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FOREIGN EXPERIENCE

# The Struggle for Technological Sovereignty: China's Experience and Lessons for Russia

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**Abstract**—The article analyzes China's experience in establishing a national innovation system of its own. An overview of the main ways for managing the development of science and technology is given. The structure of investments in the economy is considered. It is shown that China has managed to create an innovative environment, in which market mechanisms play the main role while maintaining the leading position of the state. Some promising elements of managing the development of science and technology that can be used by Russia are highlighted.

**Keywords:** China, Russian-Chinese cooperation, national innovation system, R&D, innovation development

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***Introduction.*** In September 2022, at the SCO summit, Russian President Vladimir Putin and Chinese President Xi Jinping stated that "the foreign policy tandem of Moscow and Beijing plays a key role in ensuring global and regional stability, advocates the formation of a just and multipolar world order in order to put the rapidly changing world on the path of sustainable and positive development".[1]

On September 30, 2022, addressing the Russian parliament, Putin expanded on these theses, stating the goal of the collective West as the preservation of a neocolonial system, the essence of which is to collect hegemon rents from the rest of the world through the power of the dollar and technological dictate.[2]

The key instrument used by the United States to retain technological leadership has become restraining other countries' innovative development potential by imposing restrictions on their use of technology and banning the export of high-tech goods in order to slow down or stop the scientific and technological development of competitors. The technological war, according to a number of experts, may well become the defining struggle of the 21st century.[3]

Thus, it is becoming critically important for both Russia and China to achieve technological sovereignty by working out their own effective ways of scientific and technological development, allowing them to overcome their dependence on Western technology markets and standards. It is no coincidence that the joint statement "On the Development Plan for Key Areas of Sino-Russian Economic Cooperation until 2030" signed by the leaders of Russia and China on March 21, 2023, includes cooperation in technology and innovation as one of the most important areas of cooperation.[4]

By order of the President of the Russian Federation, the preparation of draft "Concepts for the technological development of the Russian Federation until 2030" has been underway since 2022.[5] The document is designed to define the concept, goals, objectives, and principles of achieving technological sovereignty of the country, as well as target indicators of technological development. It consists of three sections: sus-

† Deceased.

[1] Meeting with Chinese President Xi Jinping 15.10.2022, Presidential Administration of Russia. http://www.kremlin.ru/events/president/news/by-date/15.09.2022.

[2] Full text of Vladimir Putin's address on September 30, 2022: Transcript of the speech, 30.09.22. Komsomolskaya Pravda online edition. https://www.kp.ru/daily/27452.5/4655517/.

[3] Stephen S. Roach, the Sino-American Tech Trap. 24.01.2023. Project Syndicate. https://www.project-syndicate.org/commentary/america-china-tech-war-no-us-strategy-by-stephen-s-roach-2023-01.

[4] Joint Statement of the President of the Russian Federation and the President of the People's Republic of China on the Development Plan for Key Areas of Sino-Russian Economic Cooperation until 2030, March 21, 2023. http://kremlin.ru/supplement/5919.

[5] M. V. Mishustin, "The Cabinet of Ministers will soon approve a new concept of technological development until 2030," Rossiyskaya Gazeta, no. 98(9043), May 4, 2023. https://rg.ru/2023/05/04/mishustin-kabmin-v-blizhajshee-vremia-utverdit-novuiu-koncepciiu-tehnologicheskogo-razvitiia-do-2030-goda.html.

tainable technological sovereignty, technology as a factor of economic growth and development of the social sphere, and technological support for sustainable functioning of production systems.

At the same time, it is not about creating a fully autonomous system. The complexity and high cost of many major modern technologies require huge R&D expenses and a large market [1]. Taking into account economic and demographic limitations of Russia, it seems reasonable to develop such technologies in partnership with other centers of innovation development. Considering that in the foreseeable future Asian countries, primarily China, will become key trade and economic partners of Russia, their experience in this area should be studied, including the ways of fostering optimal options for collaboration with them.

Since the end of the 20th century, China has set the goal of achieving technological sovereignty, making purposeful efforts to form an integrated system for managing the development of science and technology [2]. This allowed the country to become a recognized world leader in such areas as artificial intelligence, 5G telecommunication networks, ultra-high-voltage power grids, high-speed railroads, renewable energy sources, as well as in some areas of nuclear power, industrial robotics, and space technology. According to the monitoring data of the Australian Institute for Strategic Policy, China holds leading positions in 37 of 44[6] critical technologies[7] tracked by them, and according to the World Intellectual Property Organization, 38% of all patents in the world in 2021 were registered in China[8] (in the US and Japan, it was 18 and 16%, respectively).

At the same time, China itself is under increasing sanction pressure from the collective West[9] in the technological sphere. Therefore, strengthening cooperation with Russia seems natural and mutually beneficial for it. During the Russia–China summit in March, it announced 79 joint projects worth 165 billion US dollars that are planned for their implementation.[10] Doubtless, these projects can be effectively implemented only on the path of deepening Russian–Chinese cooperation in science and technology.

The Chinese experience in managing the development of science and technology is unique in its own way. The scale of the economy and population are not comparable with those in Russia. Since the late 1970s, China has not experienced a radical transformation of the social system and has been developing within the paradigm of building socialism with Chinese characteristics (which was confirmed at the 20th Congress of the CPC in October 2022).

In addition, one cannot disregard the civilizational differences between historically formed differences between Russian and Chinese societies, which predetermine the specifics of the national mentality of the peoples in the two countries.

At the same time, certain mechanisms and tools worked out by China for scientific and technological development can certainly be useful to Russia. In general, many experts emphasize China's outstanding achievements in mastering mass and advanced technologies [3], as well as establishing institutional foundations of the national innovation system [4]. At the same time, the state increasingly seeks to become an intermediary between business and scientific organizations and to define the strategy of innovation, rather than to stay the main actor [5, 6, 7, pp. 209–210]. The major challenge for the Chinese innovation sector seems to be the transition from short-cycle to long-cycle technologies based on self-priming [8].

Nevertheless, there are still some unsolved problems in innovative development. Those include among others the following:

— There are certain gaps in innovation policies for small and medium-sized enterprises, particularly because the current research and development system is largely oriented to large companies [9].

— These gaps ultimately create barriers to the flow of quality resources from major market leaders to other enterprises, even if they are more efficient [3].

[6] Nanoscale materials and manufacturing; High-tech coatings; Smart materials; Advanced composite materials; New metamaterials; High-performance machining processes; Advanced explosives and energy materials; Mining and processing of essential minerals; Advanced magnets and superconductors; Advanced protection; Continuous chemical synthesis; Additive manufacturing (including 3D printing); Advanced radio frequency communication (including 5G and 6G); Advanced optical communication; Artificial intelligence (AI) algorithms and hardware accelerators; Distributed registries; Advanced data analytics; Machine learning (including neural networks and deep learning); Cybersecurity technologies; High-performance computing; Advanced design and production of integrated circuits; Natural language processing (including speech and text recognition and analysis); Hydrogen and ammonia for energy; Supercapacitors; electric batteries; Photovoltaics; Nuclear waste management and recycling; Directed energy technologies; Biofuels; Nuclear energy; Quantum computing; Post-quantum cryptography; Quantum communications (including quantum key distribution); Quantum sensors; Synthetic Biology; Biological Production; Vaccines and medical countermeasures; Photonic sensors; Advanced aircraft engines (including hypersonic); Drones, swarming and collaborative robots; Small satellites; Autonomous Systems operation technology; Advanced robotics; Space launch systems.

[7] Jamie Gaida. ASPI's Critical Technology Tracker, The Australian Strategic Policy Institute. February 2023. ISSN 2209-9689. https://www.aspi.org.au/report/critical-technology-tracker.

[8] J. Tangorra, "Which countries are granted the most new patents?," Visual Capitalist, April 23, 2023.

[9] In January 2023, Japan and the Netherlands joined the U.S. restrictions on supplies of semiconductor manufacturing equipment to China.

[10] P. Khimshiashvili and V. Vishnyakova, "Convergence up to closer ties," RBC, March 21, 2021. https://www.rbc.ru/newspaper/2023/03/22/641968429a794764a55efa3c.

— China depends on foreign suppliers for a number of basic technological components [3].

— There are gaps in innovative regional development [10, 11].

At the first session of the 14th National People's Congress held in March 2023, the focus on China's achievement of technological sovereignty was reaffirmed. It was stressed that it is by relying on China's own technological reserves that it is possible to contain external pressure and improve the quality of economic growth.

***China's experience.*** Establishing ways to manage scientific and technological development took place simultaneously with implementing Deng Xiaoping's policy of openness and reforms. Special economic zones were created. The state had spent colossal resources on the arrangement of their infrastructure. Thus, in 1992, 1996, and 2000, the share of export production facilities[11] in investment in fixed assets amounted to 64%, 56, and 51%, respectively [12, pp. 221–223]. At the same time, the share of capital construction in investment in fixed capital (throughout the country) from 1990 to 2000 increased from 57 to 81%. This made it possible to attract increasing amounts of foreign capital. Leading Western corporations began to compete in the Chinese market, attracted by cheap labor, developing infrastructure, and a favorable investment regime. Such conditions allowed the Chinese authorities to dictate their rules to foreign businesses, forcing foreign enterprises to transfer technology in exchange for access to a huge market and production base. Ultimately, all this enabled China to achieve unprecedented growth rates of social and economic development and to become a universally recognized "factory of the world" by the end of the 20th century.

The strategic National Conferences on Science and Technology held since 1978 played a special role in the formulation of future objectives for scientific and technological development, during which proposals and recommendations were elaborated and taken into account in the future five-year plans of socio-economic development of the PRC [13].

Since the second half of the 1980s, special programs aimed to support innovation activities, such as Spark, Torch, 863, and others, began to play an important role in the formation of China's scientific and technological potential. The essence of these programs was to provide tax benefits, budget financing, create appropriate infrastructure, etc. Each program involved a different range of sectors and was financed from different sources. In particular, the Spark program was aimed at modernizing agriculture, the Torch program at creating favorable conditions for domestic innovative development, and the 863 program at fostering R&D.

The implementation of these programs clearly revealed the need to develop the country's own scientific and technological base in order to overcome the limitations associated with reliance on imports of Western technology [14, 15]. Many enterprises with foreign capital worked exclusively for exports and were almost unconnected to the rest of the country's economy. Any interruption of supplies threatened to aggravate the problem of technological security.

A landmark milestone on the way to establishing China's own innovation system was the large-scale and ambitious program of military-technical modernization initiated by the Politbureau of the CPC Central Committee, called "Program 995" (995—May 1999)[12] [16]. The program was aimed at accelerating the development of several breakthrough military technologies. Taking into account the decades of borrowing foreign military and dual-use technologies in Europe, Israel, and the countries of the former Soviet Union, the 995 Program was primarily focused on the priority development of its own scientific and technological base of the national defense industry.

For decades, special efforts have focused on nurturing the country's own human resources capacity in order to develop high-tech industries. China is actively sending students to study at leading technical universities in the world, primarily American ones. In 2019, the number of Chinese students studying abroad amounted to 703500 people.[13] At the same time, almost half of Chinese students who have gone abroad study at American universities [17]. While at the initial stage only a small proportion of them returned to China, already in 2019 more than 80% of students came back to their homeland. In particular, it was also because within the framework of the Torch program in the zones of high-tech development, preferential conditions were created for setting up small businesses by students educated abroad [13].

Moreover, China was able to lure thousands of highly skilled engineers from Taiwan's TSMC, the world leader in chip manufacturing. Many leading specialists from Chinese-American companies are returning to their homeland.[14] Prominent Western researchers are lining up for jobs at major Chinese companies, as well as teaching positions at the country's leading technical universities (the average monthly salary for a university lecturer is between

[11]The delta of the Zhujiang River (Guangdong), Fujian, the Delta of the Changjiang River (Shanghai, Jiangsu, Zhejiang), the Zone of the Bohai Bay (Beijing, Tianjin, Liaoning) and Shandong.

[12]As is known, on May 7, 1999, during the armed conflict between NATO and Yugoslavia, an American bomber "by mistake" bombed the Chinese Embassy in Belgrade, killing three people.

[13]According to the National Bureau of Statistics of China.

[14]In particular, in recent years, leading AI specialists Zhu Songchun and Ma Yi have returned to China from the US.

5500 and 6000 US dollars).[15] In terms of R&D expenditures per researcher, China lags behind the world leaders (see Fig. 1), but has the largest body of researchers.

There is a program in China for supporting candidates of science who are engaged in research activities. The state allocates 630000 yuan annually to 400 candidates for two years.[16] Those eligible for this support should be engaged in the field of activity from the approved list. In basic research, these are artificial intelligence, quantum information, integrated circuits, life and health, neuroscience, biological breeding, aerospace technology and deep sea research; in applied research, this activity covers a new generation of information technology and biotechnology, new energy, new materials, high-tech equipment, new energy vehicles, environmental protection, aerospace, marine technology, digital economy and basic engineering technologies in various fields, general technology, etc. It is mandatory to have a scientific supervisor.

Since 1984, successful public and private research organizations (or their subdivisions) engaged in research in strategically important areas have been granted the status of key national laboratories (KNL), which provides direct financial support from the central budget (there were 515 KNLs in China at the end of 2019). In the 14th Five-Year Plan (2021–2025), the leading role in strategic technology development is assigned to KNLs.

The leading ones are 20 national laboratories, which head the main directions in fundamental R&D, while their subordinate KNLs are engaged in specific areas of research [18]. KNLs are under the jurisdiction of various government organizations, including the Ministry of Education, the Chinese Academy of Sciences, as well as public and private enterprises.

The PRC government plays a significant role in the management and development of KNLs, including those that are parts of private enterprises.[17] This simplifies the innovation process from basic research to applied research and enables the integration of enterprises, universities, research institutes, and KNLs into sectoral clusters.

This approach is broadly modeled after the American system of national laboratories, federally funded research centers, and university research centers.[18]

KNLs play a special role in shaping the scientific potential of the country. In China, a special decree stipulates that, in addition to permanent employees, a KNL must include temporary staff: visiting researchers, scientists with doctoral degrees, and graduate students. A KNL is also actively involved in academic exchanges.

In the 14th Five-Year Plan, artificial intelligence, quantum information, integrated circuits, genetics and biotechnology, neuroscience, and aerospace technology are prioritized for development. The "Made in China 2025" program (approved in 2015) envisages increasing the share of key high-tech components produced domestically to 70% in 2025 in such industries as information technology, robotics, "green" (renewable) energy and green vehicles, aerospace equipment, shipbuilding, railroads, energy equipment, new materials, medical equipment and pharmaceuticals, and agricultural machinery.[19]

Of particular interest is China's experience in regulating large private enterprises in the IT sector. At least for the last two decades, the state has been creating favorable conditions for the cultivation of "national champions," primarily in the IT industry. Ultimately, they really emerged. In particular, Huawei,[20] Alibaba Group, Tencent, JD.com, and China Mobile have accumulated enormous economic capacity. With more than a trillion US dollars in assets in 2021, they have been able to advance their own global digital platforms, expanding their operations far beyond China. At the same time, in 2020, the state took strict measures to prevent these companies from acquiring noncore assets (for example, in shadow banking) and creating media outlets under their control to lobby their own interests. In addition, while in the West, primarily in the United States, the breakthrough area of scientific and technological development—research in the field of artificial intelligence—has been given to private IT giants, in China this area remains under state control.

To date, China has established a certain system of managing science and technology development, in which the state retains the leading and coordinating role. The key parameters of S&T development have become an integral part of the strategic planning carried out by the State Development and Reforms Committee (formerly the State Planning Committee of China). China's academic institutes are most directly involved in the development of these parameters. It should be taken into account that in China there are three academies of sciences, which are directly subordinated not to the PRC Ministry of Science and Technology but to the central government (State Council of the PRC). They are the Chinese Academy of Sciences (natural sciences), the Chinese Academy of Engineer-

[15]According to Glassdoor and Salary Explorer websites.

[16]*关于做好2022年度博士后创新人才支持计划实施工作的通知*, Office of Postdoctoral Management at Central South University, 26.01.2022. http//bsh.csu.edu.cn/info/1229/5240.htm.

[17]About a third of the total number of KNLs is included in commercial enterprises.

[18]"The US national laboratory system concentrates more than 40% of total national funding for the physical and engineering sciences, with federal funding accounting for up to 70% of all R&D spending" [18].

[19]国?院关于印?《中国制造*2025*》的通知, State Council of the People's Republic of China, May 8, 2015. http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm.

[20]As is the case with many large companies in China, nominally private business is actually quasi-public.

ing, and the Chinese Academy of Social Sciences. Besides, there are three Chinese academies directly subordinated to the corresponding ministries. They are the Chinese Academy of Medical Sciences, the Chinese Academy of Agricultural Sciences, and the Chinese Academy of Arts. The expertise of the academies of sciences is actively used in working out development plans. In particular, the Ministry of Industry and Information Technology recruited 150 leading experts from the Academy of Engineering Sciences to develop the Made in China 2025 plan.[21] The overall coordination of S&T activities is carried out by the State Council's Science, Technology, and Education Steering Committee. In addition, China has reportedly established the National Science and Technology Advisory Commission, composed of leading experts in key industries, which is engaged in approving major technology projects.[22]

Moreover, at the 1st session of the 14th National People's Congress held in March 2023, it was decided to strengthen the control of the CPC Central Committee over the process of the country's scientific and technological development by establishing the Central Commission on Science and Technology. It is intended to organize and coordinate scientific and technological work at the central level.[23] In addition, the session announced the reform of the Ministry of Science and Technology. It is expected that more favorable conditions will be created for technological breakthroughs and that the process of improving science and technology will be better integrated with socio-economic development plans; the better coherence of research organizations will be provided to optimize scientific and technological innovation and ensure more effective interaction of business and the academic environment.[24] In order to meet these challenges, lawmakers have proposed empowering the Ministry with strategic planning of research work, allocation of resources, and real-time interagency coordination.

While preserving the leading role in scientific and technological development, the state consistently introduced market mechanisms of research financing [5, 6]. Conditions stimulating financing of R&D by enterprises themselves were purposefully created. To this end, some research organizations (those that were engaged in applied developments) were transferred to a commercial basis. Subsidiary organizations that were engaged in commercialization of technologies and establishment of relations between institutes and industry were set up under research institutes. Technological markets were created for more active dissemination of technologies. For example, the Wuhan Technology Market established in 1984 consisted of about 60 technology offices in research institutes, universities, and firms in the area.

China has ensured a steady increase in investment in human capital, of which investment in the knowledge economy is the backbone[25] [19]. Thus, by the beginning of the third decade of the 21st century, the share of healthcare and biotechnology in GDP is 6%, education 4%, and information and communication technologies 10%. The share of the knowledge economy as a whole in China's GDP is 22%. (In Russia, this figure is 14%, and in the US 40%). Investment in R&D in China increased from one trillion yuan (1.91% of GDP) in 2012 to 2.7 trillion (2.44% of GDP) in 2021. According to this indicator, the country ranks second after the United States, far ahead of any of the EU countries. The share of funds spent by enterprises (with all forms of ownership) in R&D expenditures in 2020 amounted to 77.5%, state funding (budgets of central and local governments, as well as various state funds) was 19.8%. It is noteworthy that the share of the central government in public spending on R&D in 2008 was 49.3%, local (provincial and municipal) authorities 50.7%; in 2020, it was 37.2 and 62.8%, respectively. At the same time, a significant share of local R&D spending falls on a narrow circle of provinces that make up high-tech development zones [10, 11].

Due to the fact that for many years reliance on exports was the main driver of economic development, a significant part of the technologies was purchased abroad. In 2002, payments for the use of foreign intellectual property accounted for the equivalent of about 20% of all R&D spending in China.[26] By 2011, this parameter had dropped to 10% and is still at this level. To a certain extent, this indicates the maturation of the national scientific and technological complex, its ability to find its own solutions to the problems of innovative development.

The scientific and technological development of China revealed a certain lag in basic research, which cannot be compensated either by the activity of enterprises, or at the level of a province. In 2020, only 6% of R&D expenditures were on fundamental science (in the United States it was 15.2%). This is particularly

[21] S. Kennedy, "Made in China 2025," Center for Strategic and International Studies, June 1, 2015. https://www.csis.org/analysis/made-china-2025.

[22] C. Feng. China's top science and technology advisory commission emerges from the dark as Beijing charts future economic course. November 19, 2021 https://www.scmp.com/tech/policy/article/3156723/chinas-top-science-and-technology-advisory-commission-emerges-dark.

[23] China to restructure ministry in sci-tech self-reliance drive. March 7, 2023. https://www.chinadaily.com.cn/a/202303/07/WS-6406f988a31057c47ebb2d b2.html.

[24] V. Kulagin. China presented a government reform plan on 03/09/2023. https://www.vedomosti.ru/politics/articles/2023/03/09/965722-v-kitae-predstavili-plan-reformi-pravitelstva.

[25] The knowledge economy typically includes R&D, education, information and communication technologies, biotechnology and healthcare.

[26] National Bureau of Statistics of the People's Republic of China.

evident in the structure of enterprises' expenditure on R&D: 0.5% on basic research, 3% on applied research, and 96.5% on experimental research. In universities and research institutes, which are mainly financed by the state, funding of fundamental science takes 38.5 and 16.8%, respectively. To some extent, it is caused by the fact that China for a long time relied on adaptation of foreign technologies [20]. In general, the analysis of the Chinese experience of building the national scientific and technological complex allows drawing the following conclusions:

— The state retains its coordinating and guiding role in the development of science and technology, formulating and controlling the achievement of relevant parameters.

— China has formed a certain system for managing the development of science and technology, which makes it possible to implement the key parameters of scientific and technological development in the process of medium- and long-term planning. At the same time, the expert potential of the country's academic community is in demand and involved in the evaluation and prioritization of the largest national projects in key industries.

— The strengthening of China's scientific and technological potential and the national innovation system in recent decades is due to a steady increase in investment in human capital, with investment in the knowledge economy being systemically important. Overall, the share of the knowledge economy in China's GDP is 22%.

— The transition to an economic strategy based on "double circulation" makes it possible to overcome the inherent limitation of an export-oriented economy—orientation exclusively to the foreign market—and direct resources to the development of the country's lagging regions, which certainly contributes to the technological upgrading of their mass industries [21].

— Provincial R&D expenditures exceed those of the central government (62.8 and 37.2%, respectively). This indicates that a narrow range of regions, such as the Zhujiang River Delta, the Changjiang River Delta, the Bohai Bay Area and the Shandong Peninsula, remain the main driver of China's S&T development.

— The large share of enterprises' own funds in R&D expenditures (77.5%) indicates that the country has managed to create an economic environment that stimulates scientific and technological development. The reduction in payments for the use of foreign intellectual property from 20 to 10% in relation to R&D expenditures indicates the maturation of the national scientific and technological complex, its ability to find its own solutions to the problems of innovative development.

— China has managed to create the conditions for bringing back hundreds of thousands of students educated in the West to their home country, as well as to attract top-notch professionals from abroad.

— China's scientific and technological development has revealed a certain lag in basic research, which cannot be compensated either by the activity of enterprises or at the level of provinces. In this regard, measures are taken to increase central budget spending on basic research in universities and research organizations, including by giving them the status of key national laboratories.

— Despite obvious achievements, in recent years China has failed to close the gap in the development of several critical areas of scientific and technological development[27] [3], in particular, in the creation of photolithographic equipment for the production of high-performance chips, as well as in the production of high-tech CNC machines.

***Conclusions for Russia.*** During talks with President Xi Jinping in March, the Russian leader emphasized that "China has made a tremendous leap forward in its development in recent years. The whole world is truly interested in this, and we even envy you a little bit. China has created a very effective system of economic development and state strengthening".[28]

It appears that certain mechanisms and instruments worked out by China for scientific and technological development can certainly be used by Russia.

First of all, this concerns establishing a science management system, in which the strategic planning process at all stages is based on achieving certain parameters of scientific and technological development. This makes it possible to link the macroeconomic indicators of medium- and long-term development with the prioritized implementing of major scientific and technological projects funded both from the central and local budgets. In the conditions of Russia—the largest country in the world—this may be of particular importance for spatial development.[29]

An analysis of the system for managing scientific and technological development that has been worked out in China suggests that the country has essentially formed a body—the Steering Committee for Science, Technology and Education under the State Council of the People's Republic of China—similar in its functions to the State Committee for Science and Technology (SCST) that existed in the Soviet Union. The need to recreate such a body in Russia is considered a must by the country's leading experts [22].

[27] J. Gao and J. Jiang, "Scientific, technical and innovative cooperation between China and Russia in a new era: Reshaping the model and choosing an approach from the point of view of Chinese experts." Probl. Prognozirovaniya, No. 6, 109 (2022). doi 10.47711/0868-6351-195-109-119.

[28] Putin announced a colossal breakthrough in China's development in recent years. March 20, 2023. TASS. https://tass.ru/politika/17319405.

[29] A. A. Shabanova, S. V. Terebova, and G. V. Leonidova, "Dynamics of modernization development of Russian regions: Scientific and technological imbalances against the background of general progress," Probl. Prognozirovaniya, No. 1, 53 (2023). doi 10.47711/0868-6351-196-53-64.

In China, the Ministry of Education and the Ministry of Science and Technology are two independent governing bodies, while the latter is entrusted with the functions of strategic planning of research work, resource allocation, and interdepartmental coordination in real time. In Russia, the Ministry of Education and Science, as far as we know, deals with everything at once. At the same time, according to a number of leading Russian experts, there is a tendency in the activities of this ministry to "develop the scientific and educational sphere following American path, relying on the leading role of universities in the development of science and the formation of the venture market as the basis of innovative technologies and projects" [23].

As China's experience shows, the most developed regions of the country are the main drivers of scientific and technological development. Moreover, as it was emphasized earlier, their borders do not coincide with the administrative framework of individual provinces (for example, the Changjiang River Delta includes the administrative entities of Shanghai, Jiangsu, and Zhejiang; the Zhujiang River Delta includes Fujian, Jiangxi, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Hong Kong and Macau). The fact that the R&D expenditures of these regions exceed the expenditures of the central government indicates that they have certain independence, both financial and in planning their own development, while maintaining the coordinating role of the Center.

In Russia, with appropriate institutional changes, the role of drivers could be played by metropolitan agglomerations (Moscow, St. Petersburg) and individual clusters in the Urals, Siberia, the Volga, and the Far East. By analogy with the Chinese "double circulation," these regions, using the resources of neighboring regions, could contribute to the improvement of the scientific and technological level, modernizing their industries of mass production.

As China's experience shows, progress toward technological sovereignty is impossible without a consistent increase in investment in human capital. At the same time, for the last 10 years financing of Russian R&D in comparable prices has increased only by 10%, which actually means stagnation [22]. The share of total spending on education in GDP fell from 5.1 to 4.1% from 2006 to 2021 [24], and on health care it reached its peak of 6.5% in 2009 and fell to 3.9% in 2018.[30]

Despite the well-known budget constraints, the Chinese experience of attracting specialists from abroad (both compatriots and foreigners) to the scientific and technological sphere could be very useful for Russia, especially in breakthrough areas of scientific and technological development.

The high share of enterprises' own funds in R&D expenditures in China resulted from many years of purposeful efforts to foster an innovative environment. One of the main tools in this process was assigning the status of key national laboratories to enterprises and research organizations engaged in scientific and technological activities. Thus, they gained access to preferential forms of financing and taxation. It appears that this kind of tool can be very useful for Russia.

In modern conditions, it is obvious that in the coming years, the main trade and economic partners of Russia will be the countries of the East, primarily China. On analyzing promising areas of interaction, they should be divided into tactical and strategic. Tactical ones include measures aimed at responding to the current situation, which is characterized by a sharp increase in geopolitical tensions and an unprecedented escalation of anti-Russian sanctions.

At the same time, it should be taken into account that, until recently, China had been very comfortable in the conditions of globalization and was one of its main beneficiaries. For it, the importance of the Russian market is many times inferior to that of the American and European markets (according to the results of 2022, the trade turnover with the Russian Federation amounted to 190.27 billion US dollars, while with the United States and the EU it exceeded 1.6 trillion US dollars). Therefore, the desire of Chinese business to avoid secondary sanctions from the collective West is quite understandable and predictable. It is no coincidence that in the first half of 2022, against the backdrop of a 48.8% growth in Russian exports to China, Chinese deliveries to the Russian Federation increased by mere 5.2%, which, in essence, indicates a reduction in their physical volumes. At the same time, this primarily affected high-tech products that Russia urgently needs.

In view of this, at the current stage, establishing cooperation mechanisms that are not subject to Western sanctions is of particular relevance. This includes an increase in the share of settlements in national currencies (according to the results of 2022, in Russia's trade with China, it increased to almost a half[31]) and the use of digital ruble and digital yuan in mutual settlements actively developed by the central banks of the two countries. In addition, in the current conditions, the strengthening of existing and the formation of new logistics chains of trade and economic interaction between the two countries is becoming important.

The strategic directions of cooperation with China should include creating new and implementing the existing joint technological advances (in particular, we are talking about heavy helicopters, joint projects in the space, defense, and nuclear industries). Along with

[30]Total Health Care Costs, % of GDP, World Health Organization. https://gateway.euro.who.int/ru/indicators/hfa_566-6711-total-health-expenditure-as-of-gdp/visualizations/.

[31]S. V. Lavrov, "The share of trade between the Russian Federation and China in national currencies has reached almost half," Kommersant, January 18, 2023. https://www.kommersant.ru/doc/5773953.

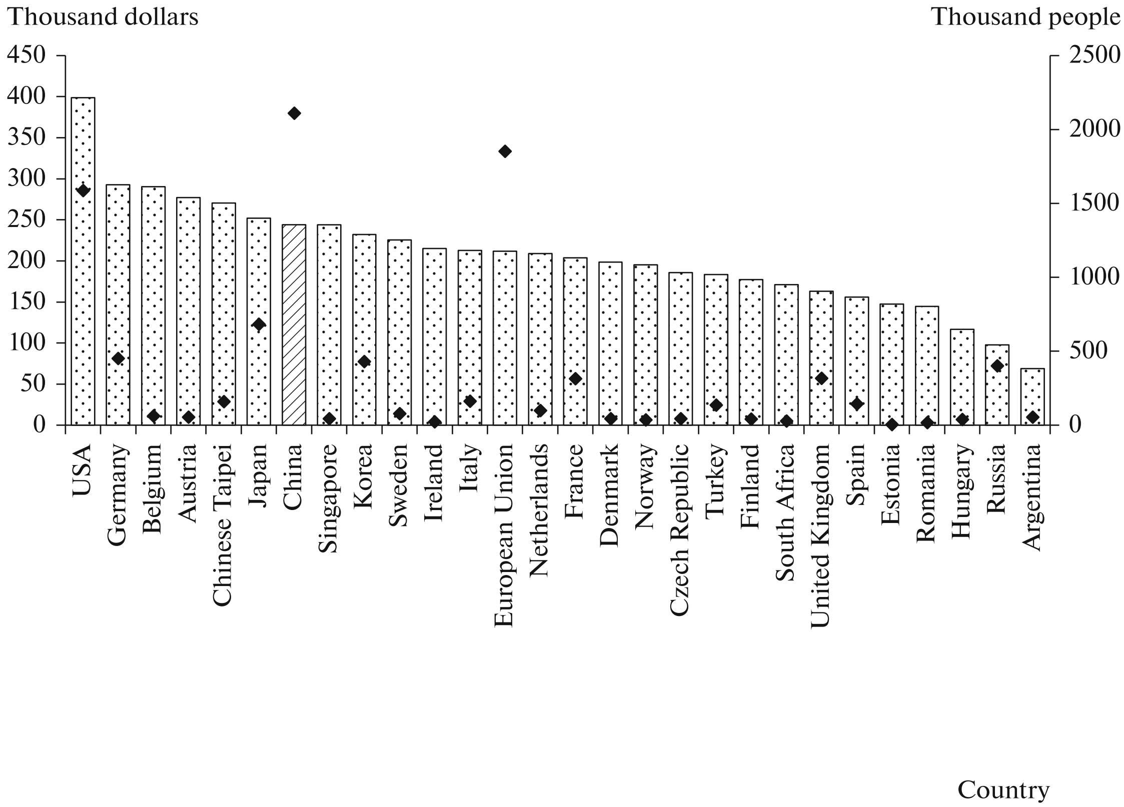


**Fig. 1.** Gross research and development costs per researcher (full-time equivalent, PPP dollars at constant 2015 prices) ⋅-costs per researcher (left scale); ◆ number of researchers (FTE) (right scale). Source: Based on OECD data.

this, it is necessary to ensure the continuity of interaction between scientific organizations of the two countries, including academies of science. A possible form of such interaction can be establishing scientific consortia to solve problems in the breakthrough areas of scientific and technological development.

An important step for the prospect of strategic cooperation between Russia and China in the field of science and technology should be a significant increase in the mutual exchange of students between leading technical universities of the two countries. The leading Russian engineering universities (Moscow Institute of Physics and Technology, Moscow Engineering Physics Institute, N.E. Bauman Moscow State Technical University, Moscow State University, etc.) should introduce Chinese as a foreign language for some students. These students should be provided with internships at major Chinese research centers. There is no doubt that in the future they will be able to act as a driving force in the implementation of joint high-tech projects. In the academic year 2021–2022, 6.5 thousand students from Russia studied at Chinese universities. More than 32.5 thousand citizens of China studied at Russian universities, including their foreign branches.[32]

China managed to prevent the collapse and sharp decline in the potential of applied science through the development of the engineering academy and the system of key national laboratories. Leading Russian experts propose measures that take into account the positive experience of China and the United States in this area [23]. In particular, the following measures appear feasible:

— Setting up Centers of Applied Science based on leading state research centers of the Russian Federation and Research Center of intersectoral national research following the example of the Kurchatov Institute and the Zhukovsky National Research Center.

— Setting up a research complex in the form of a two-tiered structure organized as an association of institutes of the Russian Academy of Sciences and organizations of the state applied science sector.

## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

[32] Russia and China held the first Forum of Russian-Chinese Associations of Specialized Universities, Russian Union of Rectors, December 9, 2022. https://rsr-online.ru/news/2022/12/9/rossiya-i-knr-proveli-pervyj-forum-rossijsko-kitajskih-associacij-profilnyh-universitetov/.

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