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The Role of Research and Development in Global Technological Competition

V.N. Kiselev[a], L.M. Kupriyanova[b]
[a] INP RAS, Moscow, Russia;
[b] Financial University, Moscow, Russia

ABSTRACT

Subject. Research and development in science and technology, as well as the development of the innovation sector, are top priorities for the country's socio-economic well-being and security. **Purpose.** The competitive strategy is based on the analysis of the market for modern technologies and the identification of key areas for the development of competition. The goal is to ensure the country's future economic competitiveness and the national security of Russia and other developed countries. **Methodology.** The study of priority scientific areas within the context of national scientific and technical policies in developed countries. It also explores the key characteristics of the information technology market and the unique features of its development and operation. Furthermore, the research evaluates the financing of research and development activities. It analyzes the costs associated with these activities and their impact on economic growth. **Results.** The rationale for financing research and development in priority areas lies in the targeted strategic development of the economy. This development should be innovative, involving the creation of a high-tech complex and the effective use of the results of intellectual activity. The focus is on ensuring the security and competitiveness of the country in science, technology, and socio-economic well-being. The most important condition for the efficient use of public funds is the effective management of relevant programs and projects.

Keywords: Russia; China; EU countries; scientific policy; national priorities; digital technologies; innovations; technological sovereignty; advanced technologies; competitiveness; financing of scientific research

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INTRODUCTION

In accordance with N.D. Kondratiev's theory of cycles, the beginning of the 21st century was distinguished by the first manifestations of the sixth technological cycle, or the so-called "sixth technological cycle", which marked the start of the global transition process in the sphere of high-tech production. The new cycle is based on fundamentally new technologies, including convergent (nano-, bio-, information and cognitive), digital, managerial, production, transportation, medical innovations, etc.

The rapid technological development has spurred an impetus to emergence of new global markets of high-tech goods and services and, consequently, has intensified global competition. In particular, it is related to such areas as 6G, batteries and photovoltaics, where China has taken the top-list position in the world [1, 2].

As similar problems are detected in the economy and in the field of technological security, many experts turn to such concepts as "technological sovereignty" and "strategic autonomy", i.e. in an era of intensified global competition, the State should be able to act strategically and autonomously, including in the field of science, technology and innovation policy [3].

Thus, nowadays, due to sanctions restrictions, the need for research and development focused on the creation of breakthrough technologies is on the agenda [4].

US SCIENCE AND TECHNOLOGY POLICY

Funding for science

The report "U.S. Research and Development: Trends and International Comparisons", published under the auspices of the U.S. National Science Foundation and the U.S. National Science Board, states that the key factor for the country's success in the global economy, its ability to solve problems and seize new opportunities, is investment in research and development (R&D). The report is mainly devoted to statistical analysis of the results of research and innovation activities of American industry and universities. The table presents data on R&D funding in the United States in a few sectors:

Today, the business sector is the largest actual perpetrator and investor of R&D in the United States. In 2022, it funded 76 per cent of all U.S. R&D (69 per cent in 2000 and 61 per cent in 2010) at a cost of $ 672.9 billion.

- In 2022, the federal government funded 18 per cent of R&D at $ 159.8 billion (meanwhile subsidizing 40 per cent of basic research). The largest recipients were the higher education sector (30 per cent) and intramural federal research (29 per cent).
- As of 2019, the share of R&D spending in the U.S. exceeds 3.0 per cent of GDP. In 2022, the figure accounted for 3.4 per cent.
- In 2021, five industries accounted for 79 per cent of the $ 602.5 billion spent on R&D

Table

R&D costs in the USA in 2021–2022, USD billion

Sector / Year	2021	2022	2022 / 2021
Business	608.6	692.7	13.8%
Higher education sector	85.8	91.5	6,6%
Public sector	66.8	73.3	9.3%
Non-profit organizations	27.1	27.3	0.7%
TOTAL	789.1*	885.6*	12.2%

Source: URL: https://ncses.nsf.gov/pubs/nsb20246/

Note: * the data were subject to rounding.

which were performed by companies with 10 or more employees:

- Information and Communication Technologies (including software) — 25 per cent;
- chemicals manufacturing (including pharmaceuticals and drugs) — 18 per cent;
- manufacture of computers and electronic devices (including semiconductors) – 17 per cent;
- professional, scientific and technical services (including R&D services) — 11 per cent;
- manufacturing of transportation equipment (including automobiles and aerospace products) — 8 per cent.

- In 2021, manufacturing of semiconductors and other electronic components was one of the most science-driven industries (the ratio of R&D to the volume of sales was 20 per cent, which accounts for an increase of 9.8 per cent in current prices, and in 2020 for 22.8 per cent.
- In fiscal year 2022, the Department of Health and Human Services (HHS) and the Department of Defense allocated nearly 3/4 of the $ 196.6 billion in federal R&D obligations. At that time, 24 per cent ($ 45.4 billion) of the federal budget allocation for R&D went to fundamental scientific research, 25 per cent to applied scientific research ($ 48.4 billion), and 51 per cent to experimental development ($ 96.6 billion). Funding for life sciences was considered the highest among all knowledge areas throughout all agencies at 44 per cent ($ 41.6 billion) and was primarily granted through the Department of Health and Human Services.
- In accordance with the Semiconductor Manufacturing and Science Stimulation Law of 2022, $ 52.7 billion funding was made to rebuild the US semiconductor industry throughout the supply chain, including $ 13.7 billion for R&D, workforce development, and related programs.
- In 2021, the U.S. had the world highest domestic spending on R&D (expenses for internal research and development) accounted for $ 806.0 billion. The top five countries in this area are the US, China, Japan, Germany and South Korea accounted for 73% of global spending.

Priority areas for R&D

In August 2023, a memorandum was published in the USA regarding R&D for the fiscal year of 2025, that identified 7 priority areas that Federal Executive Bodies (FEB) funding requests must meet:

1. Developing secure and dependable drive technologies of artificial intelligence (AI) that protect the rights and safety of people.

2. Leading the way in maintaining global security and stability within the framework of enormous geopolitical change and growing risks:

- advancing critical and emerging technology areas such as microelectronics, biotechnology, quantum information science, advanced materials, high-performance computing, and nuclear energy;
- mitigating emerging and evolving national security risks, including those related to biosecurity and nuclear weapons;
- generate risk mitigation options in the field of cybersecurity risks through resilient architectures, building security into the design process, and strengthening the security and resilience of critical infrastructure;
- curbing the impact of autonomous systems and artificial intelligence on national security;
- investing in science, advanced manufacturing, digital engineering, and robotics to enhance industry capabilities aiming to accelerate the transition from demonstration to deployment;
- leveraging scientific and technical (S&T) intelligence and analytics capabilities to make assessments and define U.S. competitiveness.

3. Confronting the global climate crisis by rethinking our "relationship" with nature and maintaining environmental green-ecology justice.

4. Providing better health care services for everyone.

5. Reducing inequality, including by means of support of innovation and developing the science, technology, engineering, and medical workforce in all regions, with a special emphasis on new research institutions and historically low-income sections of communities.

Promote R&D and industrial innovation that will contribute to the country's

economic competitiveness in all spheres.

Strengthening, developing, and leveraging uniquely American research to advance the national goals:

- supporting and expanding the basic and applied research that is the hallmark of the U.S. innovation;
- helping emerging research institutions in effective competition for federal funding;
- supporting both industry and academia in identifying and addressing research safety issues;
- supporting the infrastructure and national potential capacity to provide free immediate and justifiable public access to the results of federally funded research while developing mechanisms to incentivise and encourage open, reproducible, and secure research practices that could be used by industry and innovators around the world.

Thus, a new aspect emerged in the 2025 national plans: a strong emphasis on regional and industrial innovation to ensure America competitiveness in science and technology.

It should be noted that the U.S. memorandum is issued a year and a half prior to its direct application. This period of time is necessary for the relevant committees and working groups of the U.S. Congress to coordinate detailed R&D plans throughout all federal agencies that have submitted applications for R&D funding.

SCIENCE AND TECHNOLOGY POLICY OF THE EU COUNTRIES

In the EU countries science and technology policy is waged, on the one hand, in accordance with the common European programs and, on the other hand, each EU member state determines its own priorities in the field of research and development financed from the national budget.

The common European priorities in the field of science are evidenced by the current plan Strategic Technologies for Europe Platform (STEP), focused on supporting key methodologies and strengthening European sovereignty.[1] In June 2023, the STEP budget until the year of 2027 was revised with the growth numbers in allocations aiming to create production capacity in the following areas:

- ***digital and innovative technologies*** (microelectronics, cloud computing, artificial intelligence, cybersecurity and 5G);
- ***clean and resource-efficient technologies*** (renewable energy sources, electricity and heat storage, renewable fuels of non-biological origin, sustainable alternative fuels);
- ***biotechnology*** (biomolecules, pharmaceuticals, medical technologies, etc.).

France

For a long period of time, the country has been among the leading scientific world powers. Thus, in 2017, it was in the top-list of world leaders ranked 5th in terms of investment in research and development (2.24 per cent of GDP), 10th in the total number of scientific publications and 4th in the number of patent applications (6.7% of the total worldwide) [2].

The French national science policy is formed within the framework of a centralized approach. Until 2020, budget allocations for science were made in accordance with the law on scientific research, adopted by the French National Assembly on an annual basis. The law stipulated some specific areas of research, made by the main scientific centers with the indication of the amount of funding for each of them for the

[1] URL: https://strategic-technologies.europa.eu/about _en# paragraph_207

coming year.

In 2020, members of the National Assembly began debating and elaborating the law for the ten-year period (2021–2030), which the French government presented as an opportunity for "unprecedented investment in science".[2]

The first ten-year Law No. 2020–1674 of 24.12.2020 "On Programming of Scientific Research for 2021–2030 and on various provisions in the field of scientific research and higher education" envisages additional funds from the national budget in the amount of 25 billion euros for the development of scientific research, allocated for 5 sections. The main section is "Strategic Research Directions and Budgetary Funding Programs".

It should be noted, that funding of the so-called strategic directions of science in France is structured within two budget programs: "Multidisciplinary Scientific and Technological Research" and 'Space Research'. It is determined by the French Senate on an annual basis for allocation for six state scientific and technical and four sectoral organizations.

France has 47 priority research programmes launched under the 2030 national plan to create and strengthen French leadership in scientific fields that play an important role in technological, economic, social, health or environmental transformation. The National Center for Scientific Research (CNRS) controls or takes part in most of them, along with those programmes which were impimented earlier.[3]

In France National Research Agency (ANR) maintains funding both the ongoing programs of the national acceleration strategy, with a total budget of € 2 billion for the period of 10 years, supporting scientific transformations already underway (related to 5G, cybersecurity, industrial decarbonization, quantum technologies, etc.) and priority research programs with a total budget of € 1 billion for the envisaged period of 10 years (in the field of genetics, Southwest Indian Ocean research, robotics, climate, etc.).

Germany

Since 2011, Germany has been running the Industry 4.0 program for industrial development. The essence of the program is to increase the competitiveness of the German industry by means of introduction of scientific achievements in the field of new materials and production technologies, as well as integration of digital solutions in the management of production processes, in particular, by connecting the Internet of Things to machine-tools, machines and warehouses.

It is worth noting that the Industry 4.0 program, which was designed as a targeted concept for industrial development in Germany, does not contain special priorities in the field of research and development. It predominantly finances research projects aimed at the development of production technologies, new materials, electronic services, etc. which focused on competitive product innovations.

A number of priority areas of research and development appear in the 2025 German High-Tech Strategy Plan, adopted in 2006, which is currently in its fourth phase, where research and development priorities have been given new goals within the framework of seven subject areas: health and care, sustainable development, climate protection and energy, mobility, city and countryside, security, as well as business and work.[4]

CURRENT SCIENTIFIC AND TECHNOLOGIC POLICY OF RUSSIA

Recently adopted legal acts in Russa, including The Strategy of Scientific and Technological Development of the Russian Federation approved by the Decree of the President of the

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[2] URL: https://www.legifrance.gouv.fr/loda/id/JORFTEXT000042738027

[3] URL: https://www.cnrs.fr/en/our-challenges/national-research-programmes

[4] URL: https://bmbf-prod.bmbfcluster.de/upload_filestore/pub/Research_and_innovation_that_benefit_the_people.pdf

Russian Federation No. 145 dated 28.02.2024, the Decree of the Government of the Russian Federation No. 603 dated 15.04.2023 "On approval of priority directions of projects of technological sovereignty and projects of structural adaptation of the economy of the Russian Federation...", etc., give a clear evidence that the key resource of the national economic development should be scientific research and development, first of all, aimed to compensate the challenges of the Russian economy, develop technological facilities and ensure technological sovereignty.

For the first time the priority directions of science and technology development were approved by the Governmental Commission on Science and Technology Policy in 1996. The list included eight items[5]:

- fundamental research;
- information technologies and electronics;
- manufacturing technologies;
- new materials and chemical products;
- technologies of biological and living systems;
- transportation;
- fuel and energy;
- ecology and smart use of environmental management.

Subsequently, in 2002, 2006, 2011 and 2015 similar documents were adopted with changes of composition in the list of priority directions. At the same time, as a rule, lists of critical technologies were approved.

It is worth pointing out, that all priority directions stipulated in the documents of 2015 included approximately the same list of technologies and they were of advisory, rather than of mandatory nature [5].

Since 2015, the list as such was not revised. However, the Strategy for Scientific and Technological Development of the Russian Federation, approved by the Decree of the President of Russia No. 642 dated 01.12.2016, was expanded with a section "Priorities and Prospects of Scientific and Technological Development of the Russian Federation".[6] It was also noted that the priorities developed within the Strategy for the period of the next 10–15 years are focused on ensuring the provision of technologies capable to put into effect the industrial, environmental and social development of the country:

- transition to advanced digital, artificial intelligence-driven production technologies, robotic systems, new materials and design methods;
- transition to environmentally-friendly and resource-saving energy;
- transition to personalised medicine, high-tech healthcare and health-saving technologies;
- transition to a highly productive and environmentally-friendly agro- and aquatic economy;
- countering man-caused, biogenic, sociocultural threats, terrorism and ideological extremism;
- territorial connectivity of the Russian Federation sustained by means of creation of smart-driven transportation and telecommunication systems;
- ability to respond effectively when confronting dramatic challenges imposed for the Russian society.

The Resolution of the Government of the Russian Federation No. 1325-r dated 24.06.2017 approved the activities planned for the implementation of The Strategy for Scientific and Technological Development of the Russian Federation for the period of 2017–2019 (hereinafter — the Action Plan). The Ministry of Education and Science of the Russian Federation was appointed as its coordinator and federal executive authorities, state corporations, development institutions, foundations aimed to support scientific, scientific-technical and innovation activities, the Russian Academy of

[5] URL: https://docs.cntd.ru/document/9034171

[6] URL: http://www.kremlin.ru/acts/bank/41449/

Sciences as well as executive authorities of the constituent entities of the Russian Federation were in charge of its implementation.

In accordance with the abovementioned Action Plan, the State Programme "Scientific and Technological Development of the Russian Federation"[7] was developed. The priorities of the Sate Program were determined, among other things, as the main directions of the global scientific, technological and innovation spheres and also the need to respond to major challenges associated with them.

In the late-December 2020, the Government approved the "Programme of Fundamental Scientific Research in the Russian Federation for a Long-Term Period (2021–2030)".[8] The Russian Academy of Sciences was appointed as its coordinator.

In general, it should be noted, that all the adopted programmes did not have instruments for the implementation of critical technologies.

The priorities outlined in the Decree of the President of the Russian Federation № 145 dated as of 28.02.2024 "On the Strategy of Scientific and Technological Development of the Russian Federation", fundamentally correspond to those outlined in the Strategy of 2016, however, they bear an expanded and more emphasized interpretation. However, the most important thing is that for the first time it was adopted that in practice the Government of the Russian Federation should "envisage budgetary allocations for the implementation of this Decree when drafting the federal budget for the next fiscal year and for the planned period[9]".

Assessing the abovementioned approaches towards development of priorities in the field of science, practiced by the Russian Federation and other economically developed countries, it should be noted, that they are focused to build advanced technologies in the field of health care, ecology, agriculture, material production, i.e. in general, to ensure national technological sovereignty.

COMPARISON OF SCIENTIFIC RESEARCH FUNDING

According to Statista, in 2022, global research and development spending amounted to more than $ 2.47 trillion (in purchasing power parity terms). At the same time, the growth rate of global R&D expenditures has remained positive since 1996. A slight decrease in the indicator was noted only in 2019, which occurred due to the COVID-19 pandemic. [6].

Most scientific research works indicate that R&D is an important driver of economic growth. The main argument for such a conclusion being the recognition that R&D spending has a positive impact on innovation and overall productivity [7, 8]. Whereas, the improvement of technology through innovation activities is undeniably considered to be a driving force for improving living standards in the long run. Accordingly, many scholars believe that investment in science contributes to a more efficient economy [9]. To illustrate this conclusion, here is the ranking of countries by the indicator "Domestic expenditure on research and development as a percentage of gross domestic product" (*Fig. 1*). Thus, according to the top-list results of 2022, Israel has the leading indicator of 5.56%, followed by the Republic of Korea (4.93%) and the USA (3.46%). Russia ranks 40th (0.94%).

To be fair, it should be noted that this indicator gives only a rough idea of the level of expenditures on R&D and in no way indicates the effectiveness of scientific research.

Thus, according to distinguished international online journal Scimago Journal & Country Rank, in 2022 Russia ranked 12th among the global leaders of publications in international peer-reviewed scientific journals, which indicates a fairly high level of efficiency of

[7] URL: http://static.government.ru/media/files/AAVpU 2sDAvMQkI HV20ZJZc3MDqcTxt8x.pdf

[8] URL: https://docs.cntd.ru/document/573319222

[9] URL: https://www.garant.ru/products/ipo/prime/doc/408518353/

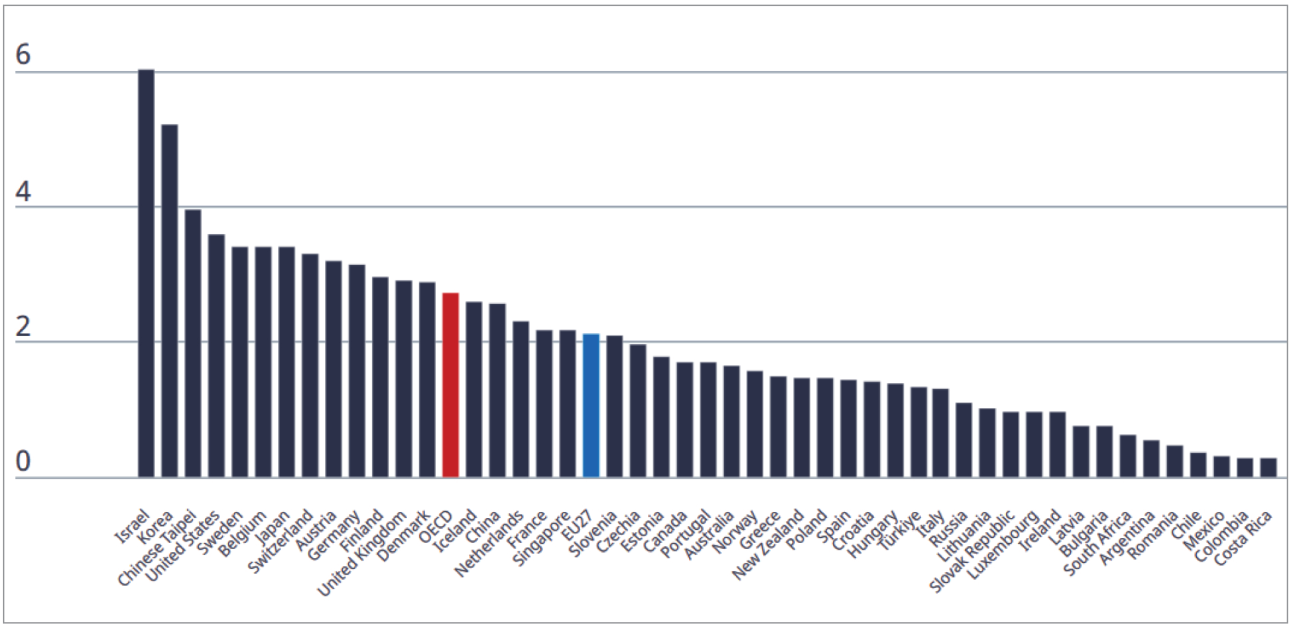

Fig. 1. **Domestic research and development costs share in GDP by 2022**

Source: https://www.oecd.org/en/data/datasets/main-science-and-technology-indicators.htm

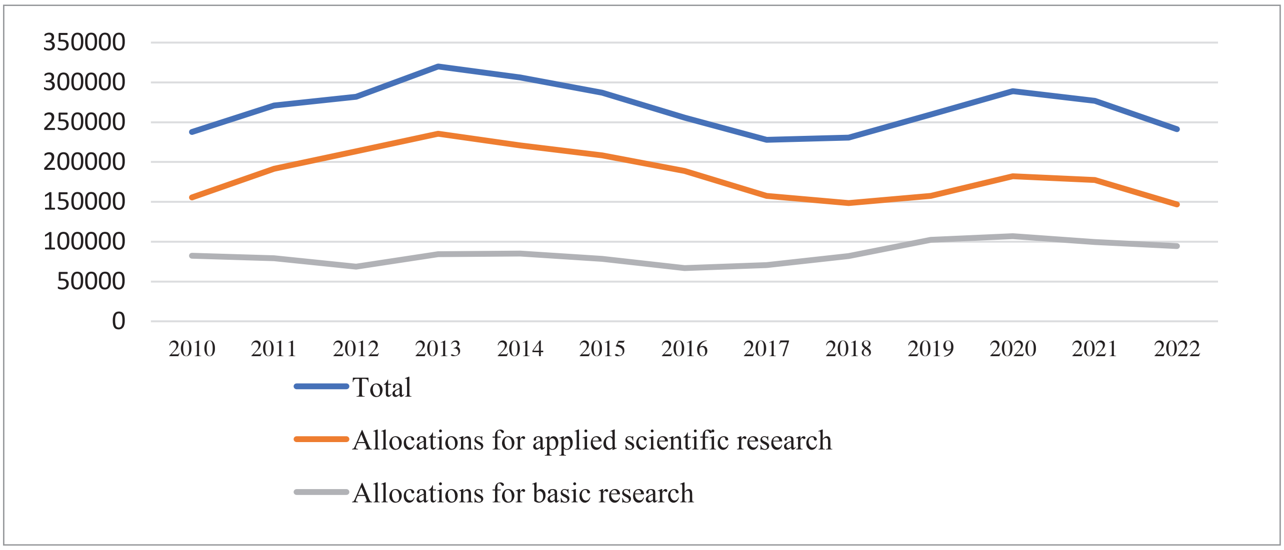

Fig. 2. **Civil science funding from the federal budget of Russia in constant prices in 2010 (in million Rubles)**

Source: compiled by the authors on: https://issek.hse.ru/mirror/pubs/share/907029023.pdf

Russian science,[10] which, unfortunately, has nothing to do with innovation activity and economic effect.

This conclusion is somewhat explained in the work of Chang-Sheng Liao and Xinyang Li [10], who used the so-called method of threshold estimation to study the impact of R&D efficiency on economic growth in different regions of China. The scientists stated, that there is a non-linear relationship between R&D efficiency and economic growth, mainly due to dynamic and static

[10] URL: //www.scimagojr.com/countryrank.php.

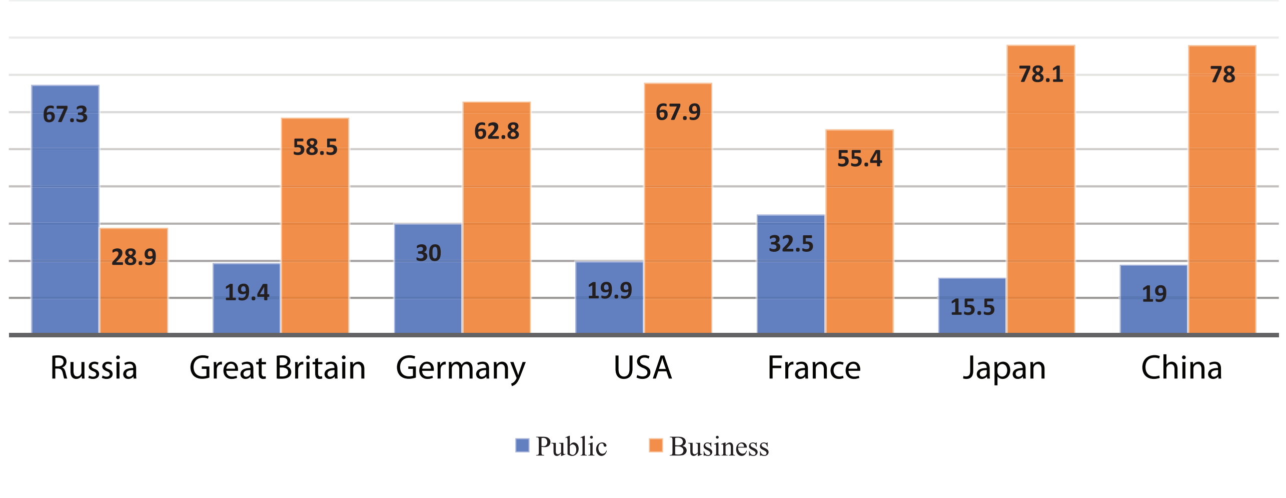

Fig. 3. **Leading countries of the world R&D domestic costs in 2022, %**

Source: compiled by the authors on: https://issek.hse.ru/mirror/pubs/share/907029023.pdf

threshold effects determined by the level of financial development of individual regions, which limits the ability to invest in the use of R&D results, i.e. in innovation. The authors make a conclusion that research results as such do not have a significant impact on economic growth in such regions. This conclusion can probably be applied to Russia as well, where enterprises and entities, especially among small and medium-sized businesses, have a limited possibility to invest in innovation and technology.

Thus, expenditures for research and developments are not always directly proportional to economic growth. This effect can be generally explained by the distribution of financial resources between fundamental and applied scientific research (*Fig. 2*).

Analyzing expenditures on research and development, it should be noted that in each country there are a few sources of funding for science, the main of which are funds from the State budget and the business sector. Notably, their shares vary greatly (*Fig. 3*).

It should be noted, that in the West the expenditure on science from the State (public funds) is less than that of the business sector, while in Russia the situation is reverse. The reasons are manifold: among the main of them are the structural peculiarities of the business sector and the historical particularities of its development.

CONCLUSION

The comparative analysis of competitiveness and allocation of funding in the field of science and technology allows us to justify the current priorities in this area. At the same time, it is necessary to create the instruments of technology implementation, taking into account the fact, that funding predominantly from the state budget is under criticism with the following arguments: public funding does not correspond to the market principles of economic development and does not generate a mature innovation environment. At the same time, it should be noted, that in modern conditions, when the Russian Federation is deprived of the opportunity to import the latest production technologies, the existing structure of national economy with predominance of state funding of science can contribute to a positive economic effect, provided that the allocations are targeted to the development of the most demanded technologies and ensuring technological sovereignty. In this case, the most urgent condition is effective management of relevant programs and projects.

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ABOUT THE AUTHORS

Vladimir N. Kiselev — Cand. Sci. (Econ.), senior research fellow, The Institute of Economic Forecasting of the Russian Academy of Sciences, Moscow, Russia
https://orcid.org/0000-0002-7053-3748
vnkiselev@rambler.ru

Lyudmila M. Kupriyanova — Cand. Sci. (Econ.), Associate professor, Deputy Head of the Department of Economics of Intellectual Property, Associate professor at the Department of Accounting, Analysis and Audit, Finance University, Moscow, Russia
https://orcid.org/0000-0002-9453-6425
Corresponding author:
KuprianovaLM@yandex.ru

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