POLICY BRIEF 21.10.2021

Scientific and Technological Development of the Russian Federation: Review of Current Status

Summary

The scientific and technological (S&T) development of the Russian federation faces many challenges related to the isolation of science as a sector of the economy such as the lack of entrepreneurial culture, market competition and private R&D investments. In terms of our analysis, which is based on comparative publication and patenting data, a particularly striking feature emerging from the material is China's rise to overtake and surpass the Russian S&T trajectory by a number of key variables in various fields, both in terms of innovation system inputs and outputs.

Despite these problems, Russia has a long history of scientific and technological excellence that continues to this day. Moreover, during the last decades Russia has reformed its S&T system by improving the quality of its scientific enterprises and higher education, by developing its legislation and technology commercialization abilities, and by focusing top-down initiatives such as science-parks and other technology platforms. Indeed, there has been no lack of policy intervention in the field of Russian STI and R&D.

However, on the basis of our analysis, it seems that Russia has been unable to address the systemic weaknesses of the National Innovation System. Instead, Russia has focused on technocratic instruments, with little attention paid to societal issues. Without the right societal conditions, such as a culture of entrepreneurship and innovation ecosystems, the impact of the various policy measures will remain modest.

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DOI: 10.32040/POLICYBRIEF.2021.SCITECHDEV
VTT 2021

The report "Forecast of the Scientific and Technological Development of the Russian Federation for the Period until 2030" paints a dire picture of Russia's science and technology (S&T) development. In the report, the authors argued that

> **S&T development "…is deteriorating due to the continued isolation of science as a sector of the economy, which remains untouched by full-fledged market relations. Increasingly evident are the systemic issues arising from both the unfinished economic and institutional transformations and the economic crises related to changes in the world market conditions and geopolitical situation".[1]**

It is important to note that the scientific and technical development of the Russian Federation should be put in the broader context of the earlier Soviet S&T approach. The Soviet system was based on the dual assumption of linear innovation and technology as a commodity. (Hanson et al., 2013) While the notion of linearity has persisted in Russia and elsewhere (Edquist, 2014), on a global level an increasingly dominant trend has emphasized the importance of understanding scientific and technological advancement as non-linear. Similarly, many influential voices have argued that technological advancement should not be viewed as disconnected from a continuous interplay with society. However, the Russian S&T system is still affected by the inherited continuities from the old Soviet model that largely omitted non-R&D factors from science and technology development. (Radosevic, 2003) As a result,

> **Russia has not been "in step with world trends" in organizing knowledge management and technological development (Graham, 2013).**

Radosevic (2003) argued that for the Russian S&T system to recoup the technological lag it had developed in comparison to advanced nations, it would have to develop a strong innovation policy. The author envisioned a focus on a few mission-oriented areas while highlighting the need for a broad-based strategy on developing the innovation system. It is clear that the recovery of Russian S&T system depends partly on the economy and the state's broader ability to create policies that focus on research, develop higher education, and enable businesses to take a role in the innovation system (Schweitzer, 1995). However, it seems that Russia has been unable to address systemic weaknesses, nor has it been able to tackle more recent challenges affecting the innovation system. (Klochikhin, 2012) Despite these problems, new science megaprojects, aligning with the arguments by Radosevic (2003), are in the works (Seliverstov, 2020).

However, Kihlgren (2003), for example, has highlighted that policies such as the establishment of science parks in Russia have been challenged by the lack of demand by the industry for the high-tech outcomes of the research institutes and academia. Furthermore, the administrative funding priorities inherited from the Soviet system have not sufficiently considered issues such as researcher development (Radosevic, 2003). Similarly, as witnessed already in the Soviet system, Russia's more recent

[1] "Forecast of the Scientific and Technological Development of the Russian Federation for the Period until 2030" (Draft of December 19, 2017). Compliance with the Requirements of the Federal Law of June 28, 2014 No. 172-FZ "On Strategic Planning in the Russian Federation" (2017), page 7.

shake-up of the university system (Schiermeier, 2012) has its focus on administrational activity instead of addressing the structural issues of the innovation system.

One might argue that the core challenge of the Soviet system was the lack of business enterprise as an independent agent and participant in the innovation system (Radosevic, 2003). This situation has not been transformed by Russia's transition to a market economy approach. On the contrary, Russian businesses have persisted in their reluctance towards investing in R&D, while the role of the state as the central actor in the Russian National Innovation System has endured. (Dezhina & Etzkowitz, 2016; van Someren & van Someren-Wang, 2016)

Overall, it seems that Russia's transition to a market-based economy seems to have by-passed the R&D sector (Cervantes & Malkin, 2001), creating a sustained impediment for the ability of Russia to leverage research for societal and economic impacts. Moreover, the lack of entrepreneurial culture and high-tech industries seem to have created a persisting structural challenges for the functioning of the Russian National Innovation System (Bogoviz, 2019).

Reflecting on Russia's current standing among different countries, we can look at innovation system inputs. During the last twenty years, while expectations of R&D system transformation have been high, Russia has been unable to increase its inputs to the innovation system. In comparison to China, USA, EU 27 and OECD in Figure 1, Russia is the only country that has kept its expenditure at the same level, while other territories have seen at least marginal development. The comparison between China and the Russian federation is particularly striking. At the beginning of the time series, Russia had a higher Gross domestic expenditure on R&D (GERD) per GDP value than China. Since then a gap has emerged in favor of China.

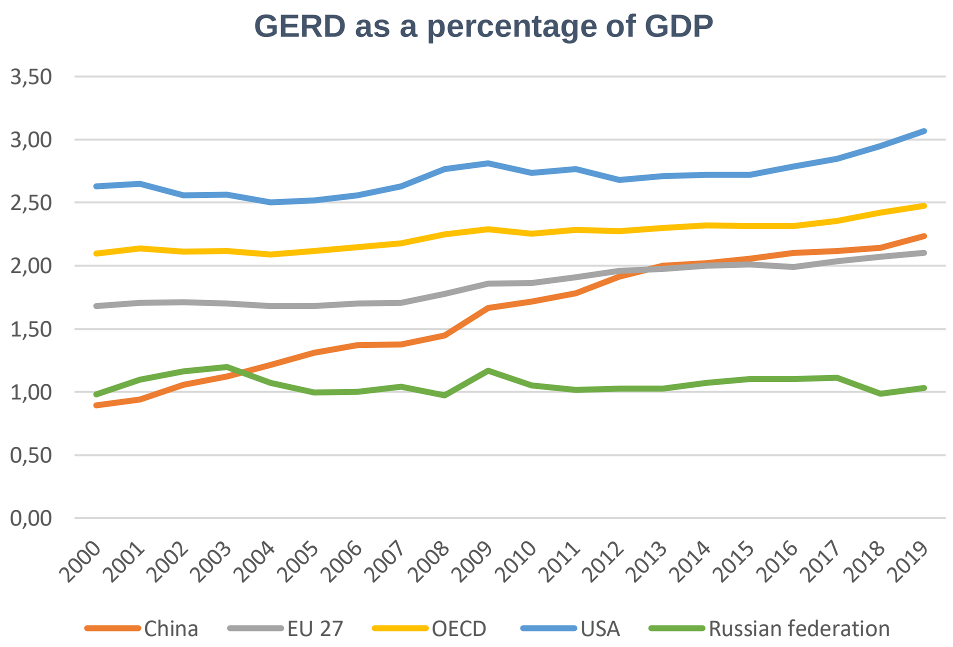

Figure 1 GERD reflecting the total of all expenditure on inputs used in performing R&D per GDP in each territory. Source: OECD

Focusing on how the GERD is divided by performing sector sheds additional light on Russia's innovation system. As seen in Figure 2, Russia has been unable to increase its public spending on R&D per GDP. We can also see that the business sector has slightly decreased its expenditures on R&D. Overall, the R&D expenditures should be reflected against previous expectations. In 2011, Gokhberg and Kuznetsova (2011) discussed the path of Russian innovation policy towards 2020 and signalled positive developments on indicators such as public funding on R&D and policy measures that focused on developing the innovation environment. Reflecting on Figure 2, it seems that the public investments have not materialized.

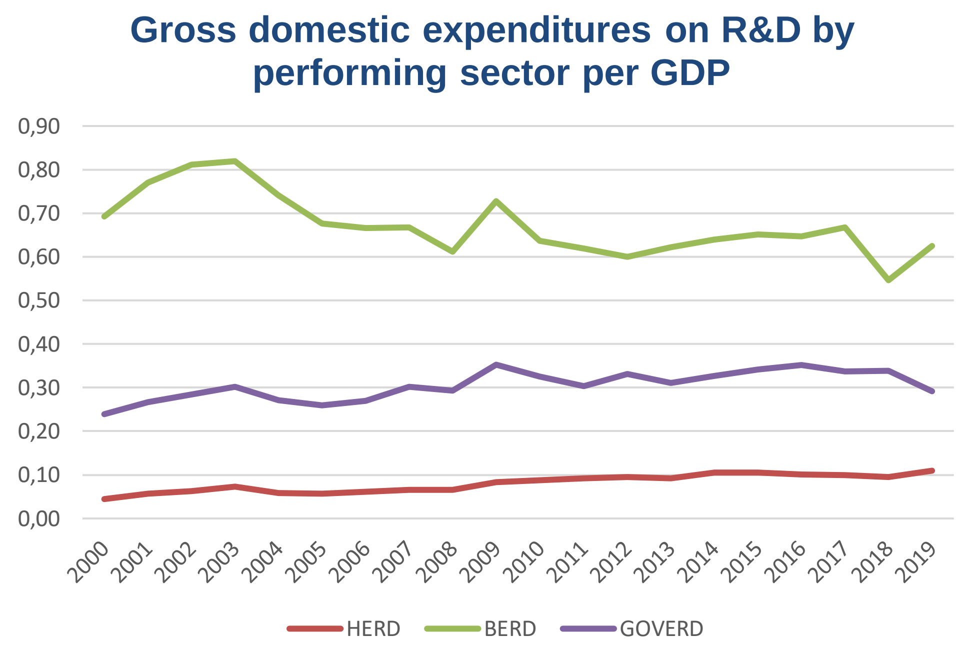

Figure 2 Russia's gross domestic expenditures on R&D by performing sector. HERD = Higher Education, BERD = Business and GOVERD = Government Source: OECD

Turning the attention from inputs to outputs, highlights the actual achieved S&T capability. In the relevant literature, an often-used comparison group is the BRICS (Brazil, Russia, India, China, and South Africa) countries. Focusing purely on science outcomes, Russia has not been able to develop its scientific capabilities in comparison to other BRICS countries (Bornmann et al., 2015). In terms of human capital development, Russia has been ahead of countries like China and India before 2010. Since then, China and India have made significant investments in human capital development, while Russia has lost ground (Garavan et al., 2012). Indeed, it can be argued that

Russia suffers from a "high-education, low-human-capital paradox" (Kotkin, 2018).

Russia has a relatively high level of education and an established strength in globally competitive basic scientific research in fields such as physics, mathematics, and chemistry (Gershman et al., 2018). However, in terms of human capital and the ability to convert basic science into technological innovation, Russia has perhaps not fully utilized the potential of its strong educational base.

In this study, we set our sights on comparing Russia, China, USA, Finland and EU 27. Focusing on scientific publications, by volume within the five years from 2015 to 2020, Russia's scholarly output is significantly lower than China's, USA's or the European Union and roughly five times that of Finland. Comparing scholarly output per capita, Finland has the highest share of publications, while Russia's scholarly output is only higher than China's in the comparative group. In terms of human resources allocated to scientific publishing, China and Russia have a similar share of authors per capita, as can be seen in Table 1.

Table 1 Science output in publication - a comparison of Russia, China, USA, Finland and EU27. Data: Scival

	Russia	China	USA	Finland	EU27
Scholarly Output	590973	3581610	4159987	132414	4759349
Scholarly Output per capita	0,0040	0,0025	0,0126	0,0239	0,0106
Authors	421433	4188082	3012853	64670	3284427
Authors per capita	0,0029	0,0029	0,0091	0,0116	0,0073
Field-Weighted Citation Impact	0,77	1,05	1,4	1,66	1,18
Citations per Publication	4,2	8,9	11,1	12,9	9

Figure 3 shows the number of authors and scholarly output per capita normalized against top-performer Finland. The figure reiterates the differences between the comparative groups/countries. While it is clear that the impact created and capabilities developed are not a full reflection of quantity produced or individuals engaging in scholarly work, the values still offer a vantage point to analyze Russian scientific capabilities.

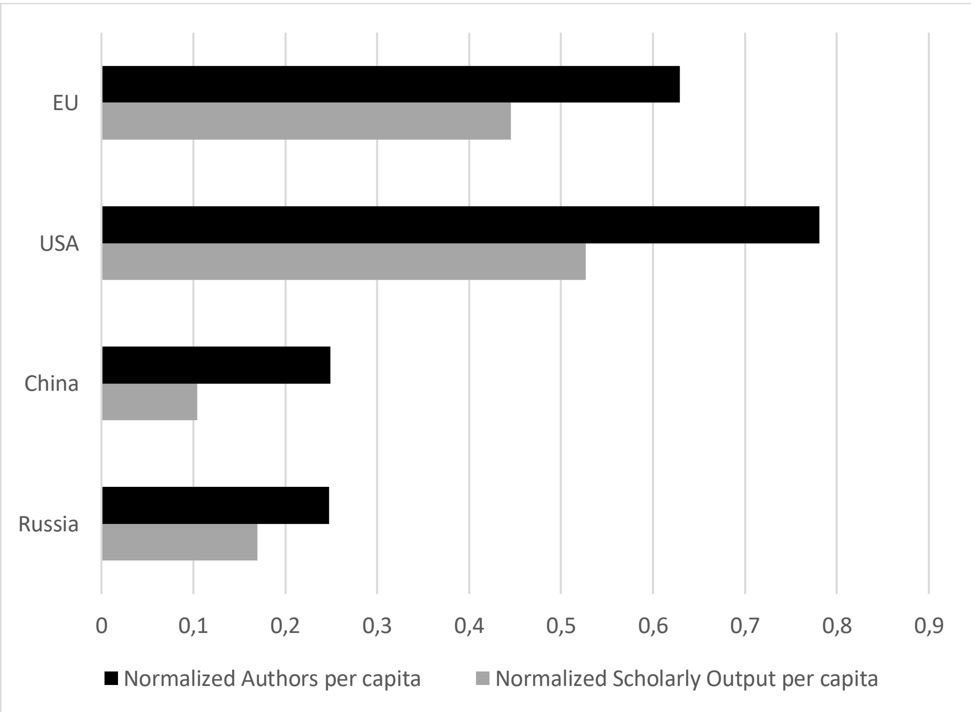

Figure 3 Authors and scholarly out per capita normalized against Finland. Data: Scopus, Calculations: Authors.

Focusing on areas of science where the comparative groups have the highest volume of publications, we again see a difference between the countries. Seen in Table 2, the difference is again pronounced with Russia and the other selected areas. For example, for all others the largest subfield is “Electrical and Electronic Engineering”, while for Russia "General Physics and Astronomy" is largest. Russia is the only one to include "Atomic and Molecular Physics, and Optics" in the top-ten list by volume highest subfields. That said, the list of subfields has significant overlap in its focus on natural sciences and engineering, particularly electronics.

Table 2 Disciplinary areas with highest volume of publications among the selected countries.

China	EU27	Finland	Russian Federation	USA
Electrical and Electronic Engineering	Electrical and Electronic Engineering	Electrical and Electronic Engineering	General Physics and Astronomy	Electrical and Electronic Engineering
General Materials Science	Computer Science Applications	Computer Networks and Communications	Condensed Matter Physics	Computer Science Applications
Mechanical Engineering	General Materials Science	Computer Science Applications	General Materials Science	General Medicine
General Chemistry	Condensed Matter Physics	Software	Electrical and Electronic Engineering	Surgery
Condensed Matter Physics	General Chemistry	General Materials Science	General Engineering	Molecular Biology
Computer Science Applications	Computer Networks and Communications	Education	Electronic, Optical and Magnetic Materials	General Biochemistry,Genetics and Molecular Biology
Electronic, Optical and Magnetic Materials	Mechanical Engineering	Ecology, Evolution, Behavior and Systematics	General Chemistry	Education
Computer Networks and Communications	Electronic, Optical and Magnetic Materials	General Computer Science	Atomic and Molecular Physics, and Optics	General Chemistry
Mechanics of Materials	General Computer Science	General Chemistry	Mechanical Engineering	Condensed Matter Physics
Materials Chemistry	General Physics and Astronomy	Electronic, Optical and Magnetic Materials	General Earth and Planetary Sciences	General Materials Science

It is important to note that while the high output clusters provide a vantage point in terms of the capabilities of Russian S&T system, they are also biased towards the existing strong capability areas. To offer an alternative view of Russia's science output, Figure 4 shows the largest Russian science topics by output in terms of two criteria: topic being in the highest quartile in both growth of publications and the count of publications. While these topics are by volume not in the top ten of Russia's research fields, they are important enough to be among the largest. A point of reflection is, that the by volume largest topic in the Figure "Industry, Innovation; Entrepreneurship" is 32 in the list of highest output research topics. Similarly, the topics selected are not the fastest growing topics, but are controlled by the expectation of high volume. The fastest growing topic in the list, "Exergy; Heat Pump Systems; Rankine Cycle", is the 24th highest topic by growth between the years 2015 – 2020.

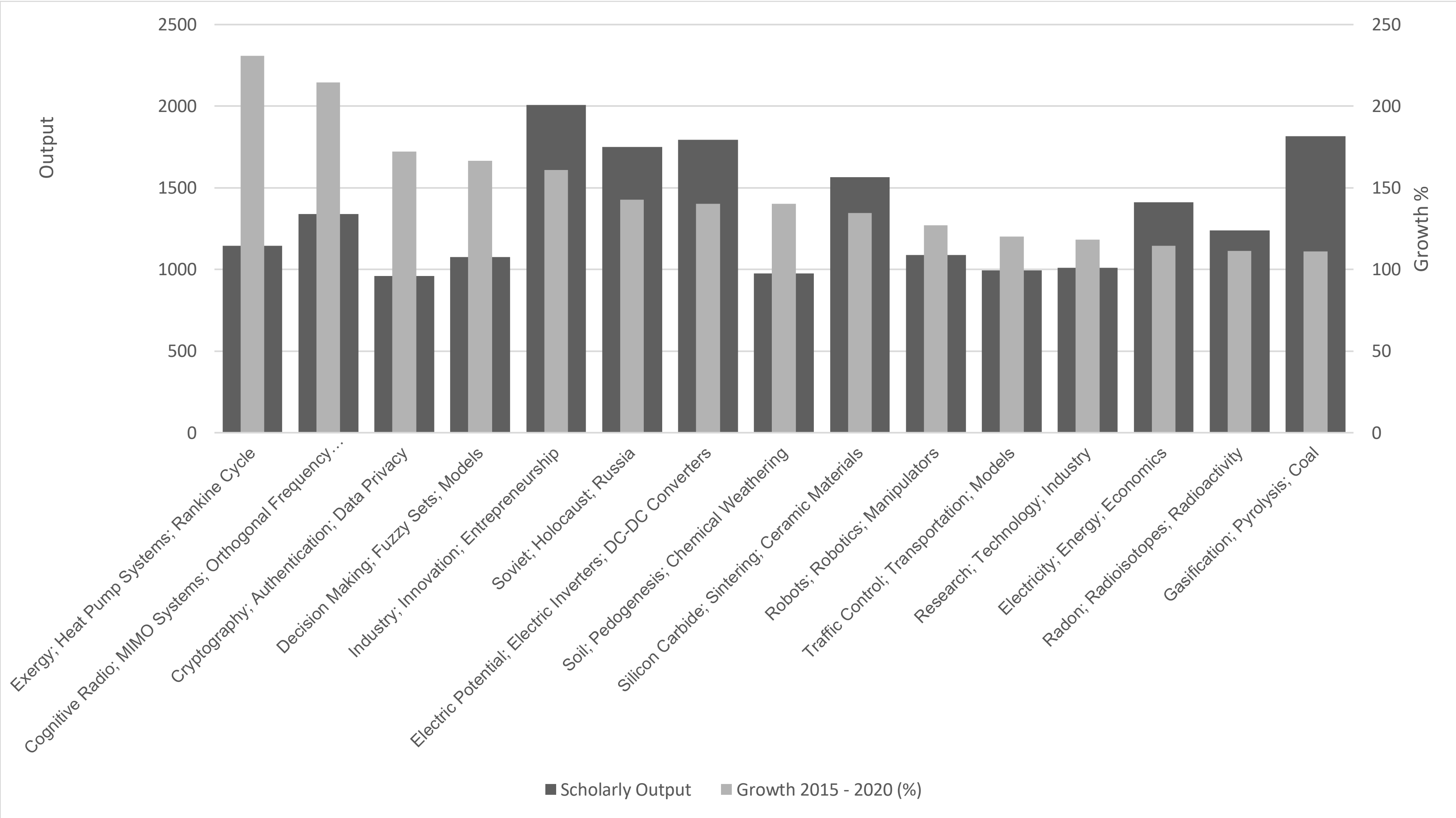

Figure 4 High growth and high output topics. By output largest topics are listed where both criteria, topic is in the highest quartile in both growth of publication and count of publications, are true. Data: Scival.

Russia has focused on leveraging on science and technological advancement, while patenting activities, compared to China and India, have been more limited. Wong and Wang (2015) show that Russia is a leading country among BRICS in acquiring innovation rents from the production of science-based patents. This suggests that Russia takes advantage of science in technological advancement more efficiently than other BRICS countries.

However, in terms of technology development, while Russia has historically been very successful inventor of various technological innovations from laser to AK-47, in many cases it has actually not managed to benefit from these inventions in terms of patent generated income (Graham, 2013). Indeed, Russia's enduring deficiency in terms of patenting activity has been the low total amount of technology and innovation commercialization. (Carayannis et al., 2016, 1139-1140)

Russia has significant and substantial scientific capabilities in some specific areas, but it simultaneously lags in key product and process technologies needed to internally leverage relevant technologies.

Interestingly, many of the science topics seen in Figure 4 relate to this structural issue in the Russian innovation system.

The current strong focus on topics such as innovation, entrepreneurship and "Research; Technology and Industry" might signal changes in the national innovation system. That said, many of the topics in the Figure are also technical, which align with the historical strengths of the Russian S&T system. Topics as such as cryptography, decision-making and radio transmission relevant to ICT and energy technologies, are founded on Russia's historical capability strengths in software, space and nuclear industries (Graham, 2013, 91-97).

Russia's current patenting performance can be captured by focusing the attention on immaterial property rights where the patent's assignee is Russian and where the protection of the patent has been extended beyond Russia. This focuses our attention to assignees, rather than inventors. Patent assignee is the organization or individual that has ownership of the legal rights a patent offers, thus offering a view on who has access to utilize capabilities. By focusing on IP5 patent families[2], one can have a better view on the immaterial property that the owner deems to be of significant value.

Measuring by fractional count of IP5 patents in biotechnology, in Figure 5, The US leads with over 3000 patents yearly, EU 27 with over 2000, and China with an increasing volume ending at over 500 patents by 2015. By comparison, Finland and Russia have under 50 patents yearly. Russia, moreover, has a decreasing trajectory in this field. Biotechnology patents are identified using International Patent Classification (IPC) codes. The difference between EU27 & USA and Russia, but also between China and Russia is significant. Comparing the difference between the left and right axis, to difference becomes clear. Notably, Finland has a higher volume of IP5 patent families throughout the analysis period.

[2] IP5 patent families refer to patents that have been filed in at least two intellectual property offices worldwide and one of which is the European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the US Patent and Trademark Office or the State Intellectual Property Office of the People Republic of China.

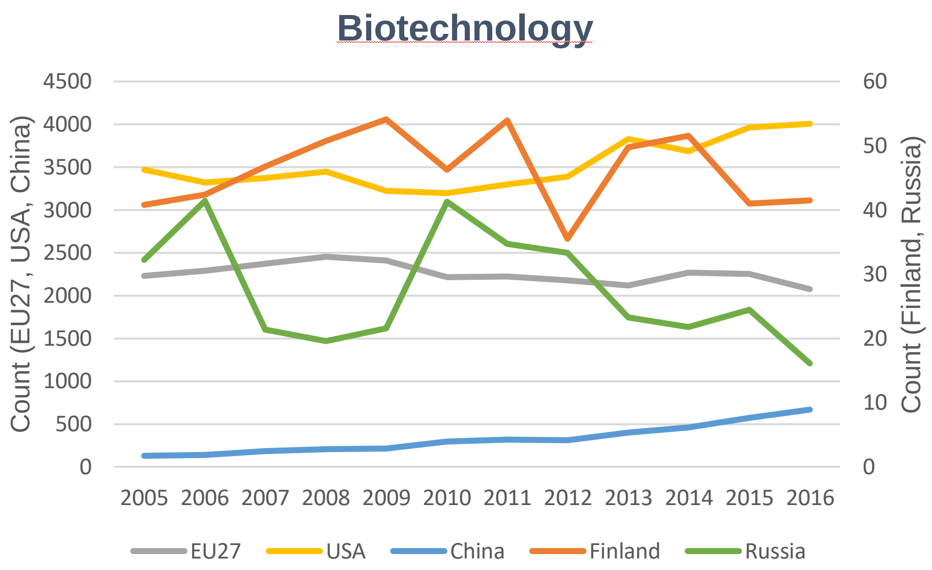

Figure 5 IP5 patents in biotechnology by country.

Measuring by fractional count of IP5 patents in the field of Artificial Intelligence, all groups show an increase in patenting in all countries. The highlight in Figure 6, is the difference between the left axis, with EU27, USA, and China, and the right axis, with Finland and Russia. Russia's patenting volume has increased significantly overtaking Finland but remaining far behind the reference group. In the graph Artificial Intelligence patents are identified using the approach created by Baruffaldi et al. (2020).

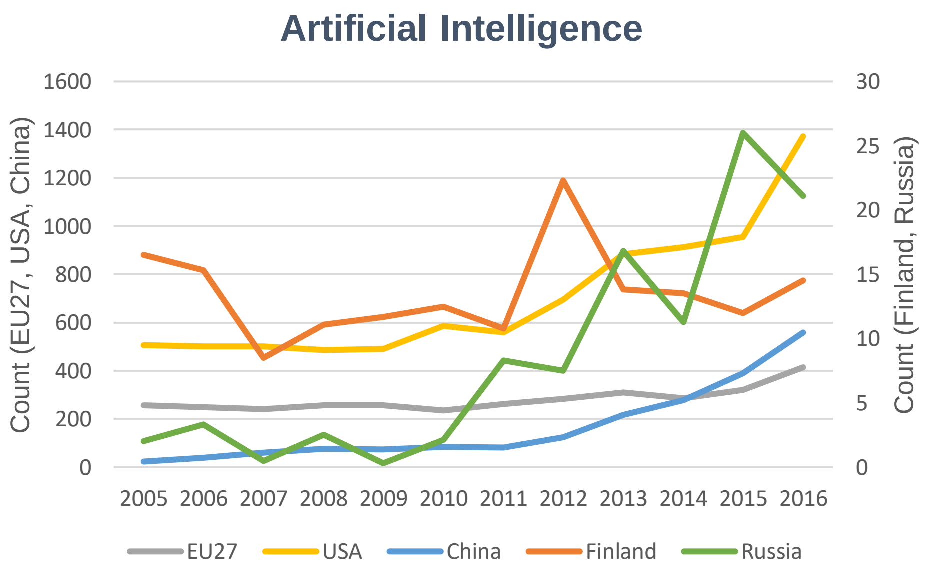

Figure 6 IP5 patents in related to Artificial Intelligence by country.

Turning the attention from the specific case of Artificial Intelligence to ICT overall, the count of IP5 patents in ICT is framed by the extremely high growth of Chinese patenting within the time-period. As seen in Figure 7, China has overtaken EU-27 and closing in on the US. In relative to country size Finland has maintained a relatively high patenting volume. Russia's patenting activities, while increasing, are significantly lower than that of Finland. Particularly striking fact is the difference between trajectories of China and Russia.

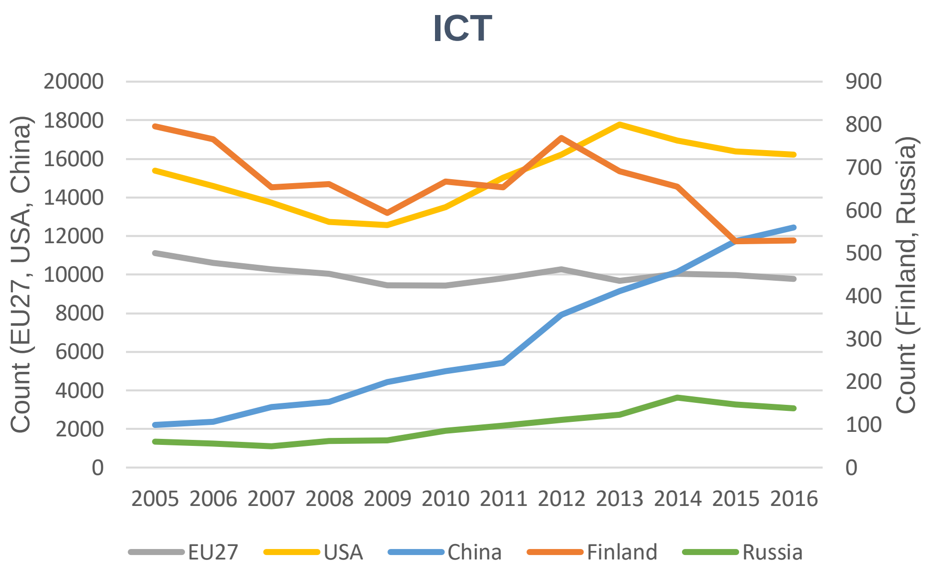

Figure 7 IP5 patents in related to ICT by country.

Measuring by fractional count of IP5 patents in Nanotechnology, Figure 8 shows aa similar decreasing trajectory across the sample countries, while noting the different scales used for EU27, USA and China when compared to Finland and Russia. In comparison to the results from biotechnology, the difference between the right and left axes is not as stark, but significant in the case of nanotechnology. In terms of Russian STI policy, an interesting aspect is the extremely low volume of nanotechnology IP5 patents, when taking into account the substantial Russian investments, programs and policy measures to promote nanotechnology during the last decade.

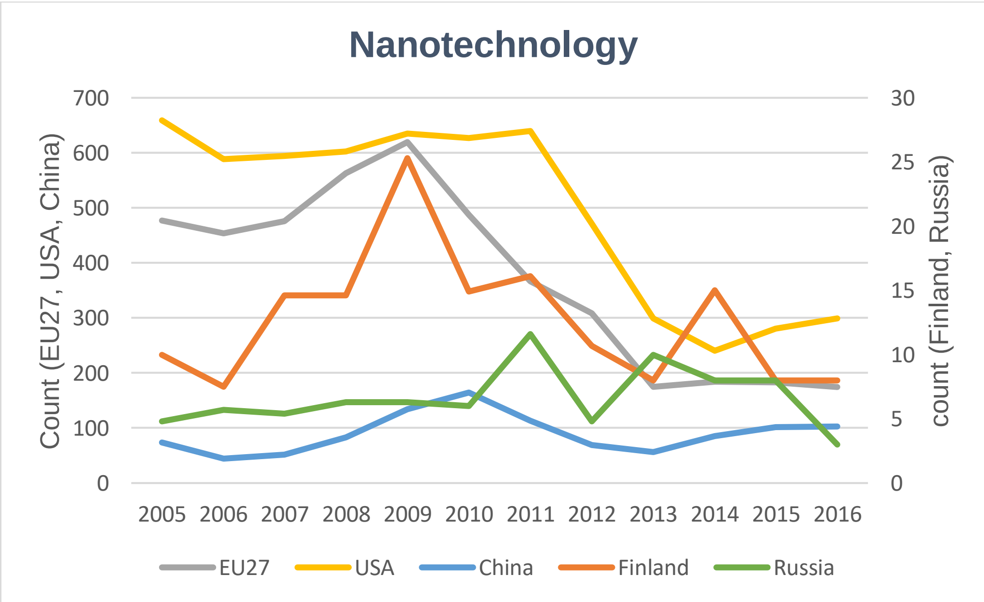

Figure 8 IP5 patents in related to Nanotechnology by country

In terms of Medical technology, we note the relatively stable behavior of USA and EU27 and the modest growth trajectory of China, if we compare for example to the volume of growth in ICT. Seen in Figure 9, Finnish patenting has almost doubled during the observed period while Russia's patenting activities have remained stable but low through the observed period. The selection of medical technology patents is based on WIPO's technology concordance table (WIPO 2013), and cover patents filed in IPC classes A61 [B,C,D,F,G,H,J,L,M,N] and H05G.

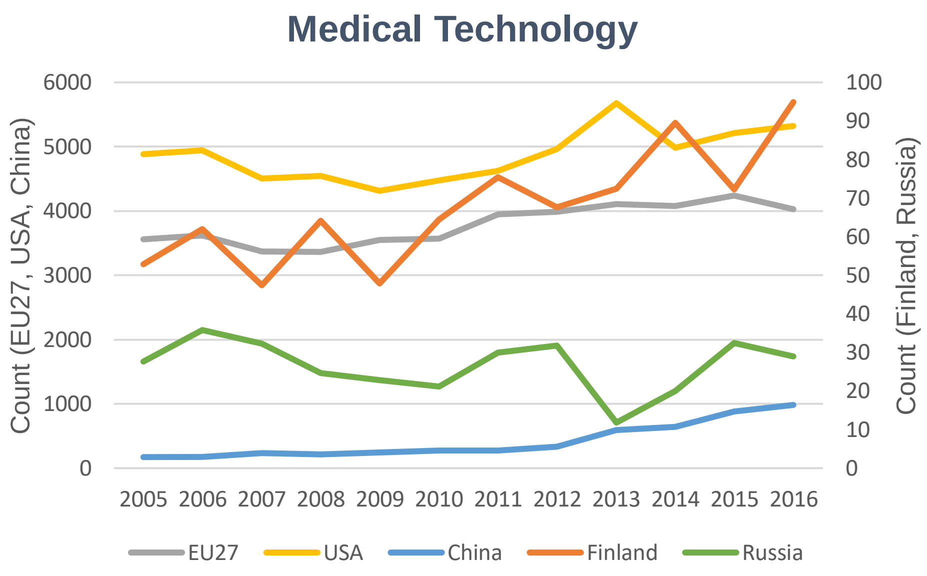

Figure 9 IP5 patents in related to Medical Technology by country

Measuring by fractional count of IP5 patents in pharmaceuticals, seen in Figure 10, we note that US patenting shows a U-shaped behavior, EU 27 decreases, while Chinese patenting increases. Russia's patenting activities have remained stable but low through the observed period, them being in a similar range of patenting activities in Finland. The selection of pharmaceuticals patents is based on WIPO's technology concordance table (2013), and cover patents filed in IPC class A61K, with the exclusion of cosmetics filed under A61K8/*.

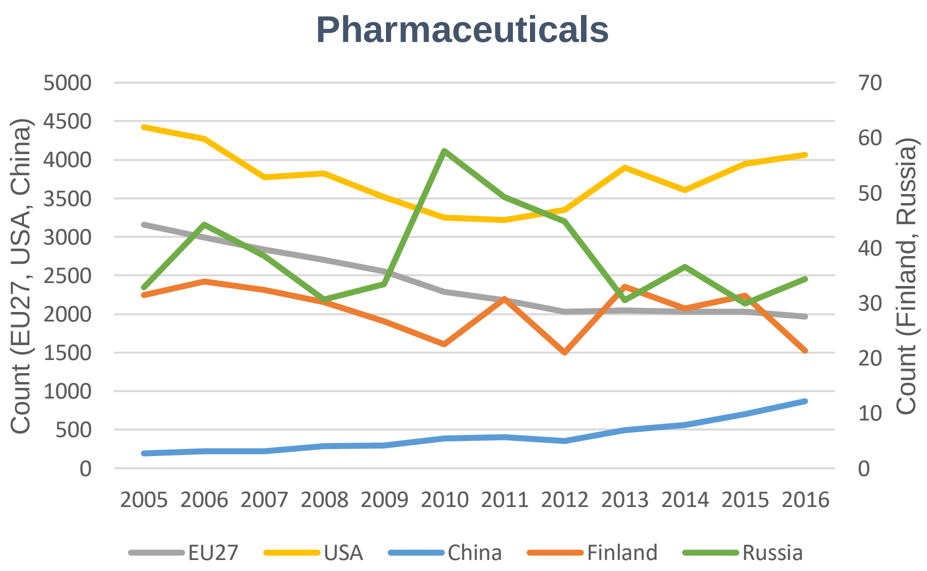

Figure 10 IP5 patents in related to Pharmaceuticals by country

Measuring by a fractional count of IP5 patents in environmental technology, we note two behavioral patterns. Seen in Figure 11, Finland, USA, and EU27 increase significantly through 2011 but decrease since. Russia and China show a stable, slowly increasing trend. Again, it should be noted that Finland and Russia are on the right axis, which reflects Russia's low volume of patents. The selection of environmental technology patents is based on OECD search strategy.

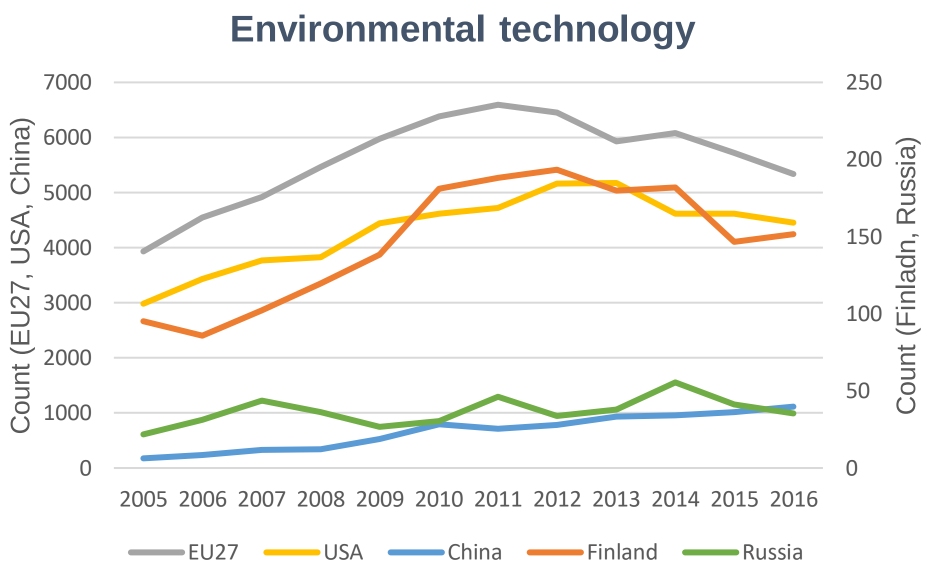

Figure 11 IP5 patents in related to environmental technologies by country

Conclusions

Overall, Russia's science and technology capability is challenged by the isolation of science and technology as a sector of the economy. Even if reflected against the starting point inherited from the Soviet S&T system (Hanson et al., 2013) the results highlight that the Russian S&T system has not been able to recoup the developed technological lag with the comparative groups. This is particularly visible when compared to the developmental S&T trajectory of China.

Despite these problems, Russia has a long history of scientific excellence that continues to this day (Gershman et al., 2018). During the last two decades Russia has attempted to combine the best elements saved from the Soviet system, such as strong educational basis and good basic scientific research, with novel top-down initiatives, often emulated from Western and Chinese successes, such as Technoparks, strategic research centres and regional R&D clusters. (van Someren & van Someren-Wang, 2016, 22-24) Moreover, Russia has increasingly invested in its ability to compete in the field of science (Schiermeier, 2020) and in the commercialization of technology in terms of legislation, infrastructure and funding (Dezhina & Etzkowitz, 2016; L. Graham, 2013).

These measures reflect Radosevic (2003), who called for strong innovation policy in the post-soviet era.

Indeed, there has been no lack of policy intervention in the fields of S&T and R&D.

Other policy measures have focused on increasing the demand for high-tech knowledge in the economy (Kihlgren, 2003), improving the quality of the higher education system (Schiermeier, 2012) and scientific excellence (Schiermeier, 2020) as well as creating mission driven science and technology spaces (Gokhberg et al., 2018; Seliverstov, 2020).

However, without the right societal conditions, such as a culture of entrepreneurship, functioning innovation ecosystems and private R&D investments, the impact of these policy measures will inevitably remain modest (Carayannis et al., 2016 1140-1141; Dezhina & Etzkowitz, 2016). Moreover, Russia has continued to suffer from structural problems in terms of its ability to convert basic science into technological innovation. (van Someren & van Someren-Wang, 2016, 6-9) According to Graham (2013), Russia has been unable to sustain and further develop its technological inventions, because the attempts to generate innovations and to modernize technology development have focused on technocratic instruments and technological fixes, with little attention paid to political and societal issues.

In short, the analysis of Russia's post-soviet development has been critical in terms of the actual progress that has been achieved. This is particularly the case in terms of the innovation systems ability to take advantage of research and development sector (Cervantes & Malkin, 2001), as well as in the development of entrepreneurship abilities (Bogoviz, 2019), but also in the lack of market competition (Gokhberg et al., 2018).

Russia has been unable to address its systemic weaknesses nor has it been able to solve the new challenges that have emerged within the National Innovation System (Klochikhin, 2012).

This is also visible in our results. Even if we count for limitations of observing Russia's S&T system via databases such as science publishing and patenting, which might not fully reflect Russia's abilities, the dynamics between China's development and comparisons to a small country like Finland are striking. That said, the Soviet era has created a strong foundation of research in specific areas that still create a platform and potential to develop the system. However, this will require that the structural challenges limiting broad based impact creation are solved.

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