation for the period up to 2030".

4. LIST OF PUBLICATIONS

The main results of the dissertation research are presented by the author in 19 articles and 2 chapters of monographs, representing a dissertation with a total volume of 28.9 p.p. (17.1 pp - contribution of the author).

4.1 Articles published in peer-reviewed journals indexed in the international scientific citation databases Scopus and Web of Science (WoS):

1. Chulok A. 2021 Applying blended foresight methods for revealing incentives and future strategies of key National Innovation System players. *Engineering Management in Production and Services* Vol. 13. No. 4. P. 160-173. Q2[176]

[176] https://www.scimagojr.com/journalsearch.php?q=21100884987&tip=sid&clean=0. Date of access – 05.09.2022.

2. Chulok A., Slobodianik S.N., Moiseichev E. 2017. Using Foresight For Smart Policy Actions: The Case Of Russian Energy Exports. *Foresight* 19 (5) : 511-527. Q3[177]

3. Dranev Y., Chulok A. 2015. Assessing interactions of technologies and markets for technology road mapping. *Technological Forecasting & Social Change* 101 pp. 320–327 . Q1[178]

4. Ena O.V., Chulok A.A., Shashnov S.A. 2017. Networking for Sustainable Foresight: A Russian Study. *Technological Forecasting and Social Change* 119: 268-279. Q1[179]

5. Gokhberg L., Kuzminov I., Chulok A., Thurner T. 2017a. The future of Russia's agriculture and food industry between global opportunities and technological restrictions. *International Journal of Agricultural Sustainability* 15(4) : 457-466. Q2[180]

6. Gokhberg L., Sokolov A., Chulok A. 2017b. Russian S&T Foresight 2030: Identifying New Drivers of Growth. *Foresight* 19 (5): 441–456. Q3[181]

7. Kasimov N., Alekseeva N., Chulok A., Sokolov A. 2015. The Future of The Natural Resources Sector in Russia. *International Journal Of Social Ecology and Sustainable Development* 6(3) : 80-103. Q4[182]

8. Kuzminov I.F., Thurner T., Chulok A. 2017. The Technology Foresight System of the Russian Federation: A Systemic View. *Foresight* 19 (3) : 291-305. Q3[183]

9. Saritas O., Dranev Y., Chulok A. 2017. A dynamic and adaptive scenario approach for formulating science & technology policy. *Foresight* 19 (5) pp. 473-490. Q3[184]

10. Sokolov A., Chulok A. 2016. Priorities for future innovation: Russian S&T Foresight 2030. *Futures* 80: 17–32. Q1[185]

11. Sokolov A., Mesropyan V., Chulok A. 2014. Supply chain cyber security: a Russian outlook. *Technovation* 34(7): 389-391. Q1[186]

12. Giglavy A.V., Sokolov A.V., Abdrakhmanova G.I., Chulok A.A., Burov V.V. 2013. Long-term trends in the development of the information and communication technology sector. Foresight 7(3): 6-24. [In Russian] Q3[187]

[177] https://www.scimagojr.com/journalsearch.php?q=16106&tip=sid&clean=0. Date of access – 05.09.2022.
[178] https://www.scimagojr.com/journalsearch.php?q=14704&tip=sid&clean=0. Date of access – 05.09.2022.
[179] https://www.scimagojr.com/journalsearch.php?q=14704&tip=sid&clean=0. Date of access – 05.09.2022.
[180] https://www.scimagojr.com/journalsearch.php?q=11600154149&tip=sid&clean=0. Date of access – 05.09.2022.
[181] https://www.scimagojr.com/journalsearch.php?q=16106&tip=sid&clean=0. Date of access – 05.09.2022.
[182] https://www.scimagojr.com/journalsearch.php?q=21100207622&tip=sid&clean=0. Date of access – 05.09.2022.
[183] https://www.scimagojr.com/journalsearch.php?q=16106&tip=sid&clean=0. Date of access – 05.09.2022.
[184] https://www.scimagojr.com/journalsearch.php?q=16106&tip=sid&clean=0. Date of access – 05.09.2022.
[185] https://www.scimagojr.com/journalsearch.php?q=25561&tip=sid&clean=0. Date of access – 05.09.2022.
[186] https://www.scimagojr.com/journalsearch.php?q=14726&tip=sid&clean=0. Date of access – 05.09.2022.
[187] https://www.scimagojr.com/journalsearch.php?q=21100775412&tip=sid&clean=0. Date of access – 05.09.2022.

13. Kaminsky I.P., Ogorodova L.M., Patrushev M.V., Chulok A.A. 2013. Medicine of the Future: Opportunities to Break Through the Lens of Technology Prediction. Forsyth 7(1): 14-27. [In Russian]. Q3[188]

14. Sokolov A. V., Chulok A. A. 2012. Long-term forecast of scientific and technological development of Russia for the period up to 2030: key features and first results. Foresight 6(1): 12–14. [In Russian]. Q3[189]

15. Chulok A. A. 2009a. Forecast of prospects for scientific and technological development of key sectors of the Russian economy: future tasks. Foresight 3(3): 30–36. [In Russian]. Q4[190]

16. Chulok A.A. 2009b. Analysis of the prospects for technological modernization of key sectors of the Russian economy in the framework of the formation of the scientific and technological Foresight. Russian Nanotechnologies 5–6: 13–19 [In Russian]. Q4[191]

17. Chulok A. A. 2022. Foresight as a tool for the formation and management of the company's ecosystem // Voprosy Economiki. V. 3. pp. 52-76. [In Russian]. Q3[192]

4.2 List of publications in journals, included in a high-level list by NRU HSE:

1. Ogorodova L.M., Kaminsky I.P., Patrushev M.V., Chulok A.A. 2013. The role of the technology-logical platform "Medicine of the Future" in the formation of high-tech markets for products and services. ECO[193] 9 (471): 5-14. [In Russian].

2. Chulok A. A. 2021. Economic analysis of foresight as a tool for the company's strategic management: global trends and Russian experience. Russian Journal of Management[194] , 19(2), 151–176. [In Russian].

4.3 Other publications

1. Chulok A. 2016. National System of Science and Technology Foresight in Russia. In L. Gokhberg et al. (eds.) Deploying Foresight for Policy and Strategy Makers, Science, Technology and Innovation Studies, Springer[195].

2. Chulok A. 2021. Bioeconomy in the Twenty-First Century: Global Trends Analysis Perspective. In E. Koukios, A. Sacio-Szymańska (eds.), Bio#Futures, Springer[196].

[188] https://www.scimagojr.com/journalsearch.php?q=21100775412&tip=sid&clean=0. Date of access – 05.09.2022.
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Appendix 1.

Below are the criteria that distinguish the onset of a new stage of foresight.

Internal criteria

1. Number of teams and teams implementing foresight studies
2. Maturity of teams and teams carrying out foresight research
3. The number of studies and scientific papers devoted to foresight, including those aimed at systematizing experience, results and errors in the implementation of foresight ("foresight evaluation")
4. Composition and combination of foresight research methods
5. Scope and scope of tasks solved by foresight
6. Type, complexity and depth of elaboration of foresight results
7. Main customers of foresight (state or private companies)
8. Scale of foresight penetration and dissemination of its results
9. Intensity of international relations with teams and centers of competence that carry out foresight research

External criteria

1. Scale of global (external) trends affecting foresight maturity, including macroeconomic stability and GDP dynamics
2. Changing incentives and demand of key stakeholders for foresight research
3. Forecasting and planning horizons of key stakeholders
4. Availability of institutional and legal foundations for forecasting and planning
5. Availability of a critical mass of foresight studies performed at the national, sectoral, regional and corporate levels
6. Level of competition and entry of companies into new markets, including international ones
7. The level of culture of innovation, foresight, forecasting and planning and their institutionalization in the management routines of stakeholders
8. The scale of investment in long-term and strategically important projects
9. Changing the system of priorities of the state and key stakeholders

Appendix 2

Table 2.1. Typical mistakes of foresight research

Types of mistakes	Foresight stages*	Foresight levels	Occurrence	Foresight stages in Russia**
1. Methodological mistakes				
1.1 Incorrect, fuzzy selection of the object of study	1-2	National, sectoral	Periodically	1-3
1.2 The foresight time horizon does not correspond to the dynamics of the life cycle of the object of study (too short or too long)	1-2	National, sectoral	Periodically	1-2
1.3 Too general goals, greatly exceeding the complexity of the object and / or, conversely, too much attention to detail	1-2	National, sectoral, corporate	Often	1-2
1.4 The foresight methodology does not contain a combination of evidence-based methods, creative methods, methods based on the expertise of specialists and ensuring their interaction	2	National, sectoral, corporate	Often	1-2
1.5 The foresight methodology contains the necessary combination of methods, but the sequence of their application is incorrect (non-optimal)	2	National, sectoral, corporate	Seldom	3
1.6 Foresight methodology focuses on only one group of methods (for example, expert panels or mathematical modeling)	2	National, sectoral, corporate	Often	2-3
1.7 The foresight methodology does not allow taking into account interdisciplinary, intersectoral effects	2	National, sectoral, corporate	Often	2-3
1.8 The foresight methodology does not take into account the influence of global trends and wildcards	2	National, sectoral, corporate	Periodically	2-3
1.9 Foresight methodology is opaque, illogical and does not meet the requirements of scientific soundness	2	National, sectoral, corporate	Periodically	1-3
1.10 Not all foresight stakeholders were identified, the concept of a stakeholder is set too narrowly or, on the contrary, is general	2-3	National, sectoral	Periodically	2-3
1.11 The foresight methodology does not contain a system of criteria for selecting experts or it does	2	National, sectoral, corporate	Often	1-3

Types of mistakes	Foresight stages*	Foresight levels	Occurrence	Foresight stages in Russia**
not meet the criteria of scientific character				
1.12 The foresight methodology is not adequate to the set goals and objectives, does not allow obtaining the necessary results	2-3	National, sectoral, corporate	Seldom	2-3
1.13 The foresight methodology was “imported” (copied) from foreign practice without taking into account Russian specifics	2	Sectoral, corporate	Periodically	1-2
1.14 Acceptance of preliminary results as final, lack of a system for rechecking and validating results	3-4	National, sectoral	Periodically	2-3
1.15 Foresight results are not integrated into the decision-making system, foresight remains “another analytical report”	4-5	National, sectoral	Often	2-3
1.16 Low or absent "institutional memory" of foresight, when each new project starts over and does not use the achievements of the previous one	4-5	National, sectoral	Often	1-2
1.17 As a result of the completion of the foresight, a set of “closing” events was not held: the final interview with the customer, analysis of the mistakes made, etc.	5	National, sectoral	Often	1-3
1.18 Foresight is not considered as a process, but as a one-time “forecast” or “document” that does not need to be updated and updated	5	National, sectoral, corporate	Often	1-2
2. Organizational mistakes				
2.1 Not all foresight stakeholders were involved in it	2-3	National, sectoral	Often	1-3
2.2 Appointed “non-working” and “inaccessible” project managers or stakeholder representatives	2-3	National, sectoral	Periodically	2-3
2.3 When forming the expert pool and conducting expert procedures, clear, transparent and scientifically based criteria for the selection of specialists were not applied	2-3	National, sectoral, corporate	Often	2-3
2.4 During expert procedures (panels, foresight sessions), we avoided involving stakeholders and experts with opposite views and positions	3	National, sectoral, corporate	Periodically	2-3
2.5 During the expert procedures (panels, foresight sessions) there	3	National, sectoral	Periodically	2-3

Types of mistakes	Fore-sight stages*	Foresight levels	Occurrence	Foresight stages in Russia**
were attempts to “impose a position from above” or vice versa “let everything take its course”				
2.6 During expert procedures (foresight sessions, panels, etc.), the team of moderators was formed incorrectly (there were no professional moderators and/or experts recognized in the community)	3-4	National, sectoral, corporate	Periodically	2-3
2.7 To use certain foresight methods, the team was not staffed with specialists (“we did everything ourselves”)	2-3	National, sectoral, corporate	Periodically	2-3
2.8 Foresight was treated too "technically" - as another consulting project	3-4	National, sectoral, corporate	Periodically	1-3
2.9 There were no specialists with strong managerial skills in the foresight team	2-3	National, sectoral	Periodically	1-3
2.10 We did not calculate the financial resources required to conduct and complete the foresight	2-3	National, sectoral	Periodically	1-2
2.11 We did not calculate the time resources required to conduct and complete the foresight	2-3	National, sectoral, corporate	Periodically	1-3
3. Communication mistakes				
3.1 The customer and beneficiaries of the foresight were not explained the goals and objectives of the foresight, the features of the methodology, its advantages and directions for using the results	3-4	National, sectoral, corporate	Often	1-3
3.2 Have not prepared a public and expert opinion on foresight, its goals, objectives, results	3-4	National, sectoral, corporate	Often	1-3
3.3 Foresight results do not adapt to different stakeholder groups	4	National, sectoral	Periodically	1-3
3.4 Underestimation of the importance of innovation and foresight culture in the foresight customer for the effective use of its results	4	National, sectoral, corporate	Often	1-3

Source: Developed by the author.

Note. * - foresight stages are determined in accordance with the methodology proposed in the work, 1-setting tasks, development of foresight plan; 2 - formation of a team, tools, preparation for the start of the foresight; 3 - foresight; 4 - integration of results into the decision-making system; 5 - evaluation of the fore-site and updating the results.

** Stages of foresight development in Russia are given in accordance with the author's methodology , where 1 - Stage 1 "There is no need for forecasts" (1990-2005), falling on post-perestroika times, when most companies were more concerned about survival than the lack of long-term and even medium-term plans; 2 - Stage 2 "Worth a try" (2005-2014) - characterized by an exponentially increasing number of companies, both with state participation and private ones, trying foresight tools;

3 - Stage 3 "Required to be available" (2015-2021), associated with the institutionalization of strategic forecasting and planning processes and the deployment of a full-scale system of scientific and technological forecasting, including national, sectoral and regional levels.