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VARIATIONS IN SOCIOECONOMIC DEVELOPMENT BY REGION

Geography of Artificial Intelligence Technologies in Russia[1]

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Abstract—The geography of innovation makes it possible to identify spatial patterns of creation, implementation, and diffusion of new technologies, but with the development of communications, an illusion appeared that space is insignificant. In accordance with the aim of the study, the article shows that creation and implementation of artificial intelligence (AI) as one of the radical innovations cannot be widespread. It will be concentrated in centers with high innovation potential and specialized tacit knowledge, where the intensity of knowledge spillovers is higher. In Russia, an education in AI can be obtained in 21 regions, research is conducted in 35, and technology is being developed in 40. The article proposes a rating of regional potential for AI creating, assessing scientific and technological development and density of the main elements of regional innovation ecosystems. The rating shows a high concentration of potential in the largest urban agglomeration, Moscow, and several creative cores: Moscow oblast, St. Petersburg, the Republic of Tatarstan, and Novosibirsk oblast. Sixteen centers have been identified capable of both creating and implementing certain AI technologies: Sverdlovsk, Nizhny Novgorod, Chelyabinsk, Samara, Tomsk, and Rostov oblasts, Krasnodar krai, etc.; 23 regions that are predominantly acceptor centers using AI advanced production technologies and 41 regions with minimal potential. Leading regions may receive priority attention and funding by investors. In acceptor regions, public policy priority may be given to supporting production automation, and in lagging regions, preference may be given to increasing the population's receptivity to digital technologies.

Keywords: geography of innovation, digital economy, technology change, innovation ecosystem, Russian regions, science and technology policy

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INTRODUCTION

The global economy is at the beginning of a new techno-economic paradigm (by 2025–2030); its signs are general digitalization, robotization, and smart networks development (Baburin, 2010; Korotaev and Grinin, 2012). The population aging observed in Russia and many developed countries makes it inevitable that the demand for automation will increase. The key to this may be the rapidly developing technologies of artificial intelligence (AI): industrial robots, chatbots in services, machine learning in analytics, drones in agriculture, voice assistants in business and in everyday life, smart homes, robotic surgeons and diagnosticians, tracking systems, and many more. AI assumes the ability of a machine (robot) to independently learn, make decisions, and perform actions of human intelligence (Blanutsa, 2019a). One of the breakthroughs in 2022 was the appearance of ChatGPT, which answers unstructured questions by analyzing Internet sources; in Russia, YandexGPT, developed a year later, became a counterpart. Such tools began to be used in a wide range of tasks: from writing articles and reports to justifying political decisions.[2]

AI technologies have received close attention from governments seeking to accelerate their development and implementation (Blanutsa, 2020a, 2020b). Generative AI could have an impact similar to nuclear or

[1] The journal *Regional Research of Russia* traditionally publishes English translations of Russian-language articles published in the journal *Regional'nye Issledovaniya*. This article is one of four similar examples in this issue, and the editorial board of Regional Research of Russia considers it useful to present its readers with *Regional'nye Issledovaniya*. The journal was founded in 2002 by the Institute of Geography of the Russian Academy of Sciences; Immanuel Kant Baltic Federal University, and Smolensk State University and is published quarterly; About 1000 scientific articles have already been published, devoted to methodology, theory, methods, and practice of regional research in Russia and abroad. This is the only journal in Russia focused primarily on economic, social, cultural, political, and recreational geography. Articles on regional and spatial economics, regional sociology, regional analysis, and regional policy also occupy an important place. In the Russian SCIENCE INDEX ranking, the journal ranks (2022) seventh among journals on the subject of "Geography"; according to the two-year impact factor by the Russian Index of Science Citation (RINTs) is the most cited among Russian journals on the subject of "Geography"; it ranks third and fourth on the h-index over the past 10 years.

[2] In the first two months of 2023, the number of users worldwide exceeded 100 mln, making this AI technology the fastest growing application in history. https://chat.openai.com/.

space technology. Accordingly, lagging countries risk losing sovereignty in this area. Given the restrictions on access to foreign technologies (Zemtsov, 2024), there is a risk that Russia will lag behind, especially due to the lack of a component base and lithographic equipment. Therefore, in 2020–2022 after the launch of the Federal Project "Artificial Intelligence" (FP AI) (Artificial ..., 2023), funding increased threefold. The AI market in Russia in 2022 grew by 17% (Artificial ..., 2023), while GDP, under conditions of external restrictions, decreased by 1.2%.[3]

Accelerating development requires concentrated efforts. Previously, the geography of federal support for scientific and technological development (STD) developed largely spontaneously. For example, the location of innovation infrastructure did not take into account the position of research universities or scientific centers (Kuznetsova, 2022), which limited knowledge spillovers. As any new technology, AI may be subject to the basic spatial patterns of the geography of innovation (Baburin and Zemtsov, 2017) and therefore it is one of the new objects of regional research.

The purpose of the research is to assess the potential for AI technologies creation and implementation in the Russian regions to determine spatial policy priorities in this area.

REVIEW OF EARLIER STUDIES

In recent years, with the development of information and communication technologies and the spread of remote employment, especially after the pandemic, the misconception arose that new technical solutions can be developed remotely from science and technology centers. With the development of digital trading platforms (such as Alibaba or Ozon), a similar misconception has become characteristic of technology diffusion processes: a new product can be sold worldwide, and local consumers are not important. In other words, the geography of innovation has ceased to be significant—the "death of geography" has arrived (Han et al., 2018).

In reality, new breakthrough inventions, such as AI or quantum computer, require an even greater concentration of human, technological and financial resources, since individual inventors cannot solve the entire complex of problems. Moreover, the project team must, at a minimum, include an entrepreneur (visionary), engineer (inventor) and programmer for the project to become commercially successful. And such diverse functions are found together in a limited number of places. Reducing communication costs leads to the concentration of scientific and technological activities due to the global migration of highly qualified personnel and capital to places with the most favorable conditions. Thus, while routine functions are widely distributed, such as access to the Internet, unique ones, such as the development of AI technologies, are, on the contrary, concentrated (Berger and Frey, 2017).

The creation, implementation, and distribution of AI technologies cannot be ubiquitous, since this is only possible in centers with high innovative potential (Baburin and Zemtsov, 2017; Sinergiya ..., 2012), where all stages of the innovation cycle are concentrated: personnel training, fundamental research and development of applied technologies, commercial implementation, and potential demand. At the same time, for each stage—creation, implementation, and consumption (Baburin and Zemtsov, 2017)—there are specific patterns and placement factors. Regions lacking the conditions to create AI technology may in the future prove successful in terms of its implementation in production or its distribution in everyday life. At each stage, a separate subsystem is formed in the local innovation system (or ecosystem) (Asheim et al., 2011), represented by relevant agents: universities, research organizations, private laboratories, start-ups, large enterprises and consumers. Their interaction generates an innovation space (Baburin, 2002; Makarov et al., 2016): a larger number of agents leads to more intense exchange, which accelerates the creation and dissemination of new ideas and technologies through mutual learning and knowledge spillovers.

A specific feature of a significant part of knowledge, including in the field of AI, is such characteristics as indivisibility, the ability to use it an unlimited number of times and the impossibility of completely excluding other agents from its use (Sinergiya ..., 2012). Therefore, innovative activity of some agents generates positive external effects for others, so-called knowledge spillovers. Knowledge spillover is a process in which knowledge created by one company (individual or group of people) can be used by others without compensation, or with compensation less than the cost of the knowledge itself (Sinergiya ..., 2012). The development of AI technology by a large team inevitably leads to processes of exchange and development of similar technologies; some specialists can subsequently create new enterprises and manage similar projects.

The concentration of the main participants in the creation of AI technology within the regional innovation ecosystem (Kwon et al., 2021) leads to increased external effects (knowledge spillovers) and increases the speed and efficiency of processes (Murata et al., 2014). Therefore, e.g., the number of joint patents or patent citations decreases dramatically as the distance between inventors increases by 300 km or more (Bottazzi and Peri, 2003). Moreover, contrary to ideas about the "death of geography," the level of localization, e.g., the citation rate of local patents, is growing every year (Kwon et al., 2022), as innovation ecosystems and clusters specialize in the development of spe-

[3] Rosstat softened its estimate of the GDP decline in 2022 to 1.2%. https://www.kommersant.ru/doc/6440786.

cific technologies (Buzard et al., 2020): Silicon Valley (California, USA)—on microelectronics, information technology (IT) and AI; Bavaria (Germany)—on biotechnology; Research Triangle (North Carolina, USA)—on medicine and biotechnology; Cambridge Science Park (UK)—on biomedicine and communications; Innopolis (Republic of Tatarstan, Russia)—on IT; Zhangjiang cluster (Shanghai, China)—on semiconductors and microcircuits. At the same time, knowledge spillovers coming from university and research AI centers can be even more localized within 20–30 km (Holl et al., 2023), since uncodifiable tacit knowledge about the emerging technology is transferred only through co-education, personal cooperation, and co-creation, e.g., from a mentor to a student.

In the field of high technologies, in particular, in the field of AI, the concepts of a regional innovation system (Asheim et al., 2011) and entrepreneurial ecosystem (Jones and Ratten, 2021; Malecki, 2018; Zemtsov and Baburin, 2019) complement each other, since technology startups create many AI technologies (Cetindamar et al., 2020), and without sufficient entrepreneurial capital from the local community, this would be difficult. However, success requires the involvement of a large number of interested parties (stakeholders): inventors, scientists, politicians, venture investors, etc. The concentration of human capital and scientific potential in the field of AI is fundamental (Fu and Qian, 2023). Also important are strong connections between them in favorable environmental conditions: comfortable urban space, a fruitful business climate, a creative environment, etc. Therefore, breakthrough AI technologies can hardly be created outside of large urban agglomerations or science cities.[4]

When technological structures change, new industries, fields of activity, professions arise, e.g. those related to AI, in some regions, while in others they can shrink, transform and even disappear (Berger and Frey, 2017). Large cities with a significant diversity of activities and large modern universities specializing in STEM specialties[5] may benefit in the era of AI, but manufacturing and mining centers, on the contrary, will lose jobs and development potential. It is not without reason that university campuses[6] are being created in Russia and around the world that combine educational, scientific and entrepreneurial competencies.

The development of the digital economy and introduction of AI require Internet access. The digital divide is not only technical accessibility, but also the ability to use AI and make a profit (Mikhaylova, 2021; Zemtsov et al., 2022); therefore AI products cannot yet be used universally, but only by a limited number of consumers in the few places that have combined financial, human, and other resources for implementation. For example, when using self-driving cars, remote robotic surgery, and virtual reality, where high data transfer rates (uninterrupted flow) are required, there is a problem of availability and signal speed, e.g., 5G (Blanutsa, 2019b). Russia has a high level of digital inequality: conditions near the largest urban agglomerations are better than in many settlements in the Far East, the Arctic, and the North Caucasus, where there is still no access to broadband Internet (Zemtsov et al., 2022). Therefore, AI technologies will spread gradually according to spatial diffusion models (Baburin and Zemtsov, 2017, 2014; Blanutsa, 2021; Zemtsov et al., 2022): first in the largest cities, then in more advanced regional centers, later in large second tier cities (neighborhood diffusion), and only at the end–in sparsely populated settlements. However, some deviations are possible in this hierarchy as a result of the influence of the state seeking to unify space. The innovation-geographical position may also be significant, e.g., proximity to a foreign source of innovation in border and coastal regions (Baburin and Zemtsov, 2017, 2014; Mikhaylova, 2021).

The described patterns in the development of AI technologies can be found abroad (Cetindamar et al., 2020; Muro and Liu, 2021). Thus, in the USA, AI technologies are concentrated in the main scientific and technological centers specializing in IT, directly connected to the largest universities and the innovation ecosystems formed around them (Muro and Liu, 2021): San Francisco and Silicon Valley (California), Austin and the Silicon Hills (Texas), Boston and Highway 128 (Massachusetts), New York City (New York); Seattle (Washington); Boulder and Denver (Colorado). The 15 largest cities are home to more than 70% of companies, more than 55% of job openings, and about 75% of all AI patents in the United States. The largest employers in these centers are Stanford University, NVIDIA, Alphabet (Google), Facebook, Dell, IBM, Oracle, Amazon, AMD, Deloitte, Microsoft, and Apple. Much of the potential for AI technology in the US is located on the West Coast. At the same time, many research centers exist solely through government funding.

In Canada, the government deliberately concentrates resources (more than USD 100 mln) in the Toronto supercluster, one of the country's main research centers (Muro and Liu, 2021). In 2017, the Vector Institute was created here—an independent nonprofit organization that seeks to strengthen the interaction between researchers of different directions in the field of AI, helping to create new educational programs, as well as conduct research for the real economy.

[4] A science city is understood as a small city with a high concentration of research and related functions; in Russia, such an example can be Pushchino in the Moscow oblast; in the USA, Boulder, Colorado; but most science cities are also located within large urban agglomerations.

[5] STEM—science, technology, engineering, mathematics.

[6] Russian Federation Government. http://government.ru/news/41994/.

In China, the “New Generation AI Development Program”[7] has been adopted from 2017; high-tech development zones are being created, including those with experimental legal regimes. Among them are those that specialize in AI technologies (Tu et al., 2022) in the provinces: Zhejiang (Hangzhou), where Alibaba Group is headquartered; Guangdong (Guangzhou, Shenzhen), where Tencent Holdings and ZTE are registered; Guizhou (Guiyang), where the big data pilot zone has offices, data and research centers of Huawei, Tencent, Alibaba Group, Foxconn, Microsoft, Qualcomm and Apple. China’s advantages in the field of AI are associated with microelectronics development, large volumes of data and commercial digital ecosystems with AI, in particular from Baidu, Alibaba and Tencent. An analysis of the geography of AI in China shows a high concentration of research in the most developed eastern coastal regions, especially in the Yangtze River Delta (Shanghai), the Pearl River Delta (Guangzhou, Shenzhen) and the Bohai region (Tianjin) (Tu et al., 2022). Earlier, innovations penetrated here along with foreign investments in special economic zones, but gradually the Chinese authorities stimulated the development of their own corporations and research and educational centers, which are still located in coastal regions.

In Russia, historically, the state, pursuing the goal of accelerating scientific and technological progress, also sought to concentrate resources and efforts in large cities (Baburin, 2002). In the early period, it was mainly Moscow and the Volga–Oka interfluve around the capital, later St. Petersburg was added, then some centers of the Volga Region (Nizhny Novgorod, Samara, Kazan), the Urals (Yekaterinburg, Perm), and Siberia (Novosibirsk, Tomsk) (Mikhaylov et al., 2020). In recent years, the Azov–Black Sea coast has acquired prospects as part of the southern vector of migration (Druzhinin and Kuznetsova, 2023), and in the future, Primorsky krai, with an orientation toward the rapidly growing Asia-Pacific region (Baburin and Zemtsov, 2017). At the same time, regions can be divided according to their creative-acceptor functions (Baburin and Zemtsov, 2017) into creative cores (they create significantly more technologies than they can implement), creative-acceptor (they both create and implement), acceptor (they mainly use), and innovative periphery (they neither create nor implement).

However, there are few studies of such spatial patterns for the field of AI in Russia. One of them is analysis of the intellectual maturity of regional executive authorities (REA)[8] (National Center ..., 2023), conducted on a survey basis. Only about 13% of REA use AI, although 32% of REA have already planned the implementation of AI solutions. For comparison, the level of AI implementation in federal executive authorities in 2023 was more than 60%.[9] Decision support technologies are in demand: digital platforms ‘Smart City’, video analytics of road infrastructure, automation of citizens’ requests, and document processing services. The main problems when using AI are lack of necessary digital infrastructure, including lack of capacity of data processing centers (DPCs); 62% of regions note a lack of specialists; 88% say there is a lack and/or low quality of data. The lack of ready-made technical solutions for authorities on the market is also singled out. Only 8 regions are developing strategies for using AI, but more than 62 regions (70%) have strategic documents containing blocks dedicated to the development of AI. Earlier, these documents did not always have a relationship with federal strategy; there were contradictions in terms of spatial development priorities (Blanutsa, 2020a). Leading regions with the highest level of AI maturity (National Rating ..., 2023): Moscow, Moscow oblast; the Republic of Tatarstan; Chelyabinsk, Tyumen, Voronezh, and Rostov oblasts; the Republic of Bashkortostan; Altai krai; the republics of Mari El and Sakha (Yakutia); and the Khanty-Mansi Autonomous Okrug. However, the efforts of regional and local administrations are insufficient for developing AI technologies; the region must have a certain objective potential to create breakthrough development.

MATERIALS AND METHODS

In accordance with the methodology for assessing innovation potential (Baburin and Zemtsov, 2017), taking into account the available data, an integral rating of the region’s potential for the creation and implementation of AI technologies was compiled, which includes several components.

First, to assess the general conditions for the development of new technologies, the most suitable national rating of scientific and technological development of regions of the Russian Ministry of Education and Science in 2022 (in points) (National Rating ..., 2023) was used, assessing the educational and research potential of the region and its innovation policy.

Second, to assess the density and diversity of the regional AI innovation ecosystem network, the assess-

[7] https://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm.

[8] The assessment was carried out based on 11 groups of indicators, including the use of artificial intelligence, the effects of its use, infrastructure and data necessary for the use of AI, personnel and competencies in the field of AI. https://files.data-economy.ru/Docs/AI_regions.pdf.

[9] In total, only 5.4% of organizations in Russia used AI technologies, but every third enterprise with more than 10000 employees did (Abdrakhmanova et al., 2021). This situation is largely due to the high complexity of solutions, the need to adapt them to specific tasks and radical restructuring of most business processes, which only large players can afford. At the same time, 59.4% of organizations surveyed by the Higher School of Economics that used AI purchased standard products, so-called packaged solutions (Vishnevskii, 2023).

ment includes data from the National Center for AI Development (National Center ..., 2023) on the number of educational programs in the field of AI,[10] research centers,[11] and scientific organizations, as well as organizations developing AI solutions[12] in 2023 (units). At the same time, educational, scientific and development centers are often different divisions of the same legal entity, e.g., the National Research University Higher School of Economics, Moscow Institute of Physics and Technology, etc., which should be taken into account when interpreting the results.

Third, it was estimated how many operating companies in the region are in the field of software product development,[13] since without them work on the development and implementation of AI may be impossible. It was important to take into account how many employees (potential programmers) they have and the volume of their revenue; i.e., it is important to indirectly assess the market size and/or financial resources that can be used, among other things, to implement AI projects. At the same time, we consider only institutionalized subjects of innovation activity, i.e., open participants registered in the relevant registers, although there are also closed units, e.g., in law enforcement agencies.

To assess the demand for solutions in the field of AI, data was taken on the number of advanced production technologies (APT) used "Artificial Intelligence Technologies" in 2022, units.[14] Obviously, this indicator takes into account only the implemented results in the production process, but underestimates consumer innovation in the service sector.

For an integral assessment of a region's position in the ranking, the arithmetic mean of its ranks (position among other regions) for all 8 mentioned indicators is taken. The data set requires further improvement in terms of more fully taking into account the specifics of the AI field, as well as regular monitoring. The rating does not take into account one of the main limitations to the development of AI—the availability of data centers and the development of ICT infrastructure.

To verify (check the adequacy) of the rating results, data available from Rosstat on advanced production technologies in the field of AI[15] created in the region were used. To solve the problem of a large concentration of values in the zero region (almost all regions do not register technologies in the field of AI), it was decided to use a binary logit model (Baburin and Zemtsov, 2017). With this approach, it is possible to determine the degree of influence of various factors, including the integral rating, on the probability of the creation (registration) of a new AI technology in the region. In addition, to test the influence of the number of potential connections on the probability of creating a new technology (Makarov et al., 2016), the number of potential connections between ecosystem participants was calculated by sequentially multiplying the number of scientific and educational, educational and entrepreneurial, scientific and entrepreneurial counterparties in each region.

The final form of the tested dependence is as follows (Baburin and Zemtsov, 2017):

$$Y_i = \frac{e^{\mathrm{const}+\alpha X_i}}{1+e^{\mathrm{const}+\alpha X_i}},$$

where Y is a binary variable equal to 1 if advanced production technologies in the field of AI were recorded in the region i in 2016–2020; 0 in other cases; e is exponent; *const* is constant; and X is a set of regional variables.

At the end, to check the demand and recognition of AI among the regional population, the per capita number of Internet user requests in the Yandex search engine for the phrase "artificial intelligence" was calculated. In the absence of statistics on the population's use of AI, this indicator can serve as an indirect indicator of the diffusion, if not of the technology itself,

[10]In 35 regions, 95 universities operate 298 educational programs in the field of AI; 17 600 specialists were trained (National Center ..., 2023). More than a third of all programs are implemented in Moscow and Moscow oblast (Moscow State University, MIREA, MIPT, Skoltech, Bauman Moscow State Technical University, HSE, etc.), another 45 programs (15%) are in St. Petersburg (ITMO, St. Petersburg State University, ETU, St. Petersburg Polytechnic University), as well as 21 in Rostov oblast (SFedU), 16 in Tomsk oblast (TSU, TPU, TSUACE), 10 in the Republic of Tatarstan (Innopolis, KGEU), 9 in Yekaterinburg (Ural Federal University), and 6 in Novosibirsk oblast (NSU, NSTU).

[11]There are 96 research centers in 21 regions (National Center ..., 2023). Almost 45% are in Moscow and Moscow oblast, 15% are in St. Petersburg, 6% are in Nizhny Novgorod oblast, 5% are in Perm krai, and 4% each are in Novosibirsk and Samara oblasts. As part of the federal AI program, 12 research centers were supported (about RUB 7 bln until 2024): Skoltech, HSE University, MIPT, MEPhI National Research Nuclear University, Blokhin National Medical Research Center of Oncology, Ivannikov Institute for System Programming of the Russian Academy of Sciences (Moscow), Innopolis University (Republic of Tatarstan), St. Petersburg State University, ITMO University (St. Petersburg), NSU (Novosibirsk oblast), Samara University (Samara oblast), Nizhny Novgorod State University (Nizhny Novgorod oblast).

[12]There are 394 organizations developing AI technologies in 40 regions (National Center ..., 2023), of which 220 (56%) are registered in Moscow (VK, MTS, Yandex, Sber, etc.); 50 (12%), in St. Petersburg; 12, in the Republic of Tatarstan and Sverdlovsk oblast; 8, in Perm krai and Moscow oblast; and 7, in Novosibirsk and Samara oblasts. Most developers are associated with universities and research institutes, or with major companies.

[13]It is impossible to directly assess the performance of the AI industry due to the lack of a corresponding code in the statistical classification (OKVED). Therefore, the generalized OKVED code 62.01 Computer Software Development was used, but only companies were selected that had nonzero revenue and employment, and they had intellectual property; i.e., they introduced innovations; SPARK Interfax. https://spark-interfax.ru/.

[14]EMIS. https://www.fedstat.ru/indicator/58662.

[15]EMIS. https://www.fedstat.ru/indicator/58661.

then at least of ideas about it, interest in the topic, and receptivity of the population (Mikhaylova, 2021).

RESULTS

The field of AI in Russia has been actively developing in recent years, and the overall research potential is growing. In 2022, Russia rose to 14th place in the number of publications (Iskusstvennyi ..., 2023) and occupied 16th place in patents in 2021. Over the past 10 years, 77 regions (out of 89[16]) have filed applications for patents in the field of AI; 138 such patents in 2022. However, not all regional innovation ecosystems have the proper potential for the development of AI technologies. As already noted, education in the field of AI can be obtained in 21 regions, research is conducted in 35, and technology is being developed in 40 (National Center ..., 2023). If we evaluate the AI market only based on data on development companies, then there are about 400 of them in Russia, with 71% registered in Moscow, and the share of the five leading regions is ≈90% (Iskusstvennyi ..., 2023).

Overall, the development of AI technologies in Russia corresponds to the laws of the geography of innovation (Fig. 1). The main potential is concentrated in the largest scientific and technological centers with a diverse economy, a developed high-tech sector, major universities and research centers (Baburin and Zemtsov, 2017): Moscow, St. Petersburg, Moscow oblast, the Republic of Tatarstan, and Novosibirsk oblast. Forty-five percent of all technology startups in Russia are concentrated here; i.e., a certain culture of entrepreneurship, a startup ecosystem, has formed, and up to 90% of all venture investments in Russia are concentrated in Moscow and St. Petersburg. Due to the large number of counterparties in the AI field, the intensity of creation of new technologies is higher here.

The first five leading regions of the ranking in terms of potential for creating AI technologies (type 1)—Moscow, St. Petersburg, Moscow oblast, the Republic of Tatarstan and Novosibirsk oblast (about 23% of Russian residents)—account for about 66% of all research groups in the field of AI, 54% of educational programs, 75% of development organizations (55% of the latter are in Moscow), 63% of companies developing software,[17] 74% of their employees, and 83% of revenue are concentrated here (Fig. 2). In fact, these are the regions where the probability of creating new AI technologies is greatest. However, these urban agglomerations have a lower share of AI-related advanced production technologies (APT) in use, at 32%. Generally speaking, creative regions have previously created more technologies than they consumed (Baburin and Zemtsov, 2017). However, in this case, this is probably also due to the predominance of service (non-production) functions in large cities, although smart city technologies are being introduced in them and experimental legal regimes are being created (Table 1).[18]

Type 2 is represented by 16 regions with the largest of the country's urban agglomerations: Yekaterinburg, Nizhny Novgorod, Chelyabinsk, Samara—Tolyatti, Tomsk, Rostov-on-Don, Krasnodar, Perm, Ufa, Voronezh, Krasnoyarsk, Irkutsk, and Yaroslavl, large educational and scientific centers, where about 31% of the inhabitants live. These regions' highly diversified industries account for 26% of all AI software, but the regions lack the scale of the development sector to create disruptive technologies (only 11% of software company revenue in the sample). However, this group contains about 26% of all research centers in the field of AI, 32% of educational programs, and 18% of development companies. Most regions have created experimental legal regimes in the field of AI, with the exception of Perm krai and Rostov, Belgorod, and Yaroslavl oblasts. Half the regions lack some significant element of the regional innovation ecosystem focused on AI; e.g., there are no research centers in Sverdlovsk and Tyumen oblasts; there are no corresponding training programs in Krasnodar krai and Belgorod oblast; Sverdlovsk, Ulyanovsk, and Belgorod oblasts and Krasnodar krai are lagging in the use of AI in the public administration system (National Center ..., 2023). Closing these gaps would strengthen ecosystems and be more likely to lead to the development of new technologies.

The next group of 23 regions (type 2) with average potential (23% of residents) contains only 5% of research organizations, 10% of educational programs, and less than 5% of developers in the field of AI. However, 25% of the APT is used, that is, a certain potential for implementation due to the presence of large manufacturing enterprises. This is due to the development of the military-industrial complex (the Udmurt Republic and Omsk, Tula, Ryazan, Penza, Arkhangelsk, and Vladimir oblasts) and the activity of manufacturing transnational corporations (TNCs)[19] (Kaliningrad, Kaluga, and Tver oblasts, Primorsky krai). The modern robotics industry can become a significant consumer of AI solutions. Most regions (15 out of 23) have experimental legal regimes. According to the typology of regions according to creative—acceptor functions (Baburin and Zemtsov, 2017), the

[16]In the article, Russia's borders are considered in accordance with the Constitution of the Russian Federation.

[17]The largest companies creating and using AI technologies in Russia are located in these regions: Sber, Yandex, VK, TsRT, ABBYY, etc.

[18]Special legal regimes for testing new developments. Federal Law no. 258-FZ of July 31, 2020 On Experimental Legal Regimes in the Field of Digital Innovation in the Russian Federation.

[19]The departure of foreign TNCs from Russia has only increased the relevance of the development and implementation of domestic AI technologies for restoration of production.

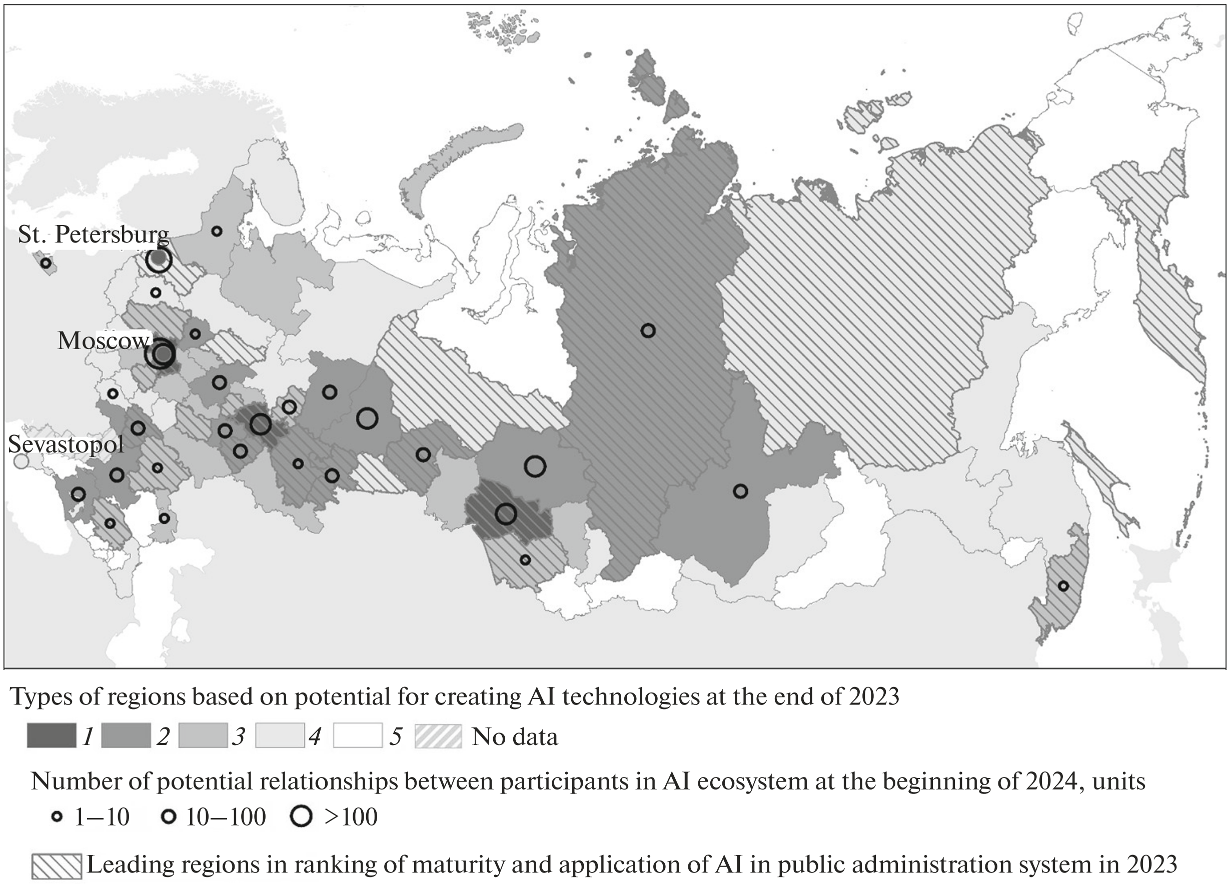

Fig. 1. Geography of AI technologies in Russia.
Note: Types of regions are shown in Fig. 2.
Source: prepared by author.

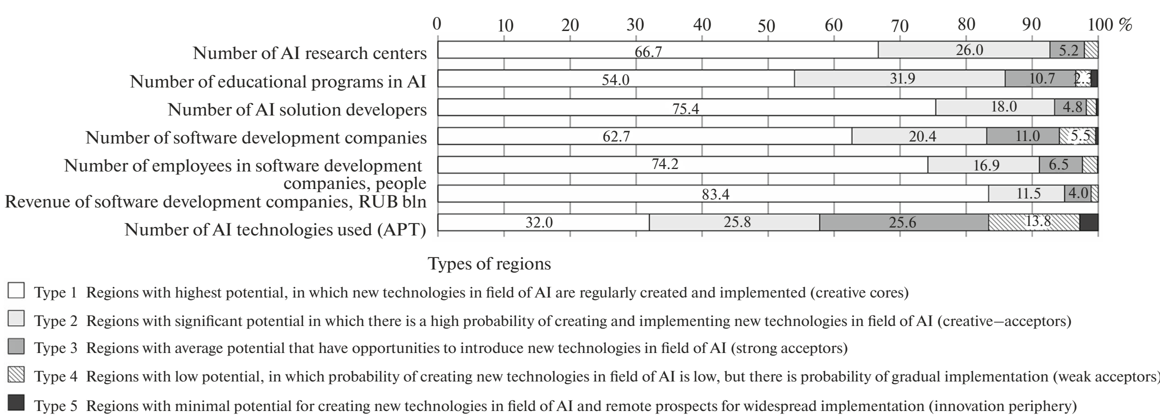

Fig. 2. Distribution of key indicators of AI sector by type of region, %.
Source: prepared by the author.

regions represented in this group predominantly master new technologies (strong acceptors).

The two remaining groups of regions (types 4 and 5)—41 federal subjects and 23% of residents—have almost no potential for creating new technologies in the field of AI (weak acceptors and innovative periphery). Most of them do not have relevant research and educational centers, but they can benefit from the replication of best practices. For example, the Republic of Sakha (Yakutia), Khanty-Mansi Autono-

Table 1. Experimental legal regimes in field of AI in the Russian regions

AI Sphere	Region/Territory
Operation of highly automated vehicles	***Moscow***, Innopolis (***The Republic of Tatarstan***), federal territory 'Sirius', M-11 "Neva" (Tver, Novgorod, Leningrad oblasts)
Operation of unmanned aerial systems and Aerial logistics	***Moscow***, *Samara*, *Tomsk*, Tver oblasts; *the Republic of Bashkortostan*; Kamchatka krai; Khanty-Mansi, Yamalo-Nenets, Chukotka autonomous okrugs
Operation of agricultural unmanned aerial systems	***The Republic of Tatarstan***; Altai and Stavropol krais; Astrakhan, Volgograd, *Voronezh*, Lipetsk, *Nizhny Novgorod*, ***Novosibirsk***, Saratov, Tambov and Ulyanovsk oblasts
Personal medical assistants	***The Republic of Tatarstan***; ***Novosibirsk***, *Samara*, *Tyumen*, *Irkutsk*, Magadan, Ryazan oblasts; Khanty-Mansi Autonomous Okrug
Providing transport services using highly automated vehicles	The Republics of ***Tatarstan***, *Bashkortostan*, Buryatia, Crimea, Chuvashia; Zabaykalsky, *Krasnodar*, *Krasnoyarsk*, Primorsky, and Khabarovsk krais; ***Moscow***, Leningrad, Amur, Vladimir, *Voronezh*, ***Irkutsk***, Kurgan, Lipetsk, Murmansk, *Nizhny Novgorod*, Novgorod, ***Novosibirsk***, Omsk, Orenburg, Penza, *Samara*, *Sverdlovsk*, Smolensk, Tver, *Tomsk*, Tula, *Tyumen*, *Chelyabinsk*, Kemerovo oblasts; ***Moscow***, ***St. Petersburg***; Khanty-Mansi and Yamalo-Nenets autonomous okrugs

Bold italics indicate the leading regions in terms of the potential for creating AI technologies (type 1), while plain italics indicate regions belonging to type 2.
Source: II RF. https://ai.gov.ru/ai/regulatory/.

mous Okrug, and Leningrad oblast are already among the leading regions with the highest level of AI implementation in state and municipal governments. Experimental legal regimes have been introduced in certain regions, e.g., in Khabarovsk krai, Tambov, Leningrad, Novgorod, and Lipetsk oblasts, and Khanty-Mansi Autonomous Okrug. In other words, lagging regions should focus primarily on leveraging AI advances. In many regions, the labor shortage observed in Russia in recent years may spur adoption of AI.

To check the identified patterns, the probability of the creation (emergence) of a new AI technology in the region was modelled depending on the regional characteristics considered in the rating.

According to Rosstat,[20] in 2020, only 46 APT "Artificial Intelligence Technologies and/or Expert Systems" were created in Russia, of which only 9 are fundamentally new, APT were created in the leading regions and in Sverdlovsk oblast.

The actual models constructed (Table 2) confirm that each of the variables we used and the integral rating have a statistically significant positive effect on the probability of creating a new AI technology, but the number of observations is small. Using a simple indicator of the potential number of connections (Makarov et al., 2016) (model 8) also describes the probability of the emergence of a new technology quite well, as judged by R^2, which proves the need for further development of innovation ecosystems in terms of expanding the number of participants and the intensity of connections between them.

[20]EMIS. https://www.fedstat.ru/indicator/58661#.

In general, model 9 allows us to estimate the probability of creating a new technology depending on the value of the integral rating (Fig. 3). This probability decreases sharply as the rating decreases.

The public's receptivity to AI is an important indicator of the technology's ability to reach mainstream consumers. The number of requests in Yandex for the phrase "artificial intelligence" in December 2023 exceeded 146.7 mln, 9% of queries were executed in Moscow (8.6% of the Russian population); in Moscow oblast, 6%; in Krasnodar krai, 3.9%; in St. Petersburg, 3.8%. The distribution of queries only to some extent corresponds to the basic patterns of spatial diffusion of innovations (Zemtsov et al., 2022). Thus, in terms of per capita number of requests, Moscow, St. Petersburg, and the surrounding regions are in the lead, which corresponds to the role of the country's largest urban agglomerations as innovating regions, where new technologies come and where they are mastered faster than in any other place in the country thanks to the highly educated population, the largest technological organizations (Baburin and Zemtsov, 2014; Zemtsov et al., 2022). The new technology then spreads through the hierarchy of cities to the country's largest second-tier urban agglomerations; Here are the leaders in AI susceptibility: the Novosibirsk, Krasnoyarsk, Krasnodar, Rostov, and Voronezh urban agglomerations, as well as in regions near large centers of innovation by neighborhood diffusion: Smolensk and Arkhangelsk oblasts in the Northwes; Vladimir, Ryazan, and Yaroslavl oblasts are located near Moscow.

Further patterns are more difficult to trace, which may be due to the short observation period, the lack of correction for the small number of residents and the

Table 2. Regression analysis results

Dependent variable: creation of AI advanced production technologies (APT) in a region (1, yes; 0, no). Logit regression.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	–84* (50)	–4.1*** (0.85)	–4.0*** (0.60)	–1,5e+02 (1.8)	–6.3*** (1.4)	–7.0*** (1.5)	–5.9*** (1.3)	–14*** (4.8)	8.3** (3.3)
Scientific and technological potential of region	0.43* (0.25)								
Number of research centers in field of AI		0.53*** (0.12)							
Number of educational programs in field of AI			0.19*** (0.06)						
Number of developers in field of AI				19*** (0.00)					
Number of APTs used in the field of AI					0.21*** (0.073)				
Share of employees in software development companies						0.001*** (0.0001)			
Revenue in software development companies							0.17*** (0.03)		
Number of potential relationships between counterparties								0.12** (0.05)	
The potential of creating AI technology									1.1*** (0.41)
R^2	0.80	0.49	0.42	0.93	0.64	0.81	0.76	0.89	0.86
Schwartz criterion	16.7	28.2	30.9	11.7	22.7	16	18	13	14

Standard errors are given in parentheses. * Is significant at 10% level of p-value. ** Is significant at 5% level. *** Is significant at 1% level. R^2, McFadden pseudo-R^2 (McFadden).

greater distribution of the Internet in the northern regions. The Republic of Tatarstan and Nizhny Novgorod oblast are not among the leaders, and among the lagging regions there are large urban agglomerations (Ufa, Perm, Yekaterinburg, and Vladivostok), which may be due to the greater role of production in employment and the lesser involvement of residents in digitalization processes in the listed regions. However, as expected, among the lagging behind (innovation periphery) are regions with small regional centers with a predominantly rural population: the republics of Chechnya, Altai, Ingushetia, Dagestan, North Ossetia, and Adygea, where innovations penetrate with difficulty due to difficult natural conditions (mountainous territories) and a conservative environment. The described patterns only partially coincide with those identified in general for the digital economy (Mikhaylova, 2021). Further development of the approach is necessary, including the use of a larger period and larger number of phrases.

CONCLUSIONS

The creation, implementation, and dissemination of AI technologies are concentrated in centers with high innovation potential, which corresponds to the patterns of innovation geography (Baburin and Zemtsov, 2017).

The creative core regions with the maximum probability of creating and implementing new technologies are identified (Moscow, Moscow oblast, St. Petersburg, the Republic of Tatarstan, and Novosibirsk oblast), 16 creative-acceptor centers capable of both creating and implementing AI technologies, predominantly acceptor centers (23 regions), and 41 regions with minimal potential. These four groups mentioned are approximately equal in population, but the first two have large urban agglomerations.

The last group of regions is generally characterized by low scientific and technological development: previous new technologies, including digital ones, were

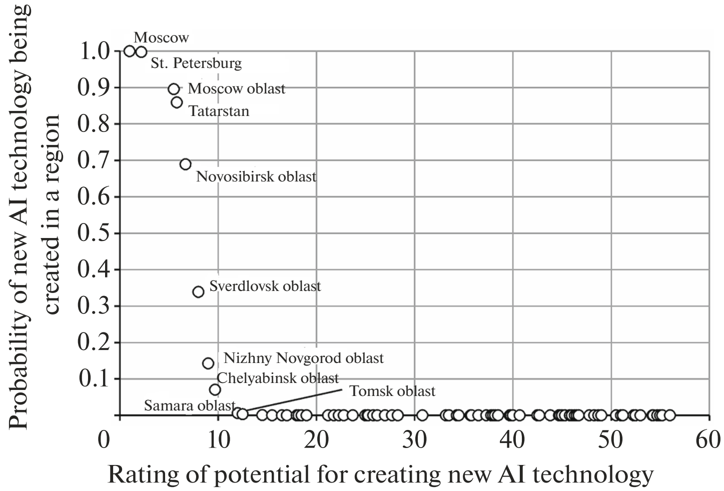

Fig. 3. Probability of creating new AI technology depending on region's position in ranking of potential for creating AI technology.
Compiled by author.

mastered here late (Baburin and Zemtsov, 2017, 2014). This group includes both economically underdeveloped peripheral republics (republics of Tyva, Kalmykia, Altai, etc.), raw materials-producing northern territories of new development (Chukotka, Nenets, Khanty-Mansi, Yamalo-Nenets autonomous okrugs, etc.), which have not accumulated sufficient volume knowledge, as well as aging old industrial regions (Pskov, Smolensk, Novgorod oblasts, etc.), which do not have adequate human capital. To some extent, the stability of such a center–periphery model may be associated with path dependency, when favorable factors (human and entrepreneurial capital, infrastructure, etc.) in the largest urban agglomerations accumulate with each new technological wave, and the negative effects in lagging, peripheral regions (lack of labor, capital, unfavorable cultural and institutional environment, etc.) persist.

Thus, the combination of four to five rather different types of regions, judging from the early propagation of the new technological wave, is highly likely to continue into the future. Although some regions pursuing an active policy for the introduction and dissemination of AI (see Table 2) have a chance at overcoming path dependency.

To determine federal and regional priorities for AI support in Russia, it is necessary to further improve the monitoring system, taking into account publication and patent activity, market volumes and venture investments, government support and digital infrastructure, and the level of digital maturity.

State regional innovation policy, in contrast to social policy, cannot be aimed at supporting those lagging behind, since the resources for a technological breakthrough are too small, especially against growing international confrontation. The lack of resources requires their concentration to save time on interaction, which was achieved, e.g., in the Soviet period using the example of nuclear and space projects, work on which at the initial stage was mainly carried out within the Moscow urban agglomeration.

State support should be differentiated depending on the potential of the region. Leading regions can receive priority attention and funding with the support of relevant projects in the field of creating AI technologies in Russia; e.g., headquarters can be created to consolidate efforts in the field of AI. In regions of the second type, it is necessary to supplement the missing elements of the innovation ecosystem and a clear specialization of AI technologies, since dispersing small resources is ineffective. In acceptor regions, preference for support should be given to AI production technologies, while in lagging regions, to increasing the population's sensitivity to digital technologies in general, eliminating digital illiteracy and inequality; in certain regions with no potential to create AI technologies, AI products can be actively distributed.

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CONFLICT OF INTEREST

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