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Russian AI Research 2010 to 2018

Topics, Trends, and Institutions

CSET Issue Brief

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Executive Summary

In October 2019, the Russian government released a national strategy for the development of artificial intelligence, promising to increase support for scientific research in the AI field. By most metrics necessary for the advancement of AI—hardware, data, talent, and investment—Russia lags behind the United States and China.[1] Yet the Russian government has an ambitious vision for AI and is committing resources to strengthening Russian science and technology more broadly.

This issue brief presents an overview of Russia's scientific research on artificial intelligence published in English-language journals over the past decade, including trends in topical focus and institutional activity. We analyzed 7,095 research papers published in English between 2010 and 2018 across different fields of science related to the development and application of AI and machine learning. The authors of these papers listed affiliations with 249 institutions in Russia. Our key findings show:

- Between 2010 and 2018, the number of English-language publications by Russian scientists in fields such as machine learning, algorithms, and robotics has increased more than six times.
- Nearly half of English-language research papers published by Russian scientists between 2010 and 2018 were linked to the following six AI related fields: computer vision, pattern recognition, linguistics, natural language processing, algorithms, and robotics.
- Russia's scientific research output in English-language journals remains relatively low compared to that of researchers from the United States and China.
- Most of the Russian institutions that lead in English-language AI research publications benefit from numerous forms of public funding, and more than half of the top 20 participate in Project 5–100, which provides federal funding to Russia's leading universities in order to increase their global competitiveness.

The Russian government will use publications in leading international scientific journals as one of the key metrics to assess progress toward its goals in AI. Given the dual-use nature of AI and the linkages between Russia's scientific research community and the government, these developments also have important implications for national security.

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Introduction

The Russian government believes the country could become a leader in AI, given the high quality of Russia's STEM education programs and achievements in the fields of information science, computational modeling, and programming.[2] These expectations are not without merit. Russia ranks among the top 10 nations in terms of spending on research and development, with a budget of between $36.3 and $41.5 billion in 2018.[3] The country also has one of the highest tertiary education degree attainment rates across OECD countries, at 63 percent of 25- to 34-year-olds, compared with the OECD average of 44 percent.[4]

Scientific research in Russia is predominantly state-led and state-sponsored, and has traditionally been divided into three sectors:

- the academic sector, composed of the state science academies and their subsidiary bodies, including the Russian Academy of Sciences,
- the university sector, represented by higher education institutes, and
- the business enterprise sector, encompassing "former industrial research organizations, state R&D companies, research institutes and construction bureaus of the defense sector."[5]

Over the past decade, the Russian government has implemented reforms designed to boost Russia's global research standing, in part by increasing the number of academic publications, patents, and researchers.[6] These measures included giving the universities a greater role in the conduct of scientific research, opening new state research centers, increasing investments in scientific equipment and infrastructure, promoting collaboration with industry, and allocating additional funding from federal and regional budgets.[7]

One of the key initiatives to raise the competitiveness of leading Russian universities is Project 5–100, which aims to place five Russian universities in the top 100 of global higher education institutions by 2020. Thus far, Project 5–100 has failed to achieve its namesake goal. Yet the past years have seen a substantial increase in the number of publications in journals indexed by international databases such as Web of Science and Scopus, with Project 5–100 institutions leading the way. According to the U.S. National Science Foundation, Russia's share of articles appearing in international databases more than doubled between 2012 and 2018, with Russia rising from the 14th to the 7th place on the list of the world's largest-producing science regions according to publication output.[8]

In this report, we evaluate Russia's public-facing scientific research output in areas related to AI, as proxied by English-language publications indexed by datasets of international scholarly literature.[9] We begin by highlighting the key AI-related topics Russian scientists have explored over the past decade and discuss how these trends fit larger developments in civilian and military AI technologies. Next, we compare overall Russian, American, and Chinese AI-related research output, as well as the distribution of publications for each country by the most frequent AI-related fields of study. The last section focuses on the Russian institutions researching AI, including those affiliated with Project 5–100.

Importantly, publication output in English-language journals is an imperfect measure of innovation and impact, especially for researchers based in a non-English speaking country.[10] Furthermore, this analysis is a partial representation of Russia's research in AI. The academic sector and higher education institutions account for most of the research published in the English-language journals covered by our analysis, but don't amount to the entirety of scientific research in Russia. Insofar as AI researchers in the business enterprise sector have fewer incentives or opportunities to publish in English-language journals, our analysis underweights their contributions.[11] That said, a focus on scholarly research provides insights into Russia's foundational research in AI, which has traditionally been the bastion of the academic sector.[12] Moreover, governmental reforms are emphasizing applied research and providing more funds to university-led research.[13] Scholarly research publications should therefore also capture university-led research in applied AI. As such, we encourage the reader to approach this analysis as a view of shifting priorities and trends in Russian research in AI.

Topics and Trends

The development and application of AI occur across a variety of scholarly disciplines whose fields differ in their methods, goals, and applications. A fundamental challenge in bibliometric study of this research is that analysts often disagree about what constitutes AI. We address this by inferring and applying a functional definition of AI-relevant research from the arXiv.org repository of preprints in physics, biology, computer science, statistics, and a few other disciplines. The result is an automated method for identifying AI and machine learning (ML) research and its applications across these fields, rather than manual categorization of each article or a hand-crafted keyword query.[14]

We conducted our search for English-language articles on the topic of AI authored by Russian researchers in Microsoft Academic Graph (MAG).[15] This corpus offers a comprehensive perspective on scientific output in English since 2010.[16] Between 2010 and 2018, we identified a total of 7,095 relevant papers across different fields with at least one author affiliated with a Russian institution.

Table 1 presents the top fields of study where such papers were published. To clarify, the below fields of study are derived from MAG, which provides scores for papers indicating their association with various fields. In our calculation of the distribution of papers across fields, each paper is only counted in one category based on the highest field score.

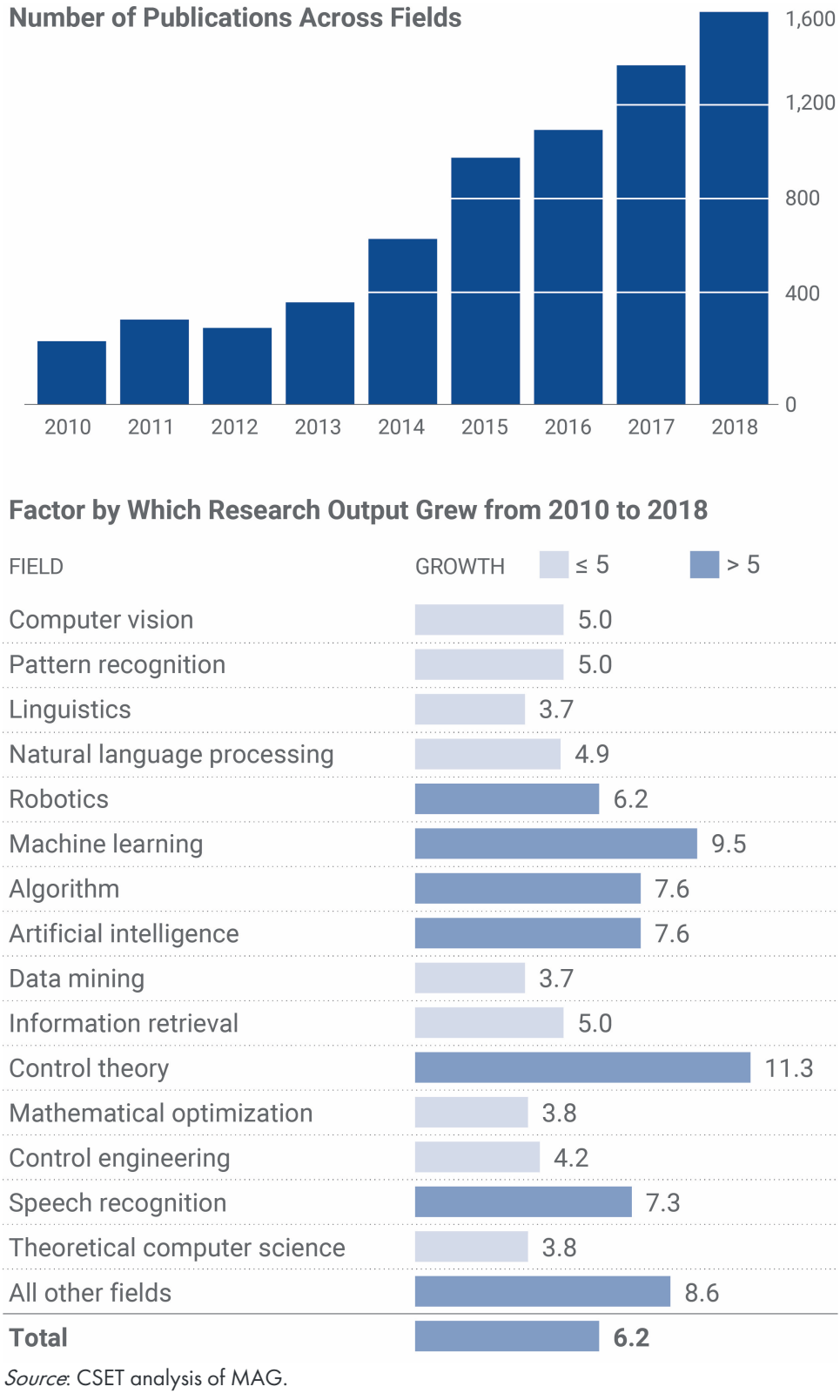
Table 1. Number of AI papers published by Russian scientists by primary field, 2010–2018.

Field	Papers	Share of total (%)
Computer vision	698	9.8%
Pattern recognition	676	9.5%
Linguistics	623	8.8%
Natural language processing	450	6.3%
Algorithm	414	5.8%
Robotics	413	5.8%
Machine learning	358	5.0%
Artificial intelligence	320	4.5%
Information retrieval	226	3.2%
Data mining	220	3.1%
Theoretical computer science	147	2.1%
Control theory	134	1.9%
Speech recognition	133	1.9%
Mathematical optimization	118	1.7%
Control engineering	109	1.5%
All Others	2,056	29.0%
Total	**7,095**	100.0%

Source: CSET analysis of MAG.

Research areas change and evolve over time, responding to scientific breakthroughs and other trends. Figure 1 demonstrates the growth in AI-related research output between 2010 and 2018, paying attention to both annual cumulative output across fields and growth within those top fields with the most research publications. Annual counts of papers are included in the appendix.

Figure 1. Growth in Russian AI publications, 2010–2018.



Source: CSET analysis of MAG.

Between 2010 and 2018, English-language publications by Russian scientists in fields related to AI increased more than six-fold. The most notable change is between the years 2014 and 2015, when the total number of publications grew from 673 to 1,003. This increase reflects both global trends in AI research and national, Russian factors. Since 2013, Russia's leading universities—especially those affiliated with Project 5–100—have focused on increasing the number of publications in journals indexed by international databases. Researchers in institutions participating in Project 5–100 have also had more opportunities to attend international conferences and undertake study tours to foreign institutions, in turn leading to more publications in English-language journals.[17]

Looking at growth within the AI-related fields between 2010 and 2018, the number of research publications linked to machine learning grew by nine and a half times, while publications indexed under artificial intelligence and algorithms each increased by over seven and a half times. Robotics is another field where research output increased significantly—over six times between 2010 and 2018. As we discuss below, the growth in scholarly research on robotics corresponds to a rising interest in robotics in Russia's commercial technology and defense sectors.

Research related to speech recognition increased more than sevenfold, while natural language processing and computer vision research each grew fivefold. Notably, the growing scientific research focus on machine learning, computer vision, and natural language processing subfields mirrors advances in the commercial sector, where Russian developers have seen breakthroughs in facial and speech recognition technologies.

Comparing Russian, American, and Chinese AI Research Output

In terms of overall English-language research output in fields related to artificial intelligence, Russian researchers clearly lag behind their American and Chinese counterparts. Between 2010 and 2018, Russian researchers published 7,095 papers related to AI, while U.S. researchers published 271,464 papers and Chinese researchers published 262,112 papers. Note that the papers authored by the American and Chinese researchers were also retrieved from MAG.

Table 2 presents a comparison between Russian, American, and Chinese AI research output across the key fields, between 2010 and 2018. Compared to Russian researchers, U.S. researchers published 23 times more papers indexed under artificial intelligence, 58 times more in machine learning, 34 times more on algorithms, and 42 times more exploring computer vision. On the same topics, Chinese researchers outproduced Russian researchers 22:1 in papers indexed under artificial intelligence, 36:1 in papers linked to machine learning, 46:1 in papers related to algorithms, and 64:1 in papers focused on computer vision.

Table 2. American and Chinese AI research output vs. Russian AI research output: numbers of papers and ratios in key fields.

	NUMBERS OF PAPERS			RATIO COMPARED WITH RUSSIA	
Field	**Russia**	**China**	**U.S.**	**China**	**U.S.**
Computer vision	698	44,762	29,453	64	42
Pattern recognition	676	52,461	30,194	78	45
Linguistics	623	5,749	6,548	9	11
Natural language processing	450	7,302	12,044	16	27
Robotics	413	12,051	14,254	29	35
Machine learning	358	12,999	20,600	36	58
Algorithm	414	19,158	14,222	46	34
Artificial intelligence	320	6,940	7,404	22	23
Data mining	220	14,584	9,699	66	44
Information retrieval	226	5,875	7,467	26	33
Control theory	134	9,882	4,618	74	34
Mathematical optimization	118	6,931	7,390	59	63
Control engineering	109	3,265	1,789	30	16
Speech recognition	133	5,079	7,775	38	58
Theoretical computer science	147	3,089	6,014	21	41
All other fields	2,056	51,985	91,993	25	45
Total	**7,095**	**262,112**	**271,464**	**37**	**38**

Source: CSET analysis of MAG.

Russia's English-language research output in AI is much lower than that of the United States and China for a number of reasons. Most basically, Russia's expenditures on research and development are smaller than that of the United States, China, and other countries like Japan, Germany, South Korea, France, United Kingdom, and Taiwan. Public funding accounts for nearly 70 percent of the total funding for science in Russia—an extremely high share when compared to other developed countries focused on strengthening their scientific base.[18] In other words, Russian science is both underfunded by the state and struggles to attract business sector funding.

Talent is equally as important as funding to scientific productivity. Russia has more researchers per million inhabitants than China—3,075 compared to 1,089. But it falls behind the United States, where there are 4,205 researchers per million inhabitants, and other scientifically advanced countries like South Korea, Japan, Singapore, or Israel.[19] Russia ranks 48th out of 132, according to the Global Talent Competitiveness Index, which analyzes "the policies and practices that enable a country to develop, attract, and empower the human capital that contributes to productivity and prosperity."[20] By comparison, the United States is ranked 2nd. Notably, China is ranked 42nd in part due to its challenges in attracting talent, and low levels of both external and internal openness—issues that Russia struggles with as well.[21]

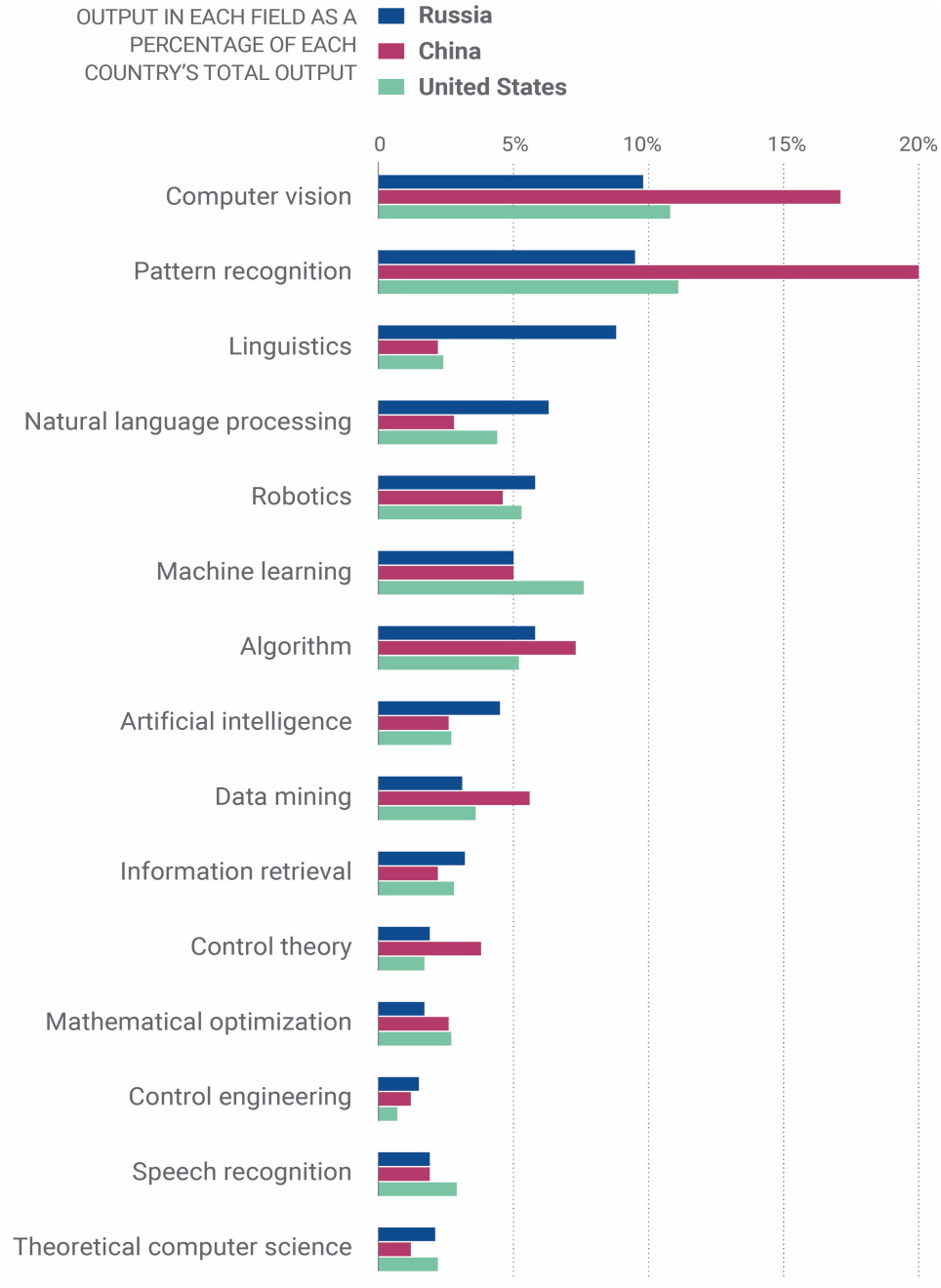
Related to talent, Russia's scientific personnel age structure is another factor damping productivity. Russia's middle-aged scientists—those between the ages of 40 and 59, who as a group tend to be most productive—account for less than a third of the country's total researchers. In countries with high research output, this group constitutes closer to 60 percent.[22]

In addition to funding and talent, there is also the question of access. Scientists from non-English speaking countries are often at a disadvantage when it comes to publishing in English-language journals. This is particularly true for publications in top journals where researchers' reputation, publication record, and institutional prestige are important factors.

Finally, despite President Putin's expressed desire to see Russian science take a more prominent place on the global stage, there are major barriers to publishing in international journals. For example, in 2015, an investigation by the scientific journal *Nature* found that at Moscow State University, research papers were subjected to vetting by the Federal Security Service (FSB) before publication, even if publications did not appear to have military or industrial significance.[23] Russian universities generally have staff responsible for scrutinizing articles and lectures researchers want to present at foreign conferences or publish in international journals. Although officials at Moscow State University denied FSB vetting, a great deal of ambiguity surrounds the expert commissions examining research papers before presentation at conferences or publication, adding to other bureaucratic hurdles to publishing.[24]

Discrepancies in overall output aside, it is perhaps most useful to examine which AI fields and topics researchers from Russia, China, and the United States each focus on. Figure 2 presents the distribution of research publications in the key AI-related fields of study as part of the total output of each country's AI-related scientific publications.

Figure 2. Field distribution of AI publications by country, 2010–2018.



Source: CSET analysis of MAG.

As Figure 2 shows, nearly half of Russia's English-language research output is concentrated in the following six AI-related fields: computer vision, pattern recognition, linguistics, natural language processing, robotics, and machine learning. While we cannot comment on the content of these research publications based on our data, some of the applied uses of the technologies explored in these scholarly fields merit consideration given their relevance to national security.

For instance, research in computer vision, pattern recognition, and machine learning has applications for facial recognition technology, which in turn has broad uses ranging from social media and smart cities to public safety and law enforcement. Russia's private sector developers have made notable progress in this field; indeed, one of the country's leading facial recognition AI startups, NtechLab, even won IARPA's 2017 Face Recognition Prize Challenge for its FindFace application, which allowed users to find people's profiles with a photo on Russia's popular social media network, VKontakte.[25] More recently, Russian companies, NtechLab and Vision Labs, claimed to have developed facial recognition technology to monitor public compliance with quarantine restrictions in Moscow during the COVID-19 pandemic.[26]

Along similar lines, AI-related research in linguistics and natural language processing can be applied to internet content monitoring, which enables information control and censorship. Since 2012, the Russian government has introduced a number of laws tightening control over internet infrastructure, imposing new technical means for monitoring internet activity, filtering and rerouting internet traffic, and strengthening government capacity to block online content.[27] Roskomnadzor—the federal executive authority charged with overseeing online and media content—reportedly hired experts from the National Research University–Higher School of Economics to customize its automated internet monitoring system. It consists of three parts: 1) "Simona" (the Violations Monitoring System) that browses websites from a list compiled by Roskomnadzor, flagging materials for operators that contain certain keywords in order to detect illegal content, including in readers' comments; 2) "Siren" (the Violation Registration System); and 3) "Revisor" (Inspector), which oversees which websites Russian internet providers are required to block.[28] Linguists are employed to administer the automation settings and manage Simona's dictionaries to ensure system flexibility and coverage.[29]

The scholarly focus on robotics corresponds to growing interest in robotics among Russia's commercial technology sector. For example, some estimates show an increasing demand for service robots, especially in the education sector.[30] There may also be opportunities for growth for industrial robots, considering the number of industrial robots per worker in the manufacturing industry in Russia is currently 20 times less than in China.[31]

The Russian defense community is also very interested in robotics. According to the Russian Deputy Minister of Defense, Nikolai Pankov, "Of the 388 scientific research institutions of the Ministry of Defense, 279 are concentrated in military schools. The majority of them are actively engaged in research in the field of artificial intelligence, robotics, military cybernetics and other promising areas."[32] Indeed, rather than academia or the private sector, the Russian Ministry of Defense is at the forefront of research and development of emerging technologies. And Russia's interest in military robotics has gone beyond research: the Russian armed forces have tested and used a range of unmanned aerial and ground vehicles in Syria for tasks such as demining, intelligence, surveillance, and reconnaissance, logistics, and combat support.[33]

To be clear, Russian researchers are inherently constrained by government regulations prohibiting the publication of research with military applications or considered "state secret." It is therefore unlikely that the AI-related publications indexed by international databases directly explore surveillance technology or military robotics. Still, scientific research in Russia is heavily subsidized by the state, and closer collaboration between the defense establishment and academia is part of Russia's vision in AI. Moreover, considering the dual-use nature of AI, advances in scholarly research could have applications and implications for national security.

Russian Institutions Researching AI

Russia's AI strategy aims to develop "world-class education" for "training highly qualified specialists and managers in the field of artificial intelligence." By 2030, the government wants to see "Russian educational institutions of higher learning... occupy leading positions the world over in areas within the field of artificial intelligence."[34] Russia's universities, however, have struggled to achieve the same levels of global recognition as leading American and Chinese institutions. Based on the U.S. News and World Report 2020 Best Global Universities Rankings, none of the Russian institutions made it to the top 200.[35]

We identified 249 institutional affiliations across the 7,095 research papers.[36] Table 3 lists the top 20 institutions producing AI-related research papers. Note that for papers with multiple co-authors and papers with authors who listed multiple institutional affiliations, we gave credit to each institution listed as an affiliation. Papers co-authored by multiple researchers from the same institution were only counted once when attributed to the relevant institution. Additionally, considering that Table 3 only includes the top 20 institutions, the sum of the share of the total ascribed to each institution does not amount to 100 percent. [37]

Table 3. Top 20 Russian institutions associated with AI publications, 2010–2018.

Institutions Affiliated with Project 5–100 Based on the Ministry of Science and Higher Education of the Russian Federation

	Institution	Papers	Share of total (%)
1.	Russian Academy of Sciences	1,530	18.7%
2.	National Research University – Higher School of Economics	895	10.9%
3.	Moscow State University	653	8.0%
4.	Saint Petersburg State University	417	5.1%
5.	Moscow Institute of Physics and Technology	303	3.7%
6.	Kazan Federal University	251	3.1%
7.	Skolkovo Institute of Science and Technology	232	2.8%
8.	National Research Nuclear University MEPhI	201	2.5%
9.	Southern Federal University	189	2.3%
10.	Tomsk Polytechnic University	163	2.0%
11.	Ural Federal University	155	1.9%
12.	Peoples' Friendship University of Russia	153	1.9%
13.	Bauman Moscow State Technical University	147	1.8%
14.	Yandex	135	1.6%
15.	Siberian State Aerospace University	125	1.5%
16.	Tomsk State University	122	1.5%
17.	Saint Petersburg State Polytechnic University	106	1.3%
18.	Novosibirsk State Technical University	97	1.2%
19.	Novosibirsk State University	86	1.0%
20.	Far Eastern Federal University	86	1.0%

Source: CSET analysis of MAG.

At the top of the list, the Russian Academy of Sciences is a prestigious public expert organization that oversees 550 scientific institutions and research centers across the country, reportedly employing more than 55,000 researchers.[38] Its leadership in publication is due to a long-standing dominance in fundamental research and an ability for its researchers to retain affiliations elsewhere. Since 2013, a series of government reforms have changed the authority, mandate, membership, and leadership structure of the Academy; such moves, according to some reports, have strengthened Putin's influence over the Academy and the national science agenda more broadly.[39] The Academy also carries out state-funded research, including on

behalf of the military-industrial complex.[40] Notably, all the major defense enterprises and companies in Russia are funded or subsidized by the state in some capacity, and the Ministry of Defense is their primary customer.[41]

Public funding is the main source of support for science research in Russia, and the top universities and research institutions producing AI-related research receive funding from a variety of federal, regional, and local funding programs. More than half of the institutions listed in Table 3 are affiliated with Project 5–100. As previously noted, over the past seven years, researchers from these institutions have had more access to research funds and opportunities for publishing in English-language journals. [42]

In addition to Project 5–100, most of the universities and research institutions in Table 3 are the beneficiaries of multiple other instruments and programs of public support. For example, four universities—Moscow State University, Saint Petersburg State University (the two largest universities in Russia), Novosibirsk State University, and Moscow Institute of Physics and Technology—accounted for a quarter of the grants provided in support of research led by prominent scientists. Large regional universities, such as Tomsk Polytechnic University, Novosibirsk State Technical University, and Ural Federal University, lead in terms of overall number of lines of state support.[43]

Another institution of note is the Moscow Institute of Physics and Technology, which has one of the best computer science programs in the world. [44] In 2017, the Russian government, as part of its National Technological Initiative, selected the Moscow Institute of Physics and Technology as the home for a new Center for Artificial Intelligence. The work at the center is being carried out as part of a consortium including the Skolkovo Institute of Science and Technology, National Research University – Higher School of Economics, Innopolis University, and industry partners, such as Sberbank, Rosseti, Rostelecom, Russian Railways, ABBYY, and FMBA.[45] Considering its position, Moscow Institute of Physics and Technology's share of research publications could likely increase in the future.

Surprisingly, only a few publications were attributed to researchers from the St. Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO), and researchers from the Saint Petersburg Electrotechnical University.[46] Both are prestigious institutions involved in Project 5–100. Moreover, St. Petersburg National Research University ITMO has the highest-ranked computer science program in Russia and is the only

Russian university in the top 100 world's best Computer Science programs rankings.[47]

While most institutions on the list are universities or other public research institutions, two different types of entities are worth highlighting. The first is the Skolkovo Institute of Science and Technology (Skoltech), a private graduate research institute in Moscow established in 2011 in collaboration with the Massachusetts Institute of Technology and the Skolkovo Foundation.[48] Skoltech is likely to continue leading in Russian AI research considering its ability to draw on industry support in addition to public grants. In 2019, for example, industry-funded research at Skoltech amounted to more than 1 billion RUB (approximately $13.3 million), and new contracts have been signed with Russian and international companies for more than 1.3 billion RUB (approximately $17.3 million) for the period 2020–2023. Some of the AI-relevant partnerships include the Skoltech-Huawei Innovation Joint Lab and the Joint Applied Research Laboratory with Sberbank, both under Skoltech's Center for Computational and Data-Intensive Science and Engineering.[49]

The second is Yandex, Russia's largest technology company and most popular search engine. Although business investment in R&D is lower in Russia compared to countries like the United States and China, Yandex carries out applied research in AI, machine learning, computer vision, machine translation, and other areas relevant to the company's products and services. Yandex researchers participate in major international AI conferences and publish scientific papers, and the company has several partnerships and joint labs with Russian universities, including the Moscow Institute of Physics and Technology.[50] With Yandex on the list, it is perhaps surprising to see no research publications affiliated with Sberbank, the pivotal commercial actor in Russian AI.

Conclusion

AI and closely related fields, such as machine learning, robotics, and automation, occupy an important place in Russia's plans to strengthen the nation's science and technology sectors. Emerging technologies also underpin government programs dedicated to the digital transformation of the national economy and Russia's military modernization efforts.[51] Support for basic and applied scientific research is one priority area of Russia's AI strategy; by the year 2024, the government expects this support to yield a "significant increase in the number and the citation index of scientific articles by Russian scientists on the subject of artificial intelligence in leading international scientific journals."[52]

Our assessment of Russia's English-language, public-facing scientific research output in areas related to AI demonstrates notable growth in fields such as machine learning, robotics, and algorithms since 2010. That said, in terms of overall English-language AI-related research output, Russian researchers significantly lag behind their American and Chinese counterparts. Russia's government and especially its business sector spend comparatively less on R&D, the country struggles to retain and attract top scientific talent, and a myriad of institutional and bureaucratic hurdles hold Russian scientists back from contributing to international journals.

The outsized significance of public funding in Russian science becomes clear when assessing the top institutions producing AI-related English-language research publications. Most of the top 20 institutions benefit from a variety of public support programs, and more than half of the top 20 are beneficiaries of Project 5–100. As evidenced by the growth in Russia's English-language AI research output over the past decade, such investments and initiatives are a step in the right direction for Russian science. Once again, though, the relatively low number of research publications in international journals reflects the serious obstacles to Russia's progress in AI—many of which, including corruption, brain-drain, economic stagnation, and lack of internal and external openness, are societal and systemic, and beyond the purview of science alone.

When examining primary areas of research related to AI, it appears that Russian scientists have predominantly focused on computer vision, pattern recognition, robotics, machine learning, linguistics, and natural language processing. These areas of scholarly research have many relatively benign commercial applications, and we cannot ascertain the content of the research

publications identified in our search. That said, developments in these AI-related fields are also relevant to surveillance, information suppression, and military robotics. And considering the financial and regulatory linkages between Russia's scientific research community and the government, as well as the dual-use nature of AI, it is prudent to assess this work through a national security lens.

Our findings therefore raise a number of important issues for U.S. policymakers. Alongside increasingly repressive legislation, scientific progress in AI-related research in linguistics, natural language processing, and machine learning could allow the Russian government to enforce even tighter control over its citizens' access to information on the internet. The spread of such tools from Russia (and China) is part of what some analysts have called the proliferation and exporting of "digital authoritarianism," posing a threat to democratic principles and institutions around the world.[53] Concurrently, advances in robotics research may also fuel breakthroughs in military robotics, providing the Russian armed forces with technological and operational advantages on future battlefields.

Russia's current and potential capabilities in AI are certainly less impressive than those of the United States and China. Yet it's worth remembering that Russia did not need to be a "cyber superpower" to execute extensive and sophisticated election interference attacks against the United States and other Western democracies, or to wage information warfare in Ukraine and Syria.

Finally, this research has looked only at English-language publications by Russian scientists—a useful but limited indicator of trends in Russian AI research. One possible direction for future research is a complementary approach focusing on Russian-language research on AI published in Russian scientific journals. Such an examination may produce results different than ours in terms of the number of publications, fields of focus, and leading research institutions. These and other potential discrepancies are perfectly reasonable in light of the differences in database coverage, different incentives for publishing in English and Russian-language journals, and higher barriers to publication in English-language journals for researchers from non-English speaking countries.[54] Another avenue for future research is to examine collaborations between Russian and Chinese, Russian and American, and American and Chinese scientists conducting scholarly research on AI. Such a study could be especially timely considering the escalating tensions between the United States and China, concerns surrounding research security in U.S. institutions, and the increasing military and technological collaboration between Russia and China.[55]

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Appendix

Table A1. Annual number of papers published by primary field.

Field	2010	2011	2012	2013	2014	2015	2016	2017	2018
Computer vision	27	57	35	48	70	101	113	112	135
Pattern recognition	32	46	41	43	56	82	96	121	159
Linguistics	21	22	37	35	90	149	89	103	77
Natural language processing	20	16	15	27	46	51	85	93	97
Robotics	18	11	9	15	28	47	70	103	112
Machine learning	10	17	13	20	19	41	69	74	95
Algorithm	16	18	10	12	31	64	59	83	121
Artificial intelligence	9	14	12	29	26	40	60	62	68
Data mining	9	10	20	14	20	35	43	36	33
Information retrieval	7	18	21	23	33	29	33	27	35
Control theory	3	5	4	9	10	18	22	29	34
Mathematical optimization	6	12	8	6	12	17	13	21	23
Control engineering	5	4	7	5	10	13	22	22	21
Speech recognition	4	7	4	13	12	15	25	24	29
Theoretical computer science	9	14	8	9	13	12	19	29	34
All other fields	61	74	67	107	197	289	298	440	523
Total	257	345	311	415	673	1,003	1,116	1,379	1,596

Endnotes

[1] Keith Dear, "Will Russia Rule the World Through AI*?" The RUSI Journal* 164, no. 5-6 (November 29, 2019). 10.1080/03071847.2019.1694227.
[2] Office of the President of the Russian Federation, *Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation*, translated by Center for Security and Emerging Technology (Office of the President of the Russian Federation, October 10, 2019), https://cset.georgetown.edu/wp-content/uploads/Decree-of-the-President-of-the-Russian-Federation-on-the-Development-of-Artificial-Intelligence-in-the-Russian-Federation-.pdf.
[3] Estimates vary depending on method of calculation. The lower figure is derived from OECD Data; the higher figure is derived from a Congressional Research Service Report on global R&D. See Organisation for Economic Co-operation and Development, Gross domestic spending on R&D, accessed July, 14 2020, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm; John F. Sargent, Jr. "Global Research and Development Expenditures: Fact Sheet" (Congressional Research Service, April 29, 2020), https://fas.org/sgp/crs/misc/R44283.pdf. From a comparative standpoint, according to UNESCO statistics, Russia spends about $40.3 million or 1.1 percent of its GDP on R&D; the U.S. spends approximately $476.4 million or 2.7 percent of its GDP on R&D, while China spends approximately $372.3 million or 2 percent of its GDP on R&D. See UNESCO Institute for Statistics, "How much does your country invest in R&D?" UNESCO, accessed on August 20, 2020. http://uis.unesco.org/apps/visualisations/research-and-development-spending/.
[4] Organisation for Economic Co-operation and Development, Education GPS, Russian Federation: Overview of the education system (EAG 2019), accessed July 14, 2020, https://gpseducation.oecd.org/CountryProfile?primaryCountry=RUS&treshold=10&topic=EO; From a comparative standpoint, the tertiary education degree attainment for the U.S. is at 49 percent of 25-to 34-year-olds. See Organisation for Economic Co-operation and Development, Adult education level. 2019. https://data.oecd.org/eduatt/adult-education-level.htm; While tertiary attainment is increasing rapidly in China, the most recent indicators place is at 18 percent of 25-to 34-year-olds. See Organisation for Economic Co-operation and Development, Education GPS, China: Overview of the education system (EAG 2019), accessed August 20, 2020, https://gpseducation.oecd.org/CountryProfile?plotter=h5&primaryCountry=CHN&treshold=5&topic=EO.
[5] Irina Dezhina, "Russia's Academy of Sciences' Reform: Causes and Consequences for Russian Science" (IFRI, May 2014), https://www.ifri.org/sites/default/files/atoms/files/ifri_rnv_77_ran_reforma_eng_dezhina_may_2014.pdf.
[6] Quirin Schiermeier, "Russia aims to revive science after era of stagnation," *Nature*, March 18, 2020, https://www.nature.com/articles/d41586-020-00753-7.
[7] Jamie L. Vernon, "Restructuring Science in Russia," *American Scientist* 105, no.3 (May—June, 2017):134, https://www.americanscientist.org/article/restructuring-science-in-russia; Ellie Bothwekk, "Questions on Russia's Research Reforms," *Inside Higher Ed*, March 7, 2019, https://www.insidehighered.com/news/2019/03/07/experts-have-doubts-russias-plans-reform-research-efforts; Vladimir Pokrovsky, "Putin tightens control over Russian Academy of Sciences," *Science,* June 27, 2017, https://www.sciencemag.org/news/2017/06/putin-tightens-control-over-russian-academy-sciences.

[8] Karen White, *Publications Output: U.S. Trends and International Comparisons* (Alexandria, VA: National Center for Science and Engineering Statistics, December 17, 2019), https://ncses.nsf.gov/pubs/nsb20206/publication-output-by-region-country-or-economy.

[9] Previous research has shown that the United States and China significantly outperform Russia in terms of overall AI research output and citation impact. Our comparison of overall Russian, American, and Chinese AI-related research output confirms some of these findings, but the core of this paper is dedicated to exploring the distribution of Russian AI research output across topics and institutions. See Raymond Perrault, Yoav Shoham, Erik Brynjolfsson, Jack Clark, John Etchemendy, Barbara Grosz, Terah Lyons, James Manyika, Saurabh Mishra, and Juan Carlos Niebles, "The AI Index 2019 Annual Report" (Human-Centered Artificial Intelligence Institute, December 2019), https://hai.stanford.edu/sites/default/files/ai_index_2019_report.pdf; Jean-Francois Gagne, "Global AI Talent Report 2019" (2019), https://jfgagne.ai/talent-2019/.

[10] We searched for the Russian-language terms for artificial intelligence (искусственный интеллект) and machine learning (машинное обучение) in MAG publications from 2010–2018. The query yielded a very small number of publications. (We found slightly more in Web of Science, but affiliation data was sparse.) Russia lags behind in AI-relevant research output, but it is also possible that MAG does not index many Russian-language journals containing such research. Considering the limitations of our query, we also probably missed many articles indexed under other AI-related research fields such as computer vision, robotics, or natural language processing. As we note later in the paper, a future direction for research is to focus specifically on Russian-language scientific journals; it is possible such research would yield finds different from ours due to variation in database coverage, different incentives for publishing in English and Russian-language journals, and higher barriers to publication in English-language journals for researchers from non-English speaking countries.

[11] According to an analysis of Russian scientific research output between 2012 and 2017, "research organizations of the enterprise sector constitute a very small proportion of the Russian research organizations although they demonstrated a large author growth of 400%—800%." This is to say that researchers in the enterprise sector don't generally publish in scientific journals. Anna A. Avanesova and Tatyana A. Shamliyan, "Comparative trends in research performance of the Russian universities," *Scientometrics* 116, (2018):2019-2052, https://dspace.ncfu.ru/bitstream/20.500.12258/2857/4/WoS%20121%20.pdf.

[12] The academic sector has undergone significant restructuring over the past decade. In 2013, the Russian Academy of Sciences, the Russian Academy of Agriculture Sciences, and the Russian Academy of Medical Sciences were merged into a single institution, and the Federal Agency of Scientific Organizations was created to oversee and evaluate the scientific output of their subsidiary research institutions. FASO and its subsidiary institutions, currently under the auspices of the Ministry of Science and Higher Education, are the largest recipients of state funding for basic research in Russia. For more information on the restructuring of Russian science and changes in output, see Dezhina, "Russia's Academy of Sciences' Reform"; Denis Kosyakov and Andrey Guskov, "Research assessment and evaluation in Russian fundamental science," *Procedia Computer Science* 146, (2019):11-19, https://doi.org/10.1016/j.procs.2019.01.072; Denis Kosyakov and Andrey Guskov, "Impact of national science policy on academic migration and research productivity in Russia," *Procedia Computer Science* 146, (2019):60-71, https://doi.org/10.1016/j.procs.2019.01.080.

[13] The universities have also experienced a broad set of reforms; local higher education institutions were merged to establish federal universities; competitive institutions were

designated as National Research Universities; and more funds were allocated for research staff to support scientific research. Still, the university sector represents a relatively small part of the country's science ecosystem, with higher education institutions accounting for about nine percent of the total volume of research and 12 percent of the number of researchers in Russia. See Alexei Kudrin, Alexander Radygin, and Sergey Sinelnikov-Murylev, eds., "Russian Economy in 2018: Trends and Outlooks. (Issue 40)" (Gaidar Institute Publishers, 2019), 463, https://www.iep.ru/files/text/trends/2018-eng/Book.pdf.

[14] The details of this approach are explained in James Dunham, Jennifer Melot, and Dewey Murdick, "Identifying the Development and Application of Artificial Intelligence in Scientific Text," arXiv, May 28, 2020, https://arxiv.org/abs/2002.07143.

[15] We prefer, in general, to use a corpus of unique publications from MAG, Digital Science Dimensions, and Clarivate Web of Science. Here our focus on research output by topic required the use of a single dataset. In prior analysis, we found that MAG contains 90 percent of the AI-relevant articles in Dimensions and 88 percent of those in Web of Science. We therefore use MAG's fields of study to characterize Russian publications by topic. During robustness checks, we found just 33 publications by Russian-affiliated scholars that appeared in Dimensions and not MAG.

[16] The characteristics of MAG and alternative data sources are discussed in Dewey Murdick, James Dunham, and Jennifer Melot, "AI Definitions Affect Policymaking" (Center for Security and Emerging Technology, June 2, 2020), https://cset.georgetown.edu/research/ai-definitions-affect-policymaking/.

[17] Kudrin et. al., *Russian Economy in 2018,* 463.

[18] Kudrin et. al., *Russian Economy in 2018,* 461.

[19] UNESCO Institute for Statistics, "How much does your country invest in R&D?" UNESCO, accessed on July 14, 2020. http://uis.unesco.org/apps/visualisations/research-and-development-spending/.

[20] Bruno Lanvin and Felipe Monteiro, eds. "The Global Talent Competitiveness Index: Global Talent in the Age of Artificial Intelligence" (INSEAD, 2020), https://www.insead.edu/sites/default/files/assets/dept/globalindices/docs/GTCI-2020-report.pdf.

[21] Lanvin and Monteiro, eds. "The Global Talent Competitiveness Index."

[22] Kudrin et. al., *Russian Economy in 2018,* 462.

[23] Quirin Schiermeier, "Russian secret service to vet research papers," *Nature*, October 20, 2015, https://www.nature.com/news/russian-secret-service-to-vet-research-papers-1.18602.

[24] Daria Litvinova, "Russian Academia Divided Over FSB Vetting of Research Papers," *The Moscow Times*, October 21, 2015, https://www.themoscowtimes.com/2015/10/21/russian-academia-divided-over-fsb-vetting-of-research-papers-a50389.

[25] Mohana Ravindranath, "Russian, Chinese Companies Win Intel Community's Face Recognition Tech Contest," *Nextgov,* November 7, 2017, https://www.nextgov.com/emerging-tech/2017/11/russian-chinese-companies-win-intel-communitys-face-recognition-tech-contest/142360/.

[26] Patrick Reevell, "How Russia is using facial recognition to police its coronavirus lockdown," *ABC News*, April 20, 2020, https://abcnews.go.com/International/russia-facial-recognition-police-coronavirus-lockdown/story?id=70299736.

[27] Human Rights Watch, *Russia: Growing Internet Isolation, Control, Censorship* (New York: Human Rights Watch, June 18, 2020), https://www.hrw.org/news/2020/06/18/russia-growing-internet-isolation-control-censorship; Human Rights Watch, *Online and On All*

Fronts: Russia's Assault on Freedom of Expression (New York: Human Rights Watch, July 2017), https://www.hrw.org/report/2017/07/18/online-and-all-fronts/russias-assault-freedom-expression.

[28] Ivan Golunov, Alexander Gorbachev, and Daniil Tuovsky, "A hybrid hunt for criminal journalists: How federal censors monitor and punish Russia's mass media," *Meduza*, June 10, 2019, https://www.pri.org/stories/2019-06-10/hybrid-hunt-criminal-journalists-how-federal-censors-monitor-and-punish-russia-s.

[29] Golunov, et al. "A hybrid hunt for criminal journalists."

[30]Alisa Konuikhovskaia, "Five Trends in Russian Robotics," *International Federation of Robotics*, August 27, 2019, https://ifr.org/post/five-trends-in-russian-robotics; World Bank Group, *Competing in the Digital Age: Policy Implications for the Russian Federation* (Washington, DC: The World Bank, September 2018), http://documents.worldbank.org/curated/en/860291539115402187/pdf/Competing-in-the-Digital-Age-Policy-Implications-for-the-Russian-Federation-Russia-Digital-Economy-Report.pdf.

[31] World Bank Group, *Competing in the Digital Age*, 68.

[32] "Most of Ministry of Defense' research institutions are working on AI and robotics," [Большинство научных школ Минобороны работает над искусственным интеллектом и роботами], Tass [ТАСС], March 15, 2018, https://tass.ru/armiya-i-opk/5034153; Nicholas D. Wright et al., "AI, China, Russia, and the Global Order: Technological, Political, Global, and Creative Perspectives" (NSI, December 2018), 163-164, https://nsiteam.com/social/wp-content/uploads/2019/01/AI-China-Russia-Global-WP_FINAL_forcopying_Edited-EDITED.pdf.

[33] Margarita Konaev and Samuel Bendett, "Russian AI-Enabled Combat: Coming to a City Near You? " *War on the Rocks*, July 31, 2019, https://warontherocks.com/2019/07/russian-ai-enabled-combat-coming-to-a-city-near-you/.

[34] Office of the President of the Russian Federation, *Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation*.

[35] "Best Global Universities Ranking," U.S. News, (Accessed on July 14, 2020), https://www.usnews.com/education/best-global-universities/rankings.

[36] Although, as previously noted, when comparing the MAG and Dimensions databases, we found only 33 publications by Russian-affiliated scholars that appeared in Dimensions but not in MAG, there was more divergence between the datasets in their institutional affiliations data. Nine of the top 10 institutions in Table 3 also appeared in the top 10 by output when using Dimensions affiliations; 16 of those in Table 3 are in the Dimensions top 20. But in a peculiar discrepancy, MAG links far fewer papers than Dimensions does with the St. Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO). Using the Dimensions data, ITMO ranks below only the Russian Academy of Sciences. We found the omission of ITMO from Table 3 surprising, and we are inclined to believe that Dimensions is capturing affiliations that MAG has missed. This led us to manually review how MAG linked the author affiliation references in publications with canonical affiliation names (in the dataset, PaperAuthorAffiliation.OriginalAffiliation vs. Affiliation.DisplayName). We corrected a non-trivial number of false-positive linkages (most frequently, errors like "Moscow State University of Civil Engineering" linked with "Moscow State University") and segmentation errors (in which two or more institutions appeared in an OriginalAffiliation). We applied the corrections to Table 3. Such misattributions are probably common in large datasets, especially when working with publications from non-English speaking countries.

[37] In some situations, researchers have more than one institutional affiliation. In fact, listing several affiliations on a publication is one method that researchers in Russia (and elsewhere) have used to increase their institutions' publication output. See Kudrin et. al., *Russian Economy in 2018,* 463.
[38] "Russian Academy of Sciences," [Российская академия наук], Scientific Russia, [НАУЧНАЯ РОССИЯ], accessed August 6, 2020 https://scientificrussia.ru/partners/rossijskaya-akademiya-nauk.
[39] Tatiana Stanoyava, "Reform of the russian Academy of Sciences: Checkmate in Two Moves" (New York, NY: Institute of Modern Russia, July 15, 2013), https://imrussia.org/en/nation/513-reform-of-the-russian-academy-of-sciences-checkmate-in-two-moves; Pokrovsky, "Putin tightens control over Russian Academy of Sciences."
[40] Kudrin et. al., *Russian Economy in 2018,* 466.
[41] Andrew Radin, et al., "The Future of the Russian Military: Russia's Ground Combat Capabilities and Implications for U.S.—Russia Competition" (RAND Corporation, 2019), 56, https://www.rand.org/content/dam/rand/pubs/research_reports/RR3000/RR3099/RAND_RR3099.pdf.
[42] Kudrin et. al., *Russian Economy in 2018,* 463.
[43] Kudrin et. al., *Russian Economy in 2018,* 463.
[44] The Times Higher Education World University Rankings, World University Rankings 2020 by subject: computer science, accessed August 5, 2020, https://www.timeshighereducation.com/world-university-rankings/2020/subject-ranking/computer-science#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/stats.
[45] "Moscow Institute of Physics and Technology becomes the center of NTI in the direction of 'Artificial Intelligence'," [МФТИ стал центром НТИ по направлению «Искусственный интеллект»], Moscow Institute of Physics and Technology [МФТИ], December 29, 2017, https://mipt.ru/news/mfti_stal_tsentrom_nti_po_napravleniyu_iskusstvennyy_intellekt; Samuel Bendett, "Russia's National AI Center is Taking Shape," *Defense One*, September 27 2019, https://www.defenseone.com/technology/2019/09/russias-national-ai-center-taking-shape/160219/.
[46] For more details on coding affiliations and specifically St. Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO) see endnote 36. In MAG, we identified 30 papers linked to researchers at ITMO and 23 papers linked to researchers from the Saint Petersburg Electrotechnical University.
[47] The Times Higher Education World University Rankings, World University Rankings 2020 by subject: computer science. Only two Russian universities were ranked in the top 100 of Computer Science programs according to rankings by the Times Higher Education: ITMO ranked 74th and Moscow Institute of Physics and Technology ranked 95th.
[48] Skolkovo Institute of Science and Technology. "Annual Report 2019" (Skolkovo Institute of Science and Technology, March 2020), https://www.skoltech.ru/app/data/uploads/2019/10/annual-report-2019-.pdf; "Key facts," Skolkovo Institute of Science and Technology, accessed August 5, 2020, https://www.skoltech.ru/en/about/key-facts/.
[49] Skolkovo Institute of Science and Technology, "Annual Report 2019"; "Welcome to CDISE!" Skolkovo Institute of Science and Technology, accessed August 5, 2020, https://crei.skoltech.ru/cdise.
[50] "Yandex and MIPT open joint lab," Moscow Institute of Physics and Technology, accessed August 5, 2020, https://mipt.ru/english/news/yandex_and_mipt_open_joint_lab.

[51] E.V. Korobeynikova, "Digital Transformation of Russian Economy: Challenges, Threats, Prospects," (conference paper) GCPMED 2018 - International Scientific Conference, March 2019, https://www.researchgate.net/publication/331905083_Digital_Transformation_Of_Russian_Economy_Challenges_Threats_Prospects; https://www.rvc.ru/en/eco/; For a comprehensive assessment of Russia's various strategies and national programs, see Alexei Kudrin, Alexander Radygin, and Sergey Sinelnikov-Murylev, eds., "Russian Economy in 2019: Trends and Outlooks. (Issue 41)" (Gaidar Institute Publishers, 2020), https://www.iep.ru/files/text/trends/2019-eng/Book.pdf.

[52] Office of the President of the Russian Federation, *Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation,* 11.

[53] Alina Polyakova and Chris Meserole, "Exporting digital authoritarianism: The Russian and Chinese models" (Brookings, August 27, 2019), https://www.brookings.edu/wp-content/uploads/2019/08/FP_20190827_digital_authoritarianism_polyakova_meserole.pdf; Andrea Kendall-Taylor, Erica Frantz, and Joseph Wright, "The Digital Dictators: How Technology Strengthens Autocracy," *Foreign Affairs*, March/April 2020, https://www.foreignaffairs.com/articles/china/2020-02-06/digital-dictators.

[54] Researchers interested in Russian scientific publications may consult a Russian-language databases such as the Russian scientific electronic library, Cyber Leninka (https://cyberleninka.ru/) and the database East View (http://online.eastview.com/index.jsp).

[55] Samuel Bendett and Elsa Kania, "The Resilience of Sino-Russian High-Tech Cooperation," *War on the Rocks*, August 12, 2020, https://warontherocks.com/2020/08/the-resilience-of-sino-russian-high-tech-cooperation/; Michael Kofman, "The Emperors League: Understanding Sino-Russian Defense Cooperation," *War on the Rocks*, August 6, 2020, https://warontherocks.com/2020/08/the-emperors-league-understanding-sino-russian-defense-cooperation/.