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Nanotechnology Research and Innovation in Russia: A Bibliometric Analysis

Project on Emerging Technologies, Trajectories and Implications of Next Generation Innovation Systems Development in China and Russia

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Abstract

This working paper presents findings from analyses of Russian nanotechnology outputs in publications and patents focusing on developments over the period 1990 through to 2012. The investigation draws on bibliometric datasets of scientific journal publications and patents and on available secondary English-language and Russian sources.

The document provides both an overview and detailed analyses of nanotechnology research and innovation in Russia. The examination of publications highlights sectoral trends, leading authors and organizations, and acknowledgements to funding sources. The analysis of patents adds further evidence about patterns of invention and ownership of intellectual property emanating from research and development in Russian nanotechnology.

The analyses in this paper have been undertaken to provide an information base for further research on the current state and trajectory of nanotechnology in Russia and on the broader development of Russia's innovation system. Comparisons with Chinese publication and patent outputs can be seen in a parallel report on Nanotechnology Research and Innovation in China (2014).[1]

[1] Maria Karaulova and Mikhail Gershman. *Nanotechnology Research and Innovation in China.* Project on Emerging Technologies, Trajectories and Implications of Next Generation Innovation Systems Development in China and Russia, Manchester Institute of Innovation Research, Manchester, 2014.

1 Introduction

This paper presents findings from analyses of Russian Nanotechnology outputs in publications and patents focusing on developments over the period 1990 through to 2012. The investigation draws on bibliometric datasets of scientific journal publications and patents and on available secondary English-language and Russian sources. The analyses have been undertaken to provide an information base for further research on the current state and trajectory of nanotechnology in Russia and on the broader development of Russia's innovation system.

The existing literature on nanotechnology research and innovation Russia is less prodigious than analogous analyses of China and other "Rising Powers" countries (such as Brazil and India). However, there have been several studies that have profiled nanotechnology developments in Russia or included Russia as a benchmark country.[2] The present study seeks to provide an updated bibliometric analysis that presents a systematic view of the structure and trends in the development of nanotechnology in Russia. We also examine aspects (such as funding acknowledgements) where novel data is now available. The following key topics are examined:

- Nanotechnology publication patterns – the structure and regional distribution of publishing, specialisations of Russian researchers, and main actors and leading institutions of publishing activity;
- Dynamics of international collaboration in nanotechnology by Russian (and Soviet) researchers over time;
- Funding trends in nanotechnology by Russian and foreign research sponsors – using funding acknowledgements data where available in publication records, including comparative analysis of domestic and foreign funding, and the impact on the research outputs;
- Research performance of Russian nanotechnology researchers;
- Nanotechnology patenting patterns of Russian inventors, including main actors and leading institutions of the patenting activity.
- Dynamics of international collaboration of Russian nanotechnology patenting.

[2] See, for example, Terekhov, A.I., "Nanotechnologies and Nanomaterials in the Modern World." *Herald of the Russian Academy of Sciences*, October 2009, 79, 5, pp 412-419; Xuan L., Zhang, P., Li, X., Chen, H., Dang, Y., Larson, C., Roco, M.C., Wang, X. "Trends for nanotechnology development in China, Russia, and India," *Journal of Nanoparticle Research,* Nov 2009, 11(8): 1845–1866; Karasev, O., Rudnik, P., Sokolov, A. "Emerging technology-related markets in Russia: The Case of nanotechnology." *Journal of East-West Business*, 2011, 17, 2-3, pp. 101-119; and Gokhberg L., Fursov K., Karasev O. "Nanotechnology development and regulatory framework: The case of Russia." *Technovation*, 2012, 32, 3–4, pp. 161–162.

2 Data Sources and Methods

The bibliometric analysis draws on datasets of nanotechnology publications and patents developed by researchers at Georgia Institute of Technology and the Manchester Institute of Innovation Research. Two data sources are used: the Web of Science (scientific publications) and Derwent Innovations (patents). Both data sources are published and made available in the Web of Knowledge by ThomsonReuters.

Nanotechnology records in these databases are identified using the two-stage search strategy detailed in Porter et al., 2008,[3] and updated in Arora et al., 2012.[4] A keyword search based on a Boolean query is applied. Unrelated records are then removed by using a series of exclusion terms. Further data cleaning to remove duplicates and consolidate organisational and author names is undertaken using VantagePoint text mining software. Search and data cleaning processes were completed in mid-2013. The resulting database covered the period from 1990 through to 2012, from the breakup of the Soviet Union until the last full year available to us.

The defining characteristic that we used to identify Russian publications was that at least one author of each included publication had to have a Russian affiliation address (Soviet Union in 1990-1992). The primary language of publications in the dataset is English, but specialised editions that include translated articles originally published in Russian are included as well. In total, 33,538 Russian nanotechnology publication records were identified (1990-2012).

Nanotechnology patent records were identified using the same search strategy. Russian patents were defined as those patents listing Russia as the patent priority country. In total, 3,350 Russian nanotechnology patent families were identified (1990-2012).

Both publication and patent databases required cleaning of the records to reduce duplicate entries. We further grouped the data according to country, region, and type of affiliation. Our analysis mostly examines these groupings to develop an understanding of broader themes and trends of in Russian nanotechnology research. Further descriptions of the cleaning and grouping strategies can be found in Appendixes 1 and 2 for publications and patents respectively.

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[3] Porter, A., Youtie, J., Shapira, P., Schoeneck, D., "Refining Search Terms for Nanotechnology," *Journal of Nanoparticle Research,* 2008, 10(5), 715-728.

[4] Arora, S., Porter, A.L., Youtie, J., and Shapira, P. "Capturing new developments in an emerging technology: An updated search strategy for identifying nanotechnology research outputs." *Scientometrics,* 2013 (April), 95, 1, 351-370.

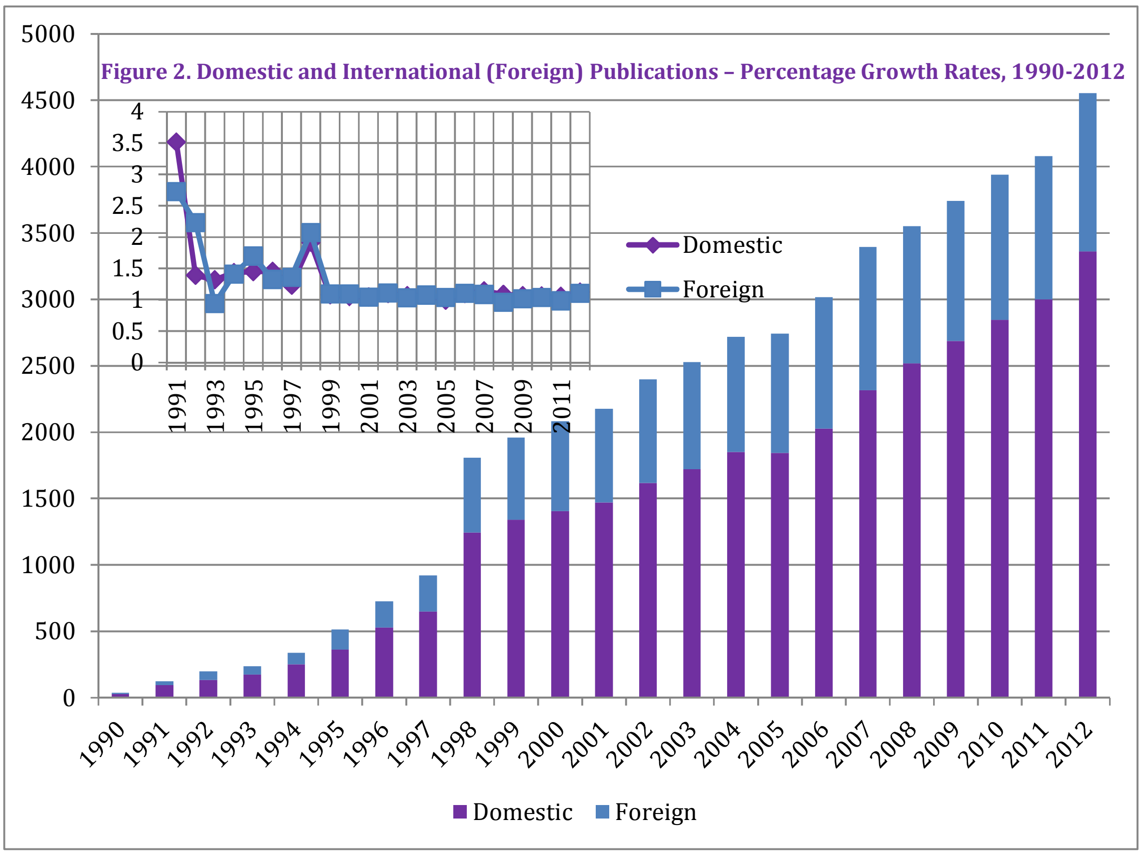
3 Analyses

3.1 Patterns of Russian nanotechnology publication activity

3.1.1 Growth of publications

The output of Russian nanotechnology publications recorded in the Web of Science (WoS) steadily increased between 1990 and 2012. The total number of publications was 33,538 over the full time period, with nearly 3,500 papers published in 2012. In 1998, there was a considerable jump in the number of publications; this probably reflects the fresh inclusion of a series of Russian journals within the WoS (Figure 1).

Figure 1. Annual Publication Growth, Russian Nanotechnology



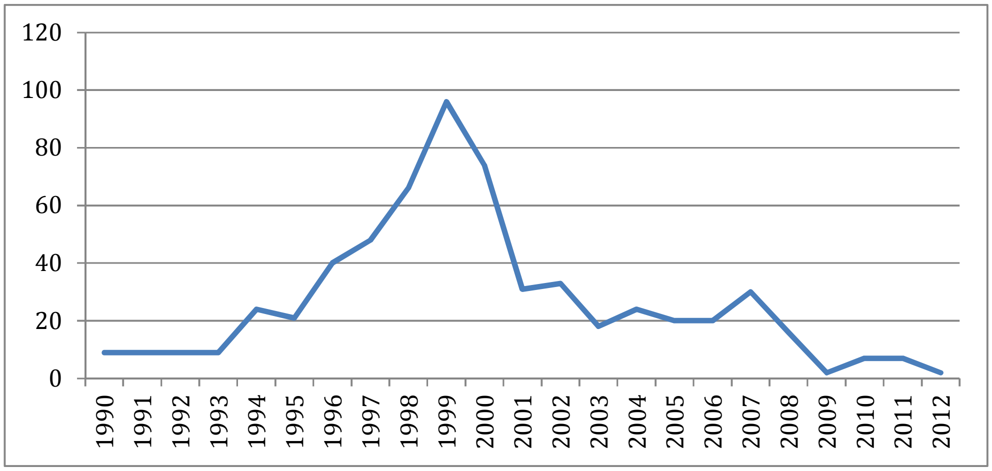
Russian Web of Science nanotechnology publications, 1990-2012 (N=33.5K).

Russian internationally collaborated nanotechnology publications (with one or more authors located outside of Russia) also grew over the study time period (Figure 1, internationally collaborated publications denoted as "foreign"). Significantly, domestic publications (all authors located in Russia) grew faster than the internationally collaborated papers over the total period. However, from 1999 until 2012 growth rates for domestic and international publications are almost identical at about 1.1% per year on average.

3.1.2 Publications Language

Russian nanotechnology papers listed in WoS are published in seven languages. Papers in English comprise 98% of publications. Papers in Russian comprise 1.83% of publications, with the other five languages being an insignificant minority. Over the study period, the growth in Russian WoS nanotechnology publications is almost entirely due to English-language publications. The number of Russian-language WoS publications grew until 1999, but since then has demonstrated a sharp decline (see Figure 3).

Figure 3. Yearly Russian Nanotechnology Publication Output, Russian-language



Russian Web of Science nanotechnology publications, 1990-2012.

The peak of WoS publishing in Russian was during the period 1998-2000. This is also the peak for annual publications produced by the Ioffe Physics Institute of the Russian Academy of Sciences in St Petersburg and of the most productive Russian scientists publishing WOS papers in Russian, according to our dataset. It should be noted that changes in WoS Russian-language publications are influenced by the specific journals that the Web of Science includes in its database. While Russian nanotechnology scientists have increased their English-language WoS publications, they also continue to publish in Russian-language journals that are not indexed in the Web of Science. Additionally, Russian scientists have other channels to publish their research in English: there are a number of English Language translations of the leading journals in Russian available internationally (see further discussion in next section).

3.1.3 Publication Journals

Field data for the journal source is available for 32,844 (or 97%) of our total database of Russian WoS papers. The majority of Russian publications in English were published in translated journals. Out of the top twenty journals with the greatest number of Russian publications, 14 were translated versions of Russian journals (Table 1).[5] About 35% of all

[5] Translated versions of Russian journals are identified not by the publishing body (the rights to publish in most cases are owned by Springer), but by the contents of the journal and the editorial board of the journal. For example, *The Physics of the Solid State* (No2 in Table 1) is published by Springer. The description says "The journal Physics of the Solid State presents the latest results from Russia's leading researchers in condensed matter physics at the Russian Academy of Sciences and other prestigious institutions. (http://www.springer.com/materials/journal/11451) However the analogous journal, called *Phyzika Tvyordogo Tela* (*The Physics of the Solid State*) is published in Russian by the Ioffe Institute in St.Petersburg (http://journals.ioffe.ru/ftt/). The Chief Editor of both journals is A.A. Kaplyanskii, and the editorial board matches the one listed on the Springer website. Tables of contents of several recent issues match as well. From this information we made the conclusion that *The Physics of the Solid State* is a translated version of *Phyzika Tvyordogo Tela*, and the 'publishing body' is therefore an Institute within the Russian Academy of Science (the publishing body of the original), not Springer (the publishing body of the translated version).

publications were published in the top twenty journals, with papers in translated Russian journals included into the top-20 sources constituting about one quarter of these papers.

Table 1. Top-20 Journals – Nanotechnology Papers by Russian Authors, 1990-2012

	Papers	Journal	Publishing Body	Share*
1	1595	Phys. Rev. B	APS	4.86%
2	1412	Phys. Solid State	RAS	4.30%
3	1255	Semiconductors	RAS	3.82%
4	848	Tech. Phys. Lett.	RAS	2.58%
5	828	Jetp Lett.	RAS	2.52%
6	511	Inorg. Mater.	RAS	1.56%
7	510	Appl. Phys. Lett.	American Institute of Physics	1.55%
8	505	J. Appl. Phys.	AIP Publishing	1.54%
9	490	J. Exp. Theor. Phys.	RAS	1.49%
10	411	Russ. Chem. Bull.	RAS	1.25%
11	403	Tech. Phys.	RAS	1.23%
12	348	Russ. J. Appl. Chem.	RAS	1.06%
13	342	Phys. Rev. Lett.	APS	1.04%
14	337	Phys. Metals Metallogr.	RAS	1.03%
15	315	Fuller. Nanotub. Carbon Nanostruct.	Taylor and Francis	0.96%
16	305	Opt. Spectrosc.	RAS	0.93%
17	305	Thin Solid Films	Elsevier	0.93%
18	296	J. Surf. Ingestig.-X-Ray Synchro.	RAS	0.90%
19	293	Glass Phys. Chem.	RAS	0.89%
20	288	Russ. J. Phys. Chem. A	RAS	0.88%

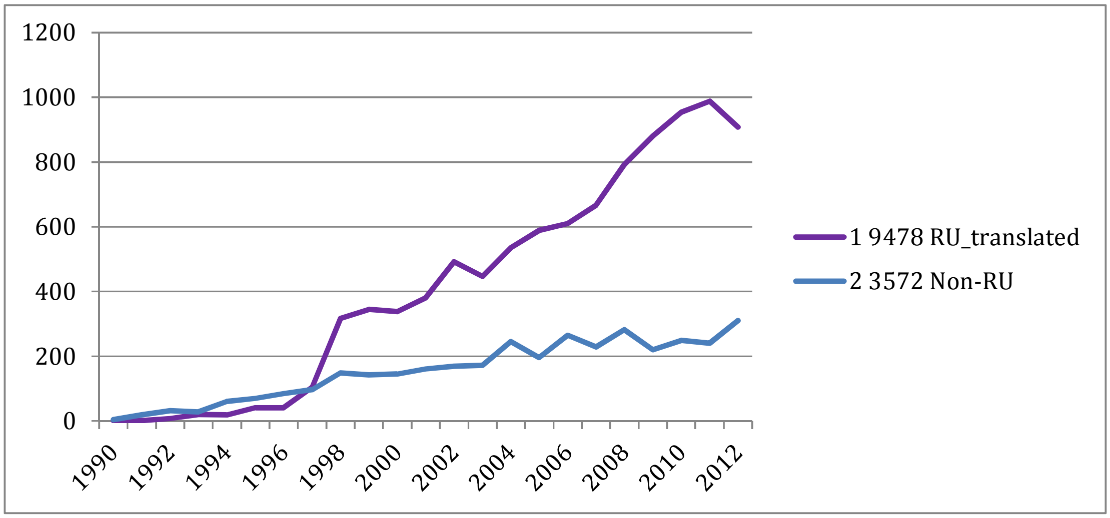
*Share of total Russian Web of Science nanotechnology publications with journal data (N=32,844), 1990-2012.
RAS = Russian Academy of Sciences (translated English-language journal).

It is common for a paper to be first published in a Russian peer-reviewed journal, and subsequently translated and published in the English version of that journal. As a side note, if our database had a large number of publications in Russian, it would mean a large number of duplicated papers; however, this is not the case.

The annual growth of publications in English is much more rapid in journals translated from Russian rather than in international journals initially published in English (Figure 4). Russian scientists prefer to publish in domestic journals, and the domestic science structure remains inward-oriented.

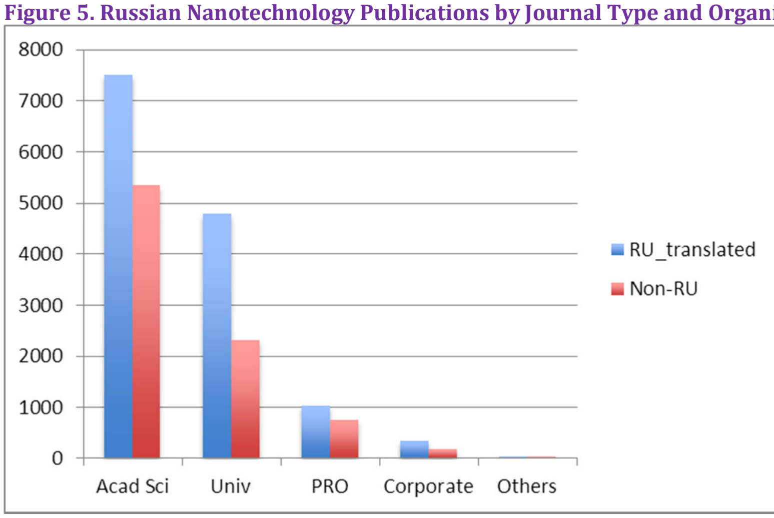
In absolute numbers there is a prevalence of publications in translated versions of domestic journals from institutes of the Russian Academy of Sciences and universities, with some representation from public research organisations (PROs) and corporate actors (Figure 5). However, there are minor sectoral differences: researchers from the Russian Academy of Sciences and public research organisations publish relatively more in non-Russian journals, whereas university researchers are more likely to publish in English-language translations of Russian journals.

Figure 4. Annual Growth of English Language Publications in Russian and Non-Russian Journals



Russian Web of Science nanotechnology English language publications, 1990-2012. RU_translated = papers published first in Russian, then in translated English-Language journals. Non-RU = papers first published in English-language international journals.

Figure 5. Russian Nanotechnology Publications by Journal Type and Organisation, 1990-2012



Russian Web of Science nanotechnology publications, 1990-2012.
RU_translated = papers published first in Russian, then in translated English-Language journals.
Non-RU = papers first published in English-language international journals.

3.1.4 Leading Russian Institutions Publishing in Nanotechnology

There is a high concentration of Russian publishing activity in nanotechnology within a few major organisations. In our study period, the top-twenty leading Russian institutions publishing in nanotechnology comprised the Russian Academy of Sciences (RAS), 15 universities and four State Research Institutes (Table 2). Although these organisations all are state-owned they differ in structure and methods of funding. Among the top-20 domestic publishers 68% of publications are produced by the Russian Academy of Sciences and another 12% by the Moscow State University (MSU). The top-20 organisations together produced 87.4% of all Russian nanotechnology publications in 1990-2012. The top three organisations – RAS, MSU and St Petersburg State University (SPSU) – produced 78% of all Russian nanotechnology publications over the study period. (The RAS has more than 500 institutes. The distribution of RAS nanotechnology publications by individual RAS institutes is discussed in Section 3.1.9.2.)

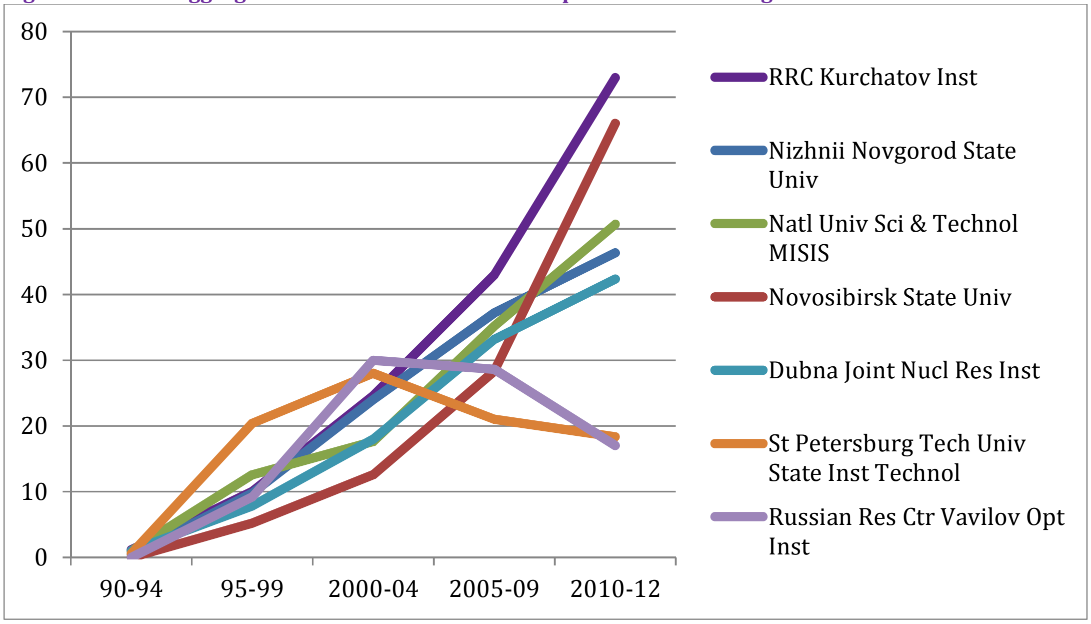
Table 2. Leading Institutions, Russian nanotechnology papers, 1990-2012

	Organisation name	Records	Share of the total
1	RAS	22794	68.12%
2	Moscow MV Lomonosov State Univ	4007	11.98%
3	St Petersburg State Univ	1208	3.61%
4	RRC Kurchatov Inst	613	1.83%
5	Nizhnii Novgorod State Univ	496	1.48%
6	Natl Univ Sci & Technol MISIS	484	1.45%
7	Novosibirsk State Univ	429	1.28%
8	Dubna Joint Nucl Res Inst	427	1.28%
9	St Petersburg Tech Univ State Inst Technol	405	1.21%
10	Russian Res Ctr Vavilov Opt Inst	390	1.17%
11	Ural Fed Univ	359	1.07%
12	Ufa State Aviat Tech Univ	325	0.97%
13	Karpov Inst Phys Chem	294	0.88%
14	Kazan Fed Univ	288	0.86%
15	St Petersburg State Univ Informat Technol Mech & Opt	286	0.85%
16	Moscow Engn Phys Inst State Univ	284	0.85%
17	Voronezh Tech Univ	283	0.85%
18	St Petersburg State Polytech Univ	274	0.82%
19	Moscow Inst Phys & Technol MFTI	233	0.70%
20	Medeleev Univ Chem Technol	218	0.65%

Russian Web of Science nanotechnology publications, 1990-2012 (N=33.5K). Total sums to over 100% due to institutional co-authorships.

It is apparent that three organisations (RAS, MSU and SPSU) dominate Russian nanotechnology publishing by the volume of papers produced. Nonetheless, the next tier of organisations (ranked 4 through 20) contributed more than one-fifth of Russian nanotechnology papers in the period 1990-2012. Looking at the ten organisations in the next tier ranked from 4 through to 11, there are two organisations that have grown rapidly by nanotechnology paper output: the All Russian Science Centre Kurchatov Institute and Novosibirsk State University. Other organisations show less rapid growth, while two organisations (the All Russia State Science Centre Optics Institute and the St Petersburg Institute of Technology) show a declining trend since the early 2000s. (Figure 5.)

Figure 5. 5-Year Aggregated Time Series Data of the top 4-10 Domestic Organisations



Note: Russian Web of Science nanotechnology publications, 1990-2012. Y-axis = papers published over the time periods indicated in the X-axis.

3.1.5 Researchers

3.1.5.1 The most productive authors over time (number of articles published by years)

This section looks at the performance of leading researchers contributing to Russian nanotechnology publication during the observed period.

Over 50,000 researchers have been involved in the development of nanotechnology research outputs in Russia from 1990 through to 2012, according to our database. The top 20 most productive researchers (Table 3) published 2,434 publications, which is 7.26% of the Russian total. The table includes one German researcher from TU Berlin who has collaborated extensively with Russia and is now one of the most productive co-authors of Russian nanoscience papers; two researchers from Moscow State University, and one researcher from Ufa State Technical University of Aviation. The remaining top 20 most productive scientists are from the Russian Academy of Sciences, with the majority from the RAS Ioffe Institute of Physics and Technology.

The peak period of publication activity (papers/year) for all of these most productive scientists was 1998-2000, following which there was a gradual decline (Figure 6). The most productive periods of the most prolific Russian nanoscientists coincides with the most productive periods of Russian nanoscience: the contribution to total publications by the top 20 most productive scientists was above 9% of annual Russian nanotechnology publication in 1996-2001, reaching a pinnacle of 11.47% in 1998. Their careers seem to have started and reached their peak at the same time, with little fluctuation, as the overall publication activity chart for the top-10 of the most productive scientists replicated the sum of their charts (Figure 7). The most productive authors of all time were trained in the last years of the Soviet system. The average productivity of a leading scientist in the 21st century dropped threefold compared to the peak in the late 1990's. The lowest contribution of the top 20 of the most productive scientists was in 2001 (where the contributed 3.96% of annual publications).

Table 3. Top 20 Most Productive Authors, Russian Nanotechnology Papers, 1990-2012

	Authors	Affiliations	Records
1	Ustinov, Victor M	RAS Inst Phys Tech Ioffe	389
2	Ledentsov, Nikolai N	RAS Inst Phys Tech Ioffe	323
3	Bimberg, Dieter	TU Berlin	239
4	Kop'ev, Pyotr S	RAS Inst Phys Tech Ioffe	237
5	Zhukov, Alexey E	RAS Inst Phys Tech Ioffe	237
6	Valiev, Ruslan Z	RAS Inst Met Superplast Prob; Ufa State Aviat Tech Univ	225
7	Ivanov, Sergey V	RAS Inst Phys Tech Ioffe	222
8	Lozovik, Yurii E	RAS Inst Spect Troitsk	205
9	Alferov, Zh I	RAS Inst Phys Tech Ioffe	187
10	Ovid'ko, Ilya A	RAS Inst Problems Mech Engn	163
11	Kovsh, Alexey R	RAS Inst Phys Tech Ioffe	161
12	Yakovlev, Dmitri R	RAS Inst Phys Tech Ioffe	161
13	Boltalina, Olga V	Moscow MV Lomonosov State Univ	151
14	Okotrub, Aleksandr V	RAS Inst Inorgan Chem Nikolaev	150
15	Lyubovskaya, Rimma N	RAS Inst Problems Chem Phys	146
16	Cirlin, Georgii E	RAS Inst Phys Tech Ioffe	139
17	Timoshenko, Victor Yu	Moscow MV Lomonosov State Univ	135
18	Maximov, Mikhail V	RAS Inst Phys Tech Ioffe	134
19	Ivanovskii, Alexander L	RAS Inst Solid State Chem	126
20	Nikiforov, Aleksandr I	RAS Inst Semicond Phys Rzhanov	125

Author analysis of Russian Web of Science nanotechnology publications, 1990-2012.

Figure 6. Time Series of the top 10 most productive authors (annual publication output)

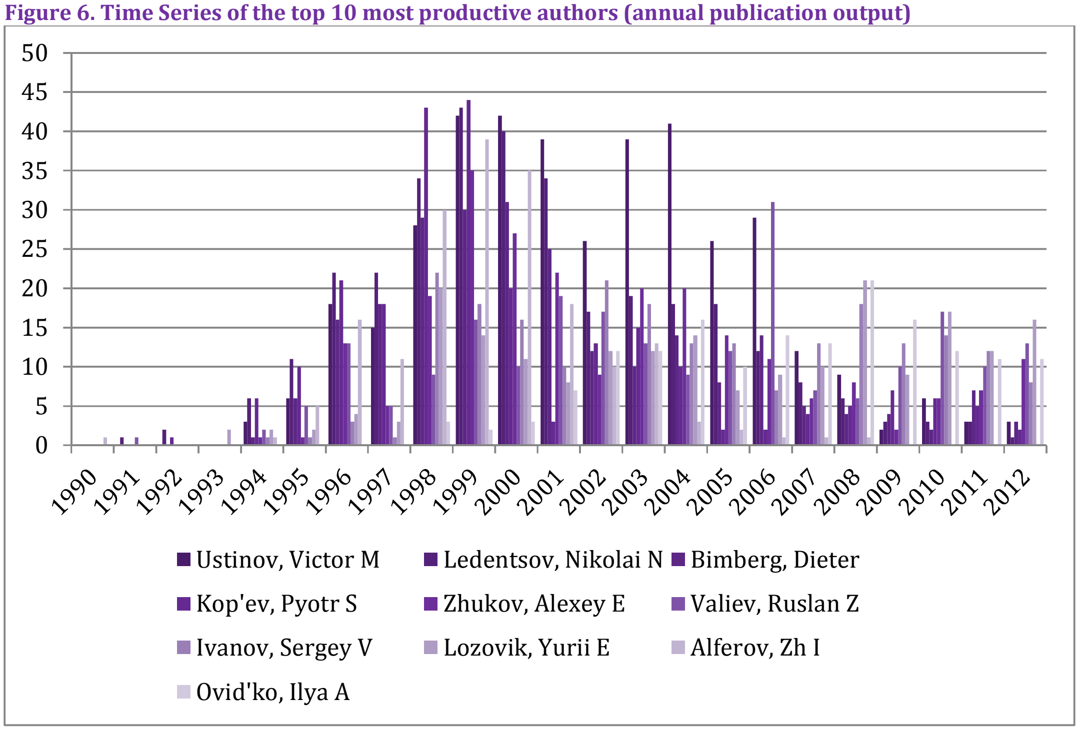
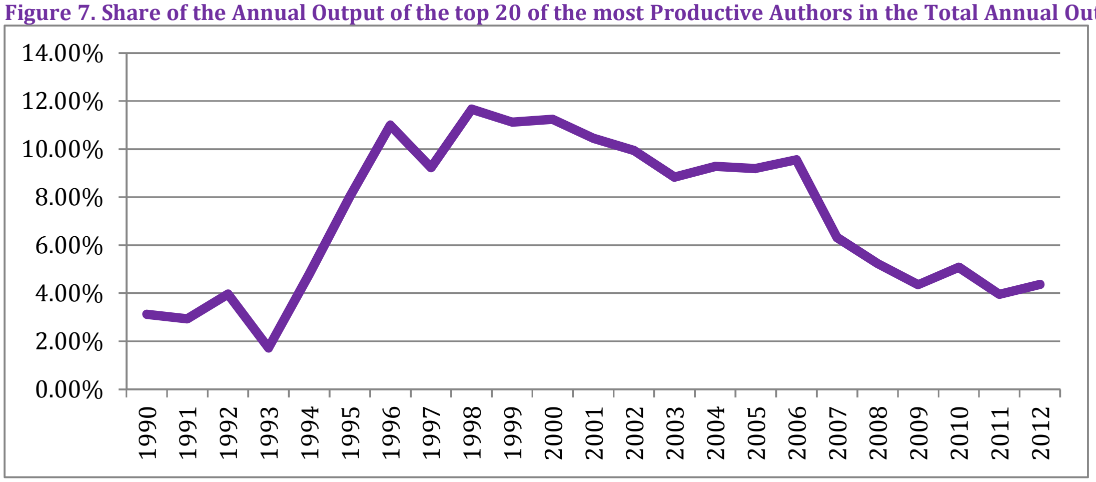


Figure 7. Share of the Annual Output of the top 20 of the most Productive Authors in the Total Annual Output



Author analysis of Russian Web of Science nanotechnology publications, 1990-2012. X-Axis = annual percentage share of Russian nanotechnology papers.

3.1.5.2 "Star" Scientists

By far the most highly cited nanotechnology paper involving Russian researchers is the award winning paper on graphene in *Science* by Novoselov et al. (2004).[6] This paper, highlighted in the laudation to the 2010 Nobel Prize in Physics for graphene[7] awarded to Andre Geim and Konstantin Novoselov of the University of Manchester, UK, attracted 9,388 Web of Science citations by 2012 (and more than 15,500 citations by 2014). Of the eight authors of the paper, five were affiliated (at the time of publication) with the University of Manchester (Novoselov, Geim, Jiang, Zhang, and Grigorieva). Three authors (Morozov, Dubonos, and Firsov) were affiliated (at the time of publication) with the Institute for Microelectronics Technology and High Purity Materials, Russian Academy of Sciences, Chernogolovka (Moscow District), Russia.

This extremely highly-cited landmark paper overshadows the underlying pattern of citations to Russian nanotechnology performance. So, while recognizing the massive impact of this paper, the following analysis does not include it. After the exclusion of this publication it becomes clear that the most highly cited scientists associated with Russian nanotechnology papers are also the most productive scientists (Table 4). The top seven most cited authors are also the most productive authors, with a slight reversal in rank. Ninety percent of the most productive scientists (see Table 3) are in the top-20 list of the most highly cited researchers. The role of the diaspora (of Russian-trained researchers now working in other countries) also becomes clear. Soviet-born Researchers such as Geim and Novoselov remain in the leading group of most highly cited scientists associated with Russian nanotechnology publications even after excluding their 2004 paper, although they no longer represent "domestic" inputs to Russian nanoscience. Other non-Russian researchers are also represented among the most highly cited scientists, as a result of their collaborations with top-cited scientists from Russia. These statistics suggest the importance of international links for publications to be highly cited.

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[6] Novoselov, KS; Geim, AK; Morozov, SV; Jiang, D; Zhang, Y; Dubonos, SV; Grigorieva, IV; and Firsov, AA. "Electric field effect in atomically thin carbon films," *Science*, 306, 5696, pp. 666-669, DOI: 10.1126/science.1102896.

[7] Royal Swedish Academy of Sciences, *Scientific Background on the Nobel Prize in Physics 2010, Graphene. Compiled by the Class for Physics of the Royal Swedish Academy of Science*, October 5, 2010. Stockholm, Sweden. http://www.nobelprize.org/nobel_prizes/physics/laureates/2010/advanced-physicsprize2010.pdf

Additionally, it is notable that RAS dominates Russian nanotechnology research in terms of both volume, journal placement, and citation impact. A portion of the research produced in RAS is world class and the most productive and highly cited people in Russian nanoscience are concentrated within the Russian Academy of Sciences.

Table 4. Highly Cited Authors, Russian Nanotechnology publications, 1990-2012

Rank	Author Name	Affiliations	Times Cited
1	Ledentsov, Nikolai N	RAS Inst Phys Tech Ioffe	6033
2	Ustinov, Victor M	RAS Inst Phys Tech Ioffe	5559
3	Bimberg, Dieter	TU Berlin	5451
4	Alferov, Zh I	RAS Inst Phys Tech Ioffe	5108
5	Kop'ev, Pyotr S	RAS Inst Phys Tech Ioffe	5052
6	Zhukov, Alexey E	RAS Inst Phys Tech Ioffe	3504
7	Valiev, Ruslan Z	RAS Inst Met Superplast Prob; Ufa State Aviat Tech Univ	3428
8	Egorov, Anton Yu	RAS Inst Phys Tech Ioffe	2788
9	Grundmann, M	TU Berlin; Max-Plank Inst	2545
10	Geim, A K	Univ Manchester; Radbound Univ Nijmegen	2382
11	Morozov, S V	RAS Inst Phys Microelect Technol & High Pur Mat	2323
12	Novoselov, K S	Univ Manchester; Radbound Univ Nijmegen	2292
13	Werner, P	Max-Plank Inst	2246
14	Katsnelson, M I	Radbound Univ Nijmegen	2166
15	Gosele, U	Max-Plank Inst	1975
16	Maximov, Mikhail V	RAS Inst Phys Tech Ioffe	1909
17	Heydenreich, J	Max-Plank Inst	1846
18	Ruvimov, S S	RAS Inst Phys Tech Ioffe	1812
19	Kovsh, Alexey R	RAS Inst Phys Tech Ioffe	1757
20	Pertsev, N A	RAS Inst Phys Tech Ioffe	1681

Citation analysis of Russian Web of Science nanotechnology publications, 1990-2012. Excludes Novoselov et al., 2004, (see discussion in text).

3.1.5.3 Newcomer Researchers

Well-established researchers tend to dominate lists of most productive and most cited researchers. However, it is important to also identify the extent to which new researchers are entering the research system. Newcomers may include new early career researchers and research students, but also established researchers who shift into the nanotechnology domain, new collaborators, and other entrants into the Russian nanotechnology research system. In our analysis of Russian nanotechnology papers, we identify newcomer researchers as those who publish for the first time by year of first publication in any year during our study period. These include Russian and non-Russian authors associated with Russian nanotechnology papers. We find that there is a curve, which reflects an increase in the number of newcomer researchers each year (Figure 8). There is a hike in 1997-98, with another noticeable escalation in the number of newcomers starting in 2005. The second jump may be explained by policy: 2005 is the year when first nanotechnology-related Federal Targeted Programmes were adopted, and increased funding was allocated to Russian nanoscience research.[8]

Figure 8. Newcomer Authors in Russian Nanotechnology Publications and their Publications Growth

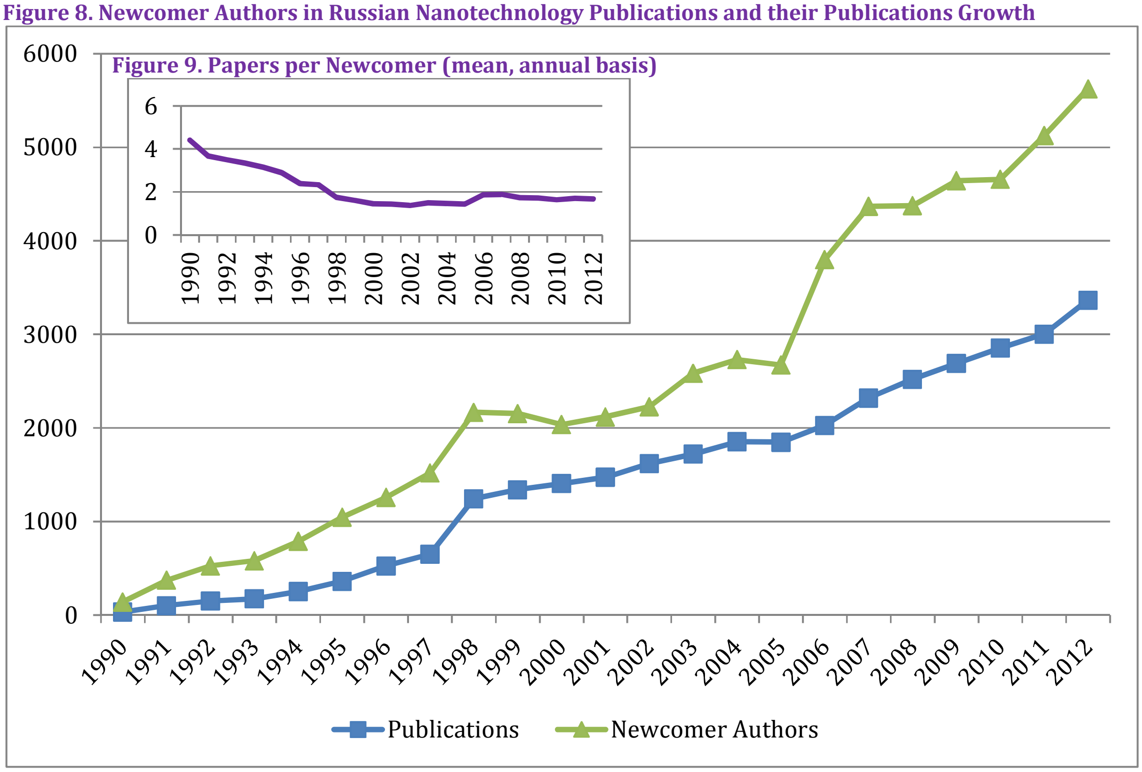

Figure 9. Papers per Newcomer (mean, annual basis)

Author analysis of Russian Web of Science nanotechnology publications, 1990-2012. Newcomers represent authors by year of their first publication. Publications = Newcomer publications.

However, the rising number of newcomer nanotechnology authors does not contribute in the same way to growth in newcomer nanotechnology publications. The ratio of papers published per newcomer annually decreases from the start of the observation period in 1990 from 4.4 papers published in 1990 until it reached the bottom of 1.37 new papers in 2002 (Figure 9). There was an increase in 2005, but then the curve stabilised at the parameter of on average 1.65 published papers per each new author entering the field. There may prospects of increased outputs in future years, as the number of newcomer authors increased by 500 respectively in 2011 and 2012.

The overall number of people employed in scientific research in Russia is decreasing and the average age is increasing, as other studies find including in the nanotechnology domain.[9] Many of the newcomers in nanoscience are probably not fresh university graduates or PhD students, but more likely are mature researchers searching for new sources of funding, and foreign researchers attracted by new opportunities that arose after Russia adopted its National Nanotechnology Initiative and several major programmes aimed at increasing international scientific collaboration.

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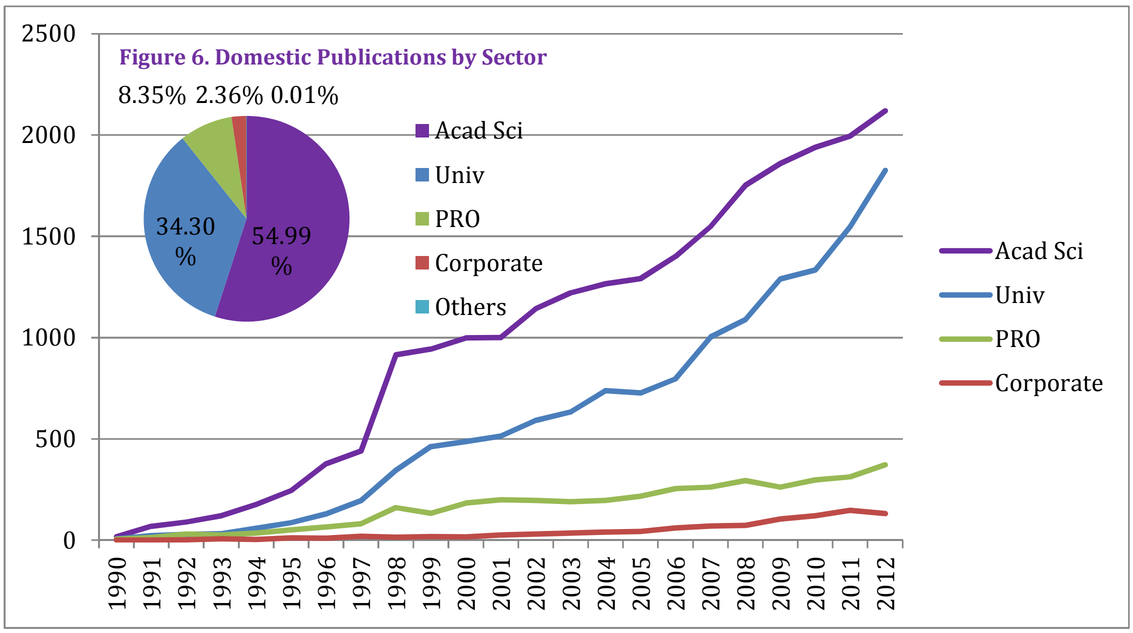
[8] See also Karalouva, M., and Gershman, M., *Russia: Nanotechnology Country Profile*, Working Paper, Project on Emerging Technologies, Trajectories and Implications of Next Generation Innovation Systems Development, Manchester Institute of Innovation Research

[9] Terekhov, A.I., Nanotechnologies and Nanomaterials in the Modern World, Herald of the Russian Academy of Sciences, October 2009, 79, 5, pp 412-419.

3.1.6 Organisational Structure of Russian Nanotechnology Research Publishing

As already noted, the Russian Academy of Sciences (RAS) is the dominant actor in producing nanoscience publications. However, university researchers are catching up with RAS in terms of annual nanotechnology publishing (Figures 10 and 11). Russian public research organisations (PROs) and corporate publishers do not demonstrate similar catch-up tendencies. In total, PROs and corporations contributed about 11% of all Russian nanotechnology publications during our study period. Corporate publishing has increased much slower than PRO publishing, and there is a declining trend for 2012. In contrast, PRO publishing consistently increases in recent years, and in the period 2009-2012 it has increased by 42% (Figure 12).

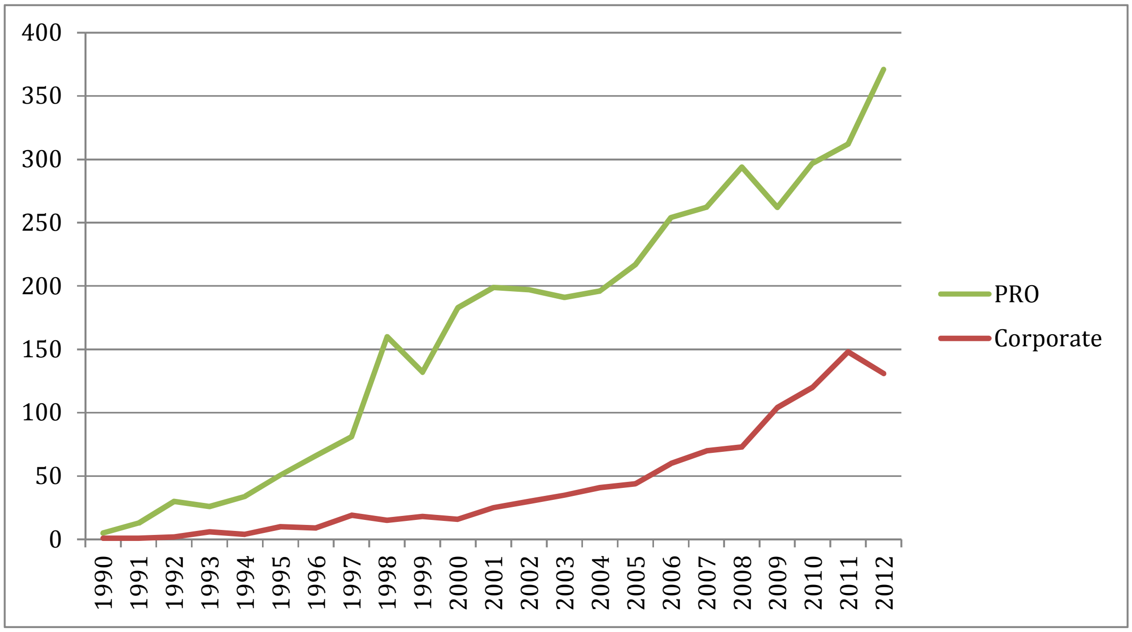
Figure 10. Time Series Dynamics of Domestic Publications by Organisation Type, Russian Nanotechnology



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by organisational type.
Acad Sc = Russian Academy of Science; Univ = universities; PRO = public research organisations; Corporate = corporations (private and state).

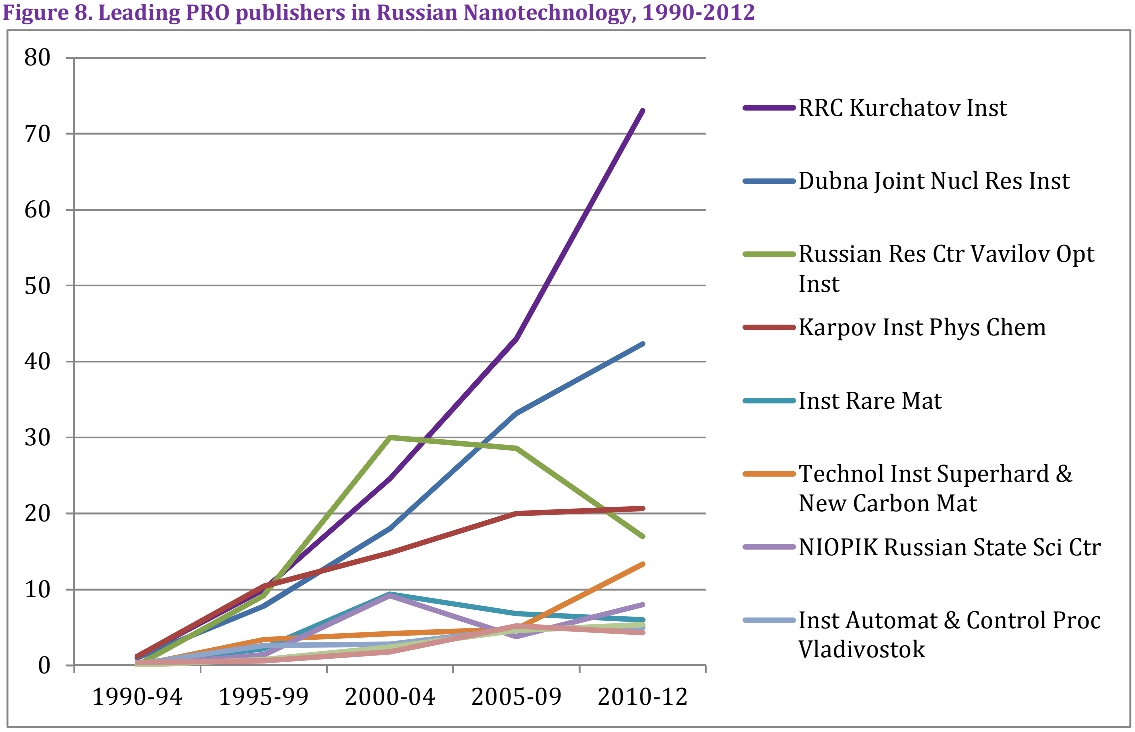
The reasons behind the growth of PRO publishing may be explained by looking at the main actors within the sector and their annual contributions to the field (Figure 13). Out of the top-10 biggest publishers, most are either on a plateau, or their annual output has decreased in recent years. However, there are two organisations whose annual contribution to the body of publications has risen. The fastest growing is the All Russian Research Centre Kurchatov Institute. The research institute is a scientific coordinator of the Russian National Nanotechnology Initiative, and has refocused its research to nano-oriented programmes recently. It has also enjoyed privileged funding and new lab equipment. The significant rise in the annual publication output from seven publications in 1997 to 82 in 2012 may be a result of these processes. The Joint Nuclear Research Institute in Dubna has also grown as the second most productive PRO actor.

Figure 7. PRO and Corporate Publications Outputs, Russian Nanotechnology Publications, 1990-2012



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by organisational type. Y-axis shows annual publications.

Figure 8. Leading PRO publishers in Russian Nanotechnology, 1990-2012



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by organisational type. Y-axis shows publications by indicated time period on X-axis.

3.1.8 Institutional Collaborations

Researchers in different types of domestic organisations in Russia collaborate with each other in producing nanotechnology research outputs. The RAS is a major hub for collaboration. About 39% of all university publications, 33% of all PRO publications and 44% of all corporate publications are collaborated with RAS (Figures 14 and 15). Lower rates for collaboration are seen among university actors: they prefer to do research on their own or with the Russian Academy of Sciences. Researchers in public research organisations collaborate more with universities rather than with the Russian Academy of Sciences: over 50% of collaborations for each type of actor in comparison with just over 30% for RAS. Corporate publishers rely heavily on collaborations, so they have relatively higher rates of collaborations with all types of actors. However, they still collaborate more with universities and RAS than with public research organisations. Corporate actors also obviously prefer Russian organisations as collaborators, whereas the split across other types of actors is roughly half and half.

Figure 9. University and PRO Collaborations, Russian Nanotechnology Publications, 1990-2012

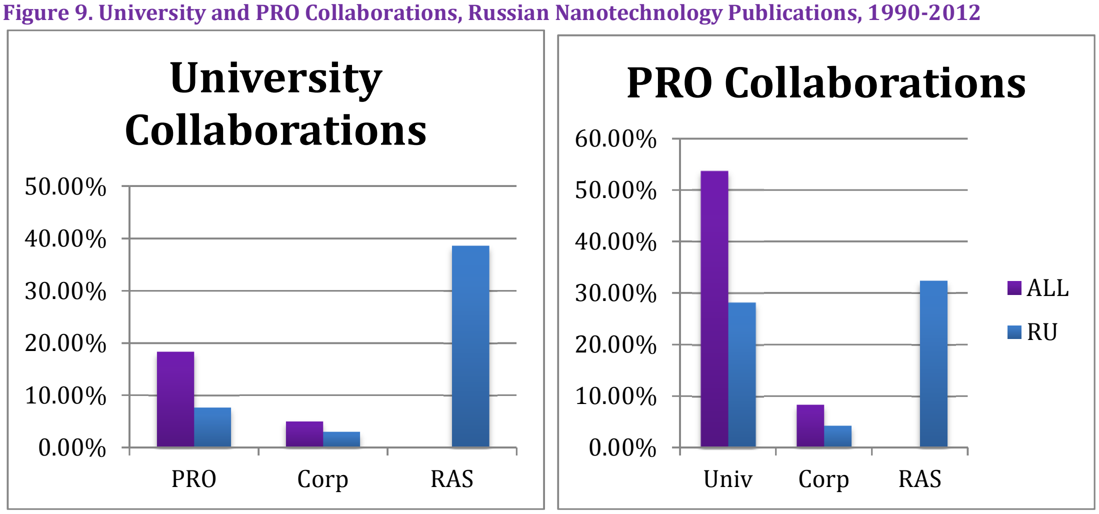
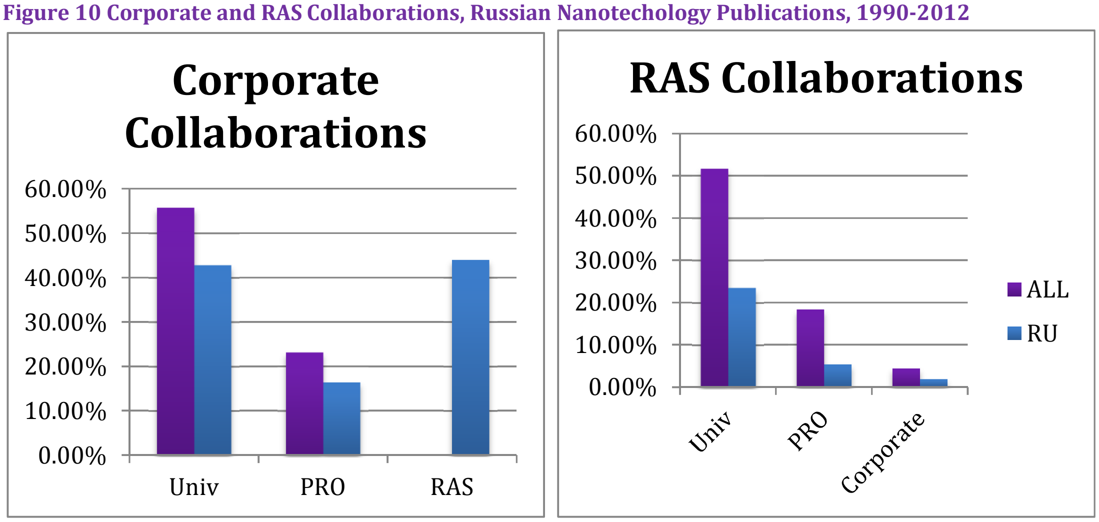


Figure 10 Corporate and RAS Collaborations, Russian Nanotechology Publications, 1990-2012



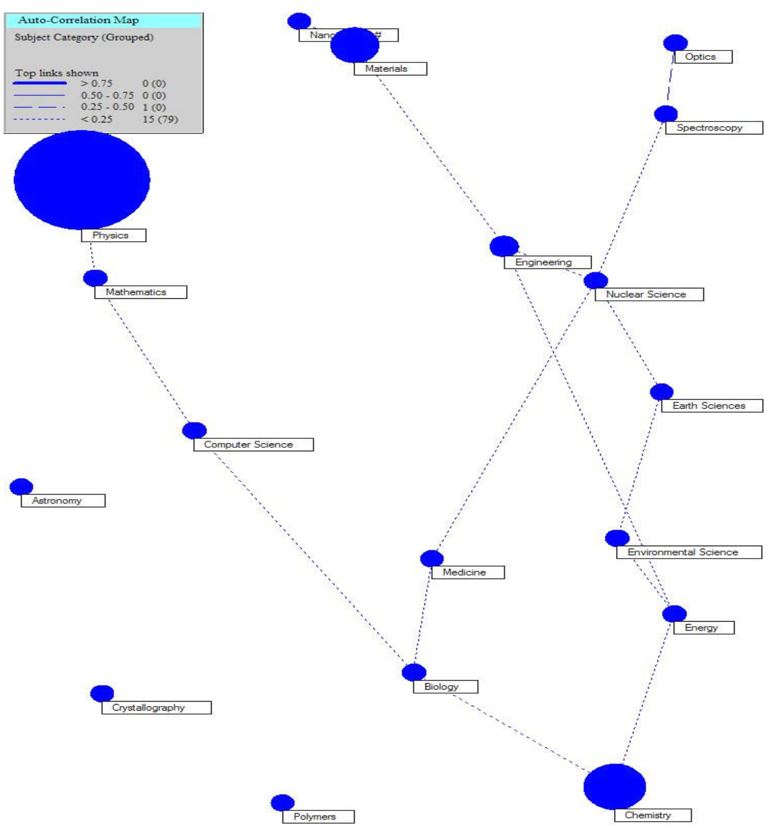
Analysis of Russian Web of Science nanotechnology publications, 1990-2012. Percentage of outputs with collaborations by other organisational types. All = foreign and domestic; RU = domestic (Russian) collaborations.

The Russian Academy of Sciences prefers to work with universities: 51% of its publications are collaborated with this type of organisations. Almost a half of those universities are Russian universities, the balance is comprised of foreign university collaborations. Only 18% of RAS publications are collaborated with public research organisations, and 4.4% of its collaborations include a corporate actor. Out of the 18% of PRO collaborations, only a third are Russian public research organisations. Here, the RAS more frequently collaborates with foreign PROs than with domestic PROS, compared with its higher collaboration rates with Russian universities and corporate actors.

3.1.9 Subject Areas

Physics is the dominant subject area of Russian nanoscience, followed by chemistry and materials according to WoS categories. Researchers producing Russian nanotechnology papers in physics do not much interact with other disciplines in which nanoscience publications are produced. The separate WoS subject of nanotechnology is disciplinarily closer to materials rather than to physics. Overall, it would be fair to suggest that Russian nanotechnology research not only remains within the established disciplinary borders, but there is also little interaction going on between the various disciplines (with the exception of optics and spectroscopy) (Figure 16).

Figure 11. Russian Nanotechnology Publications, Subject Area Map according to WOS categories



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by WoS subject categories and linkages between categories.

An analysis of publications by organisations in WoS subject categories shows some difference in specialisations (Figures 17 and 18). The RAS predominantly specializes in physics (more than twice as many publications as in chemistry, which is the following category). University type organisations mimic the specialisation distribution of RAS on a smaller scale: the proportion of physics publications of RAS/University is 0.55, and the proportion interval (0.5; 0.6) sustains over the other subject areas. Other types of research organizations also specialise in physics, but there is less disparity in publication area. Chemistry also loses its place as the second most important subject area for public research organisations and corporate publishers, and is replaced by materials.

Figure 12. Subject Areas for Russian Academies of Science and University Publications

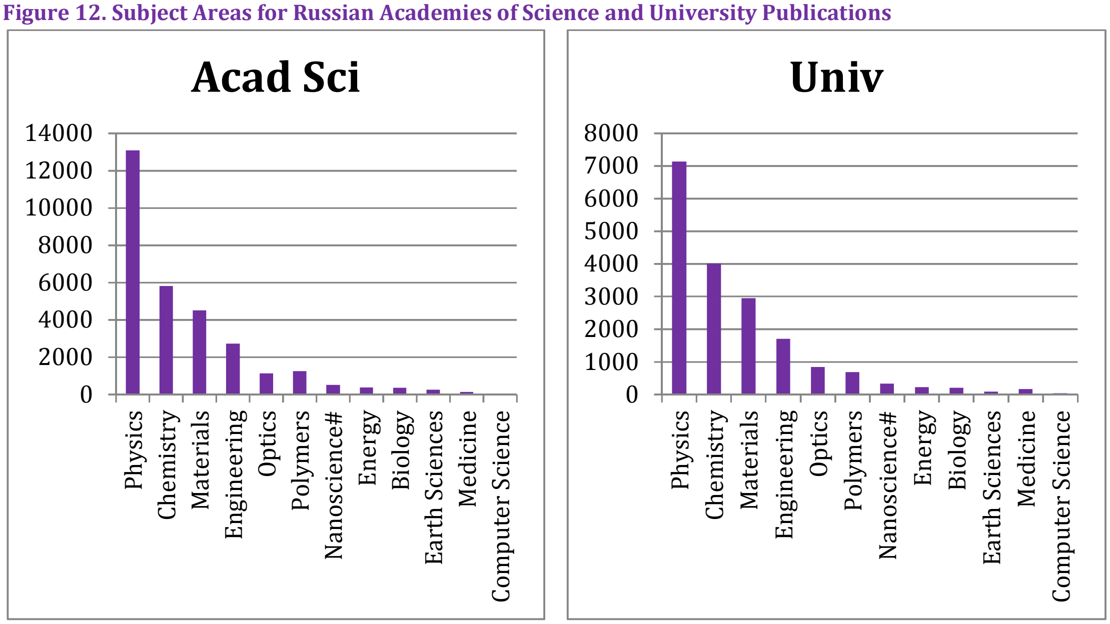
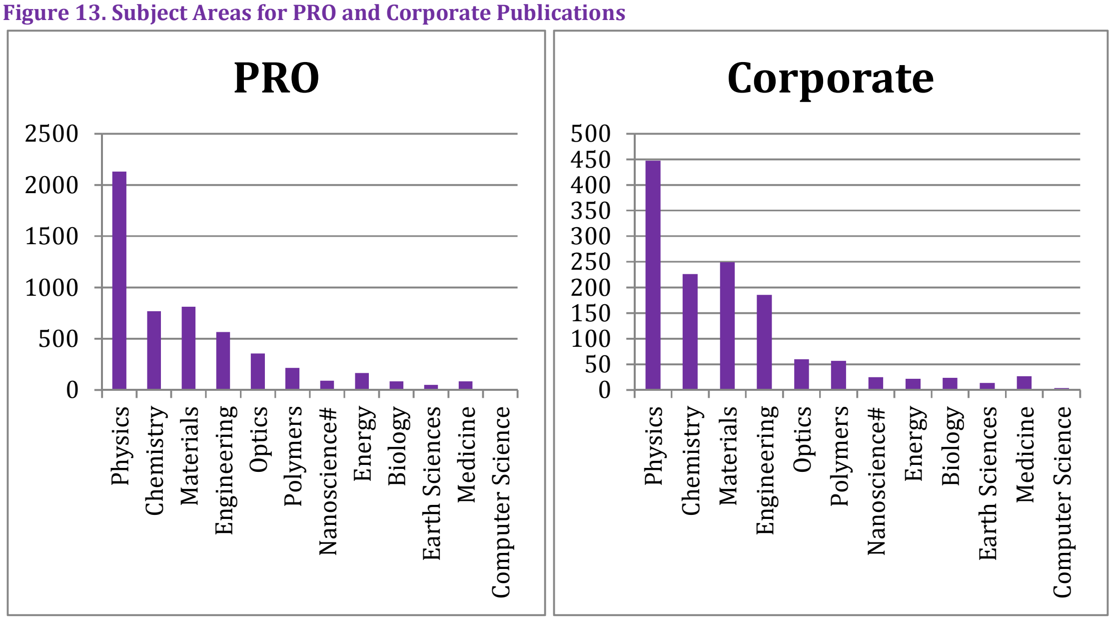


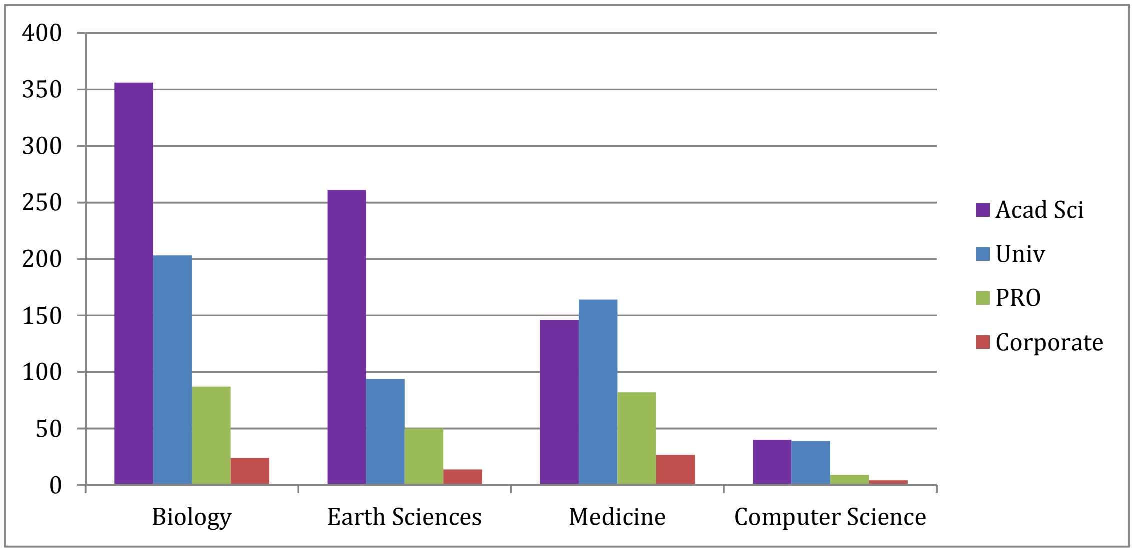
Figure 13. Subject Areas for PRO and Corporate Publications



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by WoS subject categories and organisational types. Y-axis = cumulative number of publications.

In some subject areas (physics, polymers, biology), RAS is a clear leader, but in other subjects (chemistry, engineering, optics) the gap is not as wide. Despite the overall dominance of physics in Russian nanotechnology publication outputs, there are other subject areas, albeit lagging behind in terms of the quantity of the output, where actors other than the Academy of Sciences get an opportunity to take leading positions. These areas are medicine, energy, biology, computer science, and the WOS category of nanoscience.[10] In medicine, university organisations contribute more to the body of publications, and in computer science the contribution is almost equal for universities and Russian Academy of Sciences institutes (Figure 19).

Figure 14. Russian Nanotechnology Publications by Selected Subject Areas and Organisational Type



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, by WoS subject categories and organisational types. Y-axis = cumulative number of publications.

By the number of citations received, physics is the most cited category of Russian nanotechnology publication output, followed by chemistry, materials and engineering (Table 5). Within these major categories, condensed matter physics is the most cited sub-area of Russian nanotechnology, followed by applied physics and materials science.

[10] Nanoscience is a distinct subject category of Web of Science. It is a multidisciplinary category with a growing number of journals appearing in the category in recent years. Most nanotechnology publications are published in journals in other subject categories.

Table 5. Top 10 Most Cited Subject Areas, Russian Nanotechnology Publications, 1990-2012

Subject Area	Total Citations
Physics	87713
Chemistry	32270
Materials	26621
Engineering	13253
Optics	5932
Polymers	6440
Nanoscience	2472
Energy	1666
Biology	2559
Earth Sciences	1187
Medicine	1427
Mathematics	265
Computer Science	161

Citation analysis of Russian Web of Science nanotechnology publications, 1990-2012, by WoS subject categories.

The following section focuses on the nanotechnology publication outputs of the Russian Academy of Sciences (RAS).

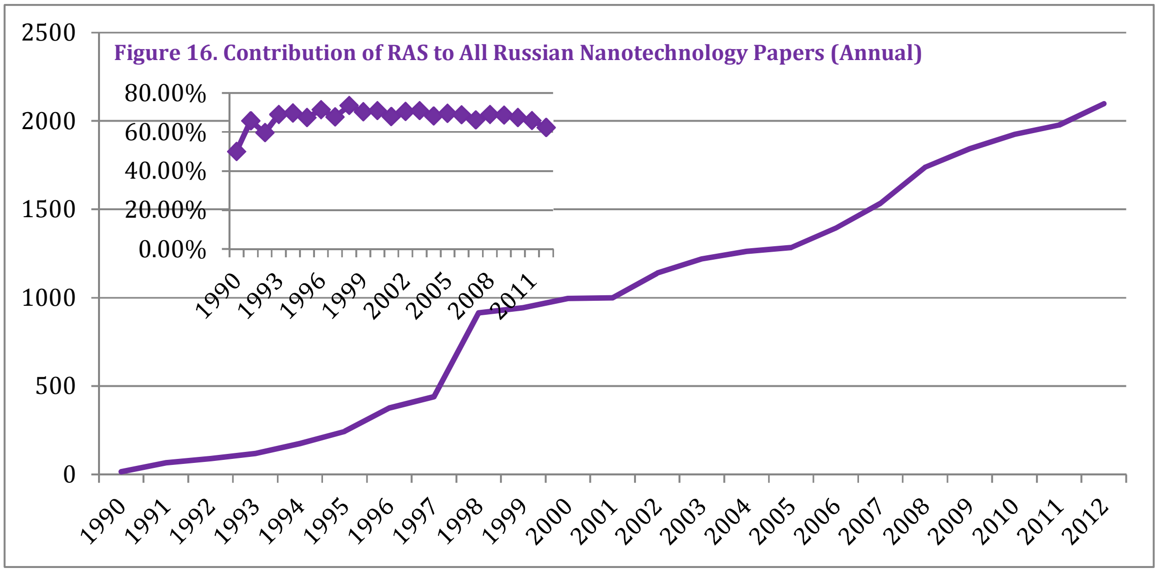
3.1.10 The Russian Academy of Sciences (RAS)

The Russian Academy of Sciences (RAS) is a public research body that occupies a special place within the Russian Science and Technology system. It has a wide regional network of research institutes stretching across all disciplines of sciences and humanities. The RAS has long dominated Russian research publishing and to work in the Academy was regarded as the peak of an academic career during the Soviet Union. In the present day its hegemony is increasingly under challenge, and Russian science is becoming more polycentric. In the field of nanoscience and nanotechnology, however, the RAS contributes to the majority of scientific outputs, and is still a prevailing player.

3.1.10.1 RAS - Growth of Nanotechnology Paper Outputs

There is a steady growth pattern in the nanotechnology publication output of the Russian Academy of Science, with a recognizable leap in 1997/98 (Figure 20). The annual publication production rate exceeded 2000 in 2011. The publication output of the Russian Academy of Sciences has generally been in line with the overall publication growth rates, with the exception of two time periods (Figure 21). During the period 1990-1993 the annual contribution of RAS to the body of publications rose from 50% to 70%. RAS has been contributing on average 70% of all Russian nanoscience publications annually from 1993 until 2009. Since 2009 a declining trend in the annual nanoscience output can be observed, with almost a 10% loss in the share by 2012.

Figure 15. RAS Nanotechnology Publications, 1990-2012



Analysis of Russian Web of Science nanotechnology publications, 1990-2012.

3.1.10.2 RAS - Leading Institutions

The Russian Academy of Sciences has about 500 constituent institutes. Publication activity within the RAS in nanotechnology is concentrated in a smaller number of these institutes. The top 20 institutes of RAS produced more than 72% of all RAS nanotechnology publications in the period 1990-2012 (Table 6).

One RAS institute – the Ioffe Physics and Technology Institute in St Petersburg – produced over 20% of RAS nanotechnology publications (1990-2012). The top three RAS institutes produced just over 30% of RAS nanotechnology publications. The regional distribution is not extensive, especially given the large geographical area of Russia. Twelve of the top 20 RAS nanotechnology publishing institutes, by volume of papers, are in Moscow or the Moscow Region (including Troitsk and Chernogolovka). The "science city" of Novosibirsk emerges as a regional centre (3 top 20 RAS nanotechnology institutes), with two institutes in St Petersburg. The cities of Ekaterinburg, Kazan, and Nizhnii Novgorod each host one of the top 20 RAS nanotechnology institutes. Except for Novosibirsk, all the other cities with leading RAS nanotechnology institutes are in European Russia (which hosts more than three-quarters of the Russian population).

The RAS also houses the most productive Russian nanotechnology researchers. Eight of the 10 most productive Russian nanotechnology research authors are affiliated with the RAS – mostly at the Ioffe Institute of Physics and Technology (see Table 4). The most productive RAS researchers in nanotechnology are indicated in Table 7. The Ioffe institute is again well represented.

Table 6. Top-20 Institutions of RAS by Nanotechnology Publications, 1990-2012

RAS Institute	Number of Pubs	% of Total	Location
RAS Inst Phys Tech Ioffe	4696	20.67%	St Petersburg
RAS Inst Problems Chem Phys	1208	5.32%	Moscow
RAS Inst Semicond Phys Rzhanov	1203	5.30%	Novosibirsk
RAS Inst Gen Phys Prokhorov	1023	4.50%	Moscow
RAS Inst Solid State Phys	926	4.08%	Moscow Region
RAS Inst Phys Lebedev	885	3.90%	Moscow
RAS Inst Catalysis Boreskov	823	3.62%	Novosibirsk
RAS Inst Crystallog Shubnikov	777	3.42%	Moscow
RAS Inst Chem Phys Semenov	727	3.20%	Moscow
RAS Inst Organoelement Cpds Nesmeyanov	655	2.88%	Moscow
RAS Inst Phys Chem & Elektrochem Frumkin	616	2.71%	Moscow
RAS Inst Met Phys	580	2.55%	Ekaterinburg
RAS Inst Inorgan Chem Nikolaev	548	2.41%	Novosibirsk
RAS Inst Spect	547	2.41%	Moscow Region
RAS Inst Gen & Inorgan Chem Kurnakov	505	2.22%	Moscow
RAS Inst Phys Microstruct	498	2.19%	Nizhnii Novgorod
RAS Inst Macromol Cpds	474	2.09%	St Petersburg
RAS Inst Radio Engn & Elect Kotelnikov	470	2.07%	Moscow
RAS Ctr Sci Kazan	438	1.93%	Kazan
RAS Inst Microelect Technol & High Pur Mat	373	1.64%	Moscow Region

Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012 (N=22,794)

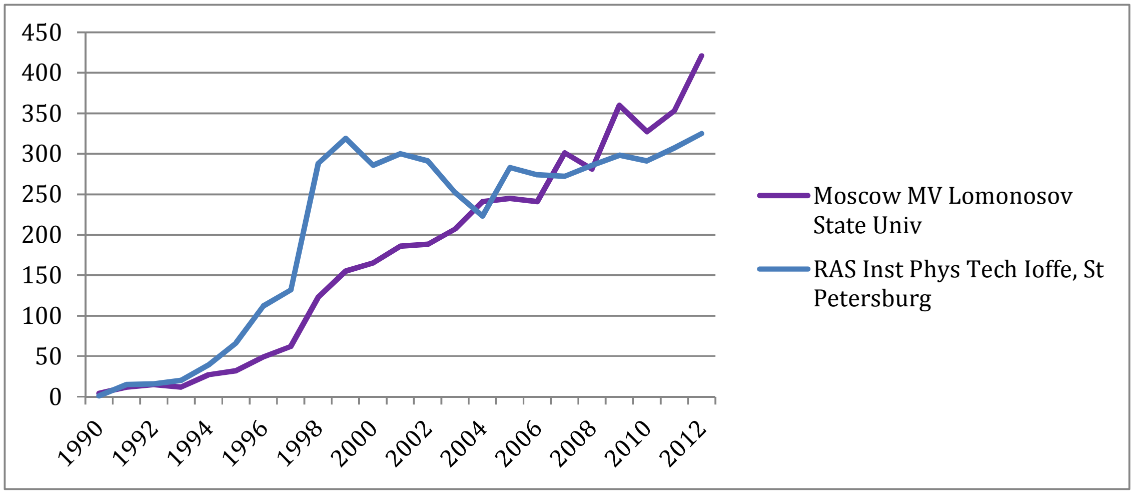
Table 7. Top-10 Contributing RAS Authors in Nanotechnology

Name	Total Number of Pubs	Affiliated with Ioffe Inst
Ustinov, V M	387	383
Ledentsov, N N	318	315
Zhukov, A E	235	227
Bimberg, D	226	215
Ivanov, S V	219	219
Valiev, R Z	200	2
Alferov, Z I	185	183
Kop'ev, P S	179	179
Ovid'ko, I A	161	9
Kovsh, A R	159	157

Author analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012 (N=22,794)

Our analyses highlight that the Ioffe Institute is not only a key organisation in RAS nanotechnology research but also occupies a key position in Russian nanotechnology research in general, having published more than any other organization, and having hosted the most prominent scientists during the observed period. However, in recent years the output productivity of the Ioffe Institute has plateaued. For example, in Figure 22, the annual nanotechnology publication output of Ioffe is compared with the leading non-RAS organisation, Moscow State University (MSU). In recent years (2008 onwards) MSU overtook the Ioffe Institute in yearly publication growth. The peak of the Ioffe Institute's publication activities came during 1998-2000, which was also the peak of publishing activities for its star scientists. Since then, the Ioffe Institute has seen a relative diminishment in its leadership position. Ioffe's relative importance within the nanotechnology research activities of the RAS has declined as well: the share of Ioffe's nanotechnology publications as a percentage of all RAS nanotechnology outputs fell below 20% in 2002 and has further declined since then, going below 10% in 2012.

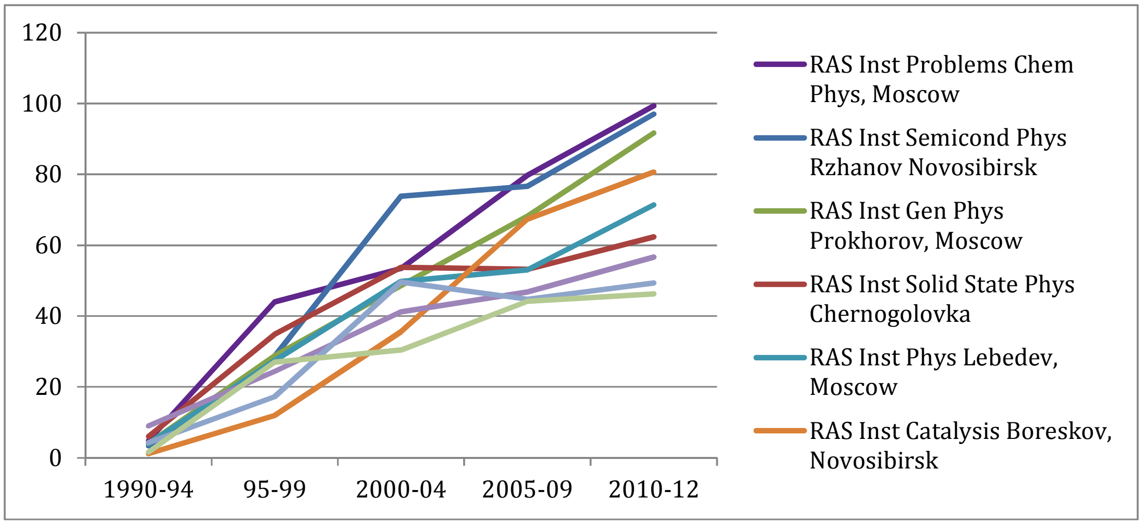
Figure 17. Ioffe Institute and MSU Annual Publication Outputs



Analysis of Russian Web of Science nanotechnology publications, 1990-2012.

After the Ioffe Institute, the next set of RAS institutes in the top 20 for nanotechnology publishing contributes at lower but comparable orders of magnitude. Based on 5-year aggregations, three groups can be distinguished among the 9 institutes that follow Ioffe Institute (Figure 23). The first group comprises of two Institutes from Moscow (*Institute of Problems of Chemistry and Physics*) and two Institutes from Novosibirsk (*Institute of Semiconductor Physics and the Institute of Catalysis*). All four institutes have demonstrated stable growth over the period and have been publishing 80-100 publications annually in 2010-2012 yrs. The second group includes the *Institute of Physics N.A Lebedev* in Moscow and the *Institute of Solid State Physics* in Chernogolovka, Moscow Region. These two institutes were keeping up with the first four in terms of publication growth in the first half of the observed period, but lost pace and fell behind by the end of the observed period producing 60-70 publications p/a in 2010-12. Finally, the last group consists of three other Moscow Institutes: the *Institute of Crystallogy*, *Institute of Chemistry* and *Physics N.A. Semenov*, and the *Institute of Organoelement Compounds*. They have maintained slower pace of growth than that of the other institutes in the top 10, and ended up producing 40-60 publications p/a in 2010-2012.

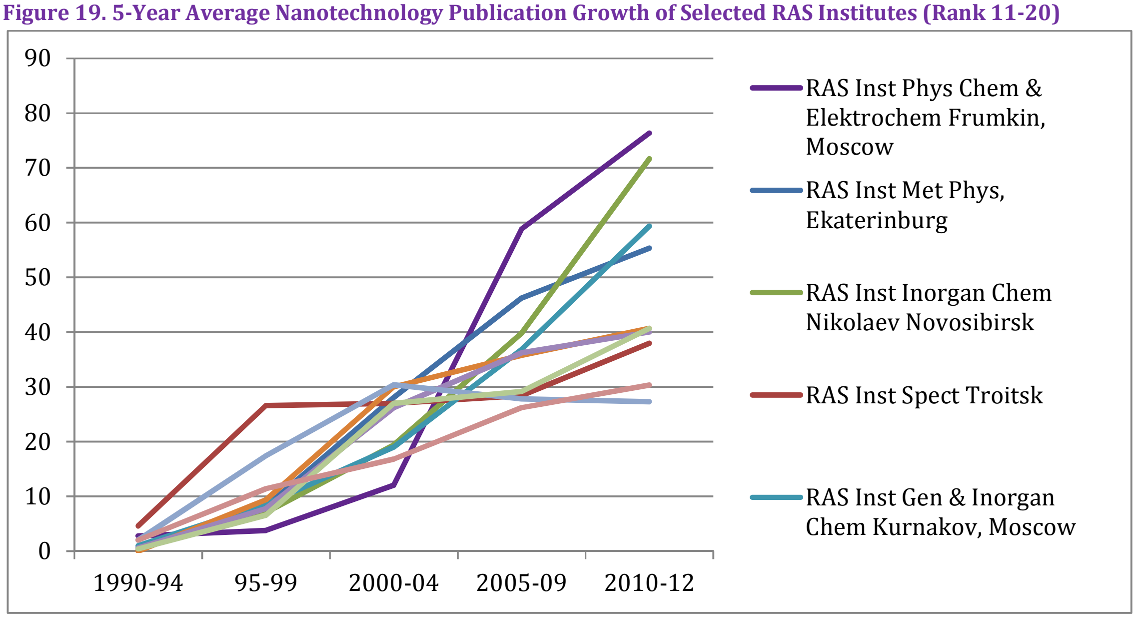
Figure 18. 5-Year Average Nanotechnology Publication Growth of Selected RAS Institutes (Rank 2-10)



Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012. Ioffe Institute is not included in this figure. Y-axis = number of publications for time period indicated on X-axis.

It should be noted that in the top-20 of the most productive RAS institutes, two institutes from Moscow and one institute from Novosibirsk made a really significant leap from producing fewer than 20 publications p/a in 2000-2004 to publishing 60-80 articles in the 2010-2012 time period. These are the *Institute of Physics Chemistry and Electrochemistry,* the *Institute of Inorganic Chemistry N.A. Nikolaev,* and the *Institute of General and Inorganic Chemistry N.A. Kurnakov* (Figure 24).

Figure 19. 5-Year Average Nanotechnology Publication Growth of Selected RAS Institutes (Rank 11-20)

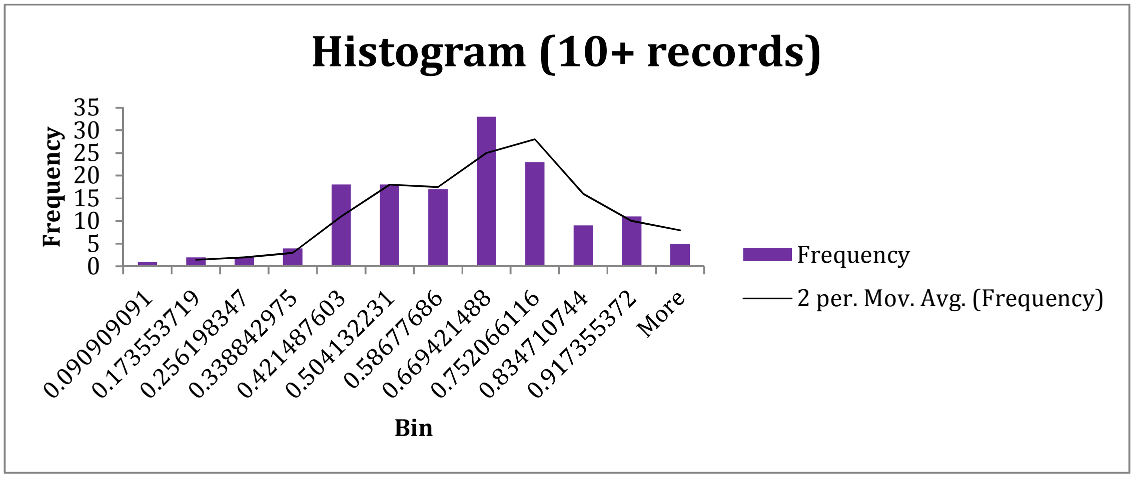


Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012. Y-axis = number of publications for time period indicated on X-axis.

3.1.10.3 RAS - Institutional Collaborations

We use a cross-correlation analysis to examine levels of collaborations between authors from different institutions. In this case, the central node for collaboration is RAS. In 1990 – 2012, RAS researchers collaborated on 64.3% of their papers with researchers from non-RAS organisations. A histogram of the variance (Figure 25) in collaboration by leading RAS institutes suggests that the majority of the RAS institutions tend to have 40-50% of publications which were collaborated with non-RAS organisations. There are several research clusters situated around Moscow (Troitsk, Sarov, Puschino) that have higher rates of collaborative publications.

Figure 20. Distribution of Variance of Collaboration for leading RAS Nanotechnology Publishing Institutes



Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012.

Collaborations across RAS are more internationally-oriented than less collaborative works within institutions. The distribution of the domestically collaborated publications is much more even, and the average reaches 29% in comparison with 42% for foreign collaborations. The leading RAS institutes are either RAS-oriented, or foreign-oriented. Among the latter are Troitsk and Chernogolovka clusters with virtually all of its non-RAS collaborations being with foreign researchers (Table 8).

3.1.10.4 Subject Areas

Institutes of the Russian Academy of Sciences demonstrate very clear subject area specialisations. For instance, the largest publisher, *Physico-Technical Institute N.A Ioffe*, is also the largest producer of physics and materials publications, *Institute of Problems of Chemistry and Physics* in Moscow and the *Institute of Catalysis N.A. Boreskov* are the top publishers in Chemistry.

The Institute of Crystallogy in Moscow is the leader in polymer-related and biology-related nano-publications, the Institute of Catalysis in Novosibirsk publishes the most in the fields of energy and earth sciences. There are other RAS centres with distinct specialisations as well. For example, the Science Centre in Kazan, Tatarstan, is the 19th in the overall number of publications, but is the 2nd in the number of energy publications.

Table 8. Non-RAS Collaborations of the leading RAS Institutes, Nanotechnology Publications

RAS Institute	D&F	Foreign	Domestic
RAS Inst Phys Tech Ioffe, St Petersburg	66.33%	55.73%	20.46%
RAS Inst Problems Chem Phys, Moscow	53.48%	38.33%	25.08%
RAS Inst Semicond Phys Rzhanov Novosibirsk	53.53%	41.06%	20.45%
RAS Inst Gen Phys Prokhorov, Moscow	67.64%	48.09%	30.89%
RAS Inst Solid State Phys Chernogolovka	66.74%	60.26%	12.63%
RAS Inst Phys Lebedev, Moscow	61.81%	45.08%	25.20%
RAS Inst Catalysis Boreskov, Novosibirsk	64.88%	41.56%	34.75%
RAS Inst Crystallog Shubnikov, Moscow	70.01%	43.50%	38.74%
RAS Inst Chem Phys Semenov, Moscow	59.15%	36.86%	32.05%
RAS Inst Organoelement Cpds Nesmeyanov, Moscow	62.90%	37.86%	41.53%
RAS Inst Phys Chem & Elektrochem Frumkin, Moscow	48.86%	27.44%	27.44%
RAS Inst Met Phys, Ekaterinburg	54.48%	25.34%	40.00%
RAS Inst Inorgan Chem Nikolaev Novosibirsk	55.84%	37.41%	24.82%
RAS Inst Spect Troitsk	72.03%	53.20%	27.61%
RAS Inst Gen & Inorgan Chem Kurnakov, Moscow	66.53%	24.75%	53.86%
RAS Inst Phys Microstruct, Nizhnii Novgorod	63.65%	39.36%	32.93%
RAS Inst Macromol Cpds, St Petersburg	62.66%	33.33%	38.40%
RAS Inst Radio Engn & Elect Kotelnikov, Moscow	65.11%	47.87%	30.00%
RAS Ctr Sci Kazan, Kazan	65.07%	44.98%	32.88%
RAS (average, top 20 institutes)	61.66%	42.43%	28.80%

Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012. D&F = Domestic and Foreign.

3.1.10.5 RAS - Regional Patterns, Nanotechnology Publications

Four regions (Moscow, the Moscow Region, St Petersburg, and Novosibirsk,) produced the largest shares of nanotechnology publications over the 1990-2012 period of time (Table 6). Moscow leads with almost 35% of all RAS nanotechnology publications. It was previously mentioned that the leading Moscow RAS institute only produced 5% of all publications, implying that in Moscow there are many RAS institutes with dispersed nanotechnology publication activities and no clear "super-publishers." In St Petersburg the situation is different, with the region producing 25% of all Russian nanotechnology publications in 1990 – 2012. However, 21% out of these 25% were published by *Ioffe institute*. Therefore, there is one dominant player with several minor ones. In Novosibirsk and the Moscow Region, there are several large centres of nanotechnology publishing activity but without a dominant actor.

Table 9. Regional Distribution of RAS Nanotechnology Publications

Author Affiliations	# Records	Share
Moscow City	7902	34.78%
St Petersburg	5743	25.28%
Novosibirsk	3054	13.44%
Moscow Region	2740	12.06%
Ekaterinburg	1099	4.84%
Nizhnii Novgorod	752	3.31%
Tatarstan	441	1.94%
Krasnoyarsk	414	1.82%
Bashkortostan	346	1.52%
Tomsk	330	1.45%
Primorskii Krai	319	1.40%
Udmurtia	232	1.02%
Saratov	186	0.82%
Irkutsk	103	0.45%
Perm	99	0.44%
Yaroslavl	65	0.29%
Murmansk	61	0.27%
Dagestan	55	0.24%
Omsk	52	0.23%
Komi Rep	41	0.18%

Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012.

A more aggregated regional picture is seen if the organisations are grouped according to Federal District divisions (Table 10). The Central Federal District (which includes Moscow and Moscow Region) publishes the most, but it is evident that not much publishing is happening outside Moscow+Region. Publishing activities in the North-Western Federal District are also concentrated almost solely in St Petersburg: only slight differences in the percentage share point to the existence of other publication centres. The situation is similar in the Ural Federal District and North Caucasian Federal District: the differences between publication activities in administrative centres, Ekaterinburg and Dagestan, and the districts as a whole, are minimal. On the other hand, publishing is much more dispersed in Siberia and Volga Districts: these Federal Districts unite independent and productive RAS institutes, and the publication activities are not concentrated in the capital cities.

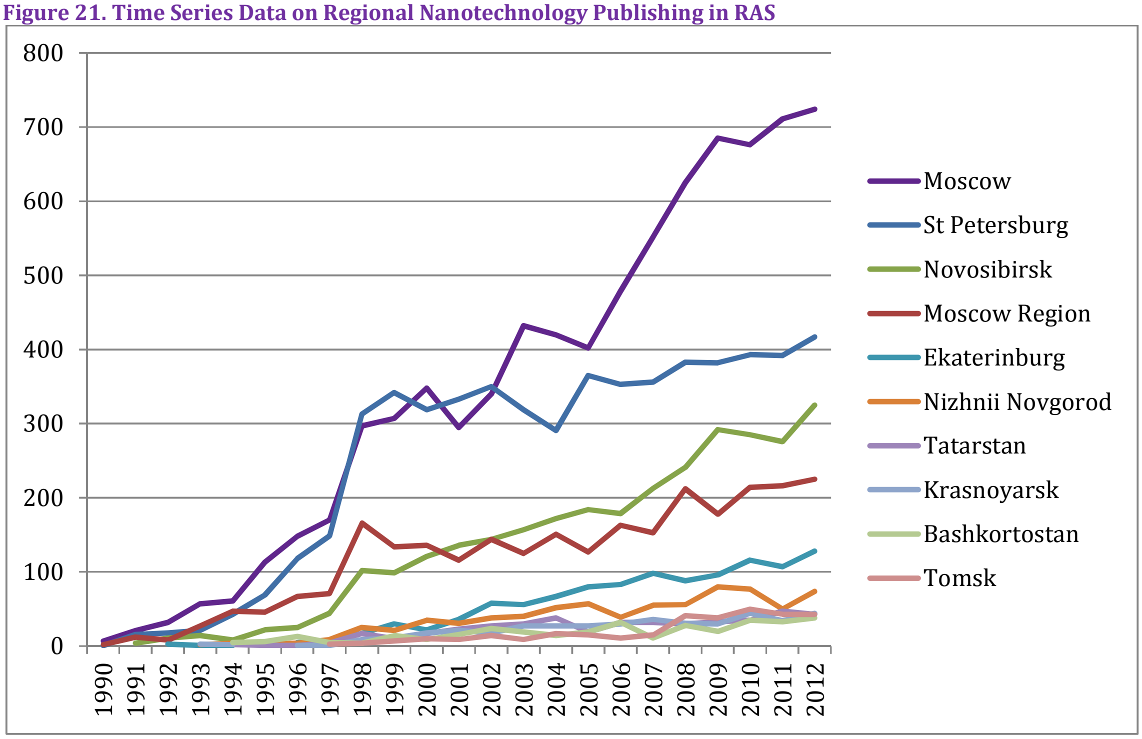
Table 10. Regional Distribution of RAS Publications Across Federal Districts

RAS Author Affiliations by Russian Federal Districts	# Records	Share
Central FD	10327	45.46%
NW FD	5882	25.89%
Siberian FD	3887	17.11%
Volga FD	2069	9.11%
Ural FD	1106	4.87%
Far E FD	374	1.65%
N Caucasian FD	68	0.30%
Southern FD	36	0.16%

Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012.

Figure 26 illustrates the regional patterns of nanotechnology publications for RAS Institutes. Although Moscow clearly dominates in the overall publishing, it was publishing as much as the St Petersburg region annually until the early 2000s, and the annual publication growth increased rapidly after that. At around the same time Novosibirsk overtook Moscow Region in the annual publication growth as well. The early 2000s seem to be a turning point for several regional RAS divisions.

Figure 21. Time Series Data on Regional Nanotechnology Publishing in RAS



Analysis of Russian Web of Science nanotechnology publications, Russian Academy of Sciences, 1990-2012.

3.1.11 Leading Institutions for International Collaboration

Internationally collaborated papers make up 42.7% of the whole body of Russian WoS nanotechnology publications (1990-2012). The Russian Academy of Sciences is the leader in collaborating with foreign institutions as well as in publishing domestically, and to the same extent: it has produced over 67% of all internationally collaborated publications (Table 11).

Amont the top 10 Russian organisations that publish the most nanotechnology papers in collaboration with foreign authors, the first three places are occupied by RAS, MSU and SPSU. The Kurchatov Institute, which is on the 4th place in the international collaboration table, has produced a relatively larger share of internationally collaborated publications (ICP) (1.94% versus 1.83% of domestic publications), but is pushed to the 4th place by Dubna Joint Nuclear Research Institute, a public research organisation with an international specialisation. The Institute, although situated in Moscow region, is an intergovernmental organisation that was set up by 18 member states in 1956. The member states of the Institute include the countries of CIS, Eastern Europe, Cuba and North Korea.[11] Three university-type organisations with clear international focus that are included into the Top 10 internationally collaborated organisations are *Ufa State Aviation Technical University* in Bashkortostan, *Kazan Federal University* in Tatarstan, and the *Moscow Steel and Alloys Institute*.

Table 11. Internationally Collaborating Russian Organisations, Nanotechnology Publications, 1990-2012

Organisation	Number of ICP	Share of ICP	Rank Compared to NCP
RAS	9672	67.46%	-
Moscow MV Lomonosov State Univ	1794	12.51%	-
St Petersburg State Univ	608	4.24%	-
Dubna Joint Nucl Res Inst	301	2.10%	↑, was 8
RRC Kurchatov Inst	278	1.94%	↓, was 4
Natl Univ Sci & Technol MISIS	205	1.43%	-
Ufa State Aviat Tech Univ	197	1.37%	↑, was 13
Kazan Fed Univ	163	1.14%	↑, was 15
Moscow Steel & Alloys Inst	148	1.03%	↑, was 12
St Petersburg Tech Univ State Inst Technol	136	0.95%	↓, was 9

Analysis of Russian Web of Science nanotechnology publications, 1990-2012. ICP = Internationally Collaborated Publication; NCP = Nationally Collaborated Publication (i.e. within Russian collaborations only).

3.1.12 Top-collaborating countries

From the records available it appears that Russian collaboration is limited to a few countries with the vast majority of research being carried out with domestic collaboration. Germany figures highly in the collaboration matrixes (Table 12) and other major economies also present highly. The USA and Japan are the only non-European countries in the top-10. South Korea occupies the 14th place and China occupies the 19th place. It is noticeable that former Soviet states and territories, such as Germany (East), Ukraine, Poland and Belarus factor highly in

[11] Further information: http://www.jinr.ru/section.asp?sd_id=39

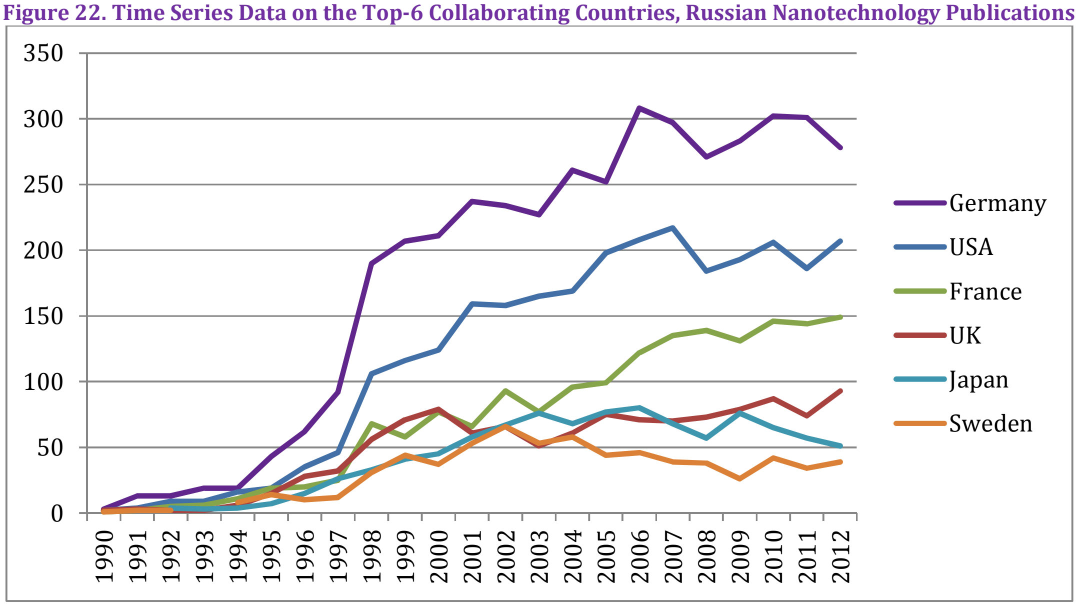
collaborative research with Russia. It implies that older research networks continue to be maintained at least at some level. Overall, Russian international collaborations in nanotechnology are strongly oriented towards selected European countries, the US, and Japan, with greatest growth in these collaborations in the late 1990s to mid-2000s (Figure 27).

Table 12. Top Collaborating Countries, Russian Nanotechnology Papers, 1990-2012

Rank	Collaborating Countries	Russia	% of Total Pubs
1	Germany	4123	12.29
2	USA	2736	8.16
3	France	1689	5.04
4	UK	1157	3.45
5	Japan	978	2.92
6	Sweden	699	2.08
7	Italy	657	1.96
8	Ukraine	597	1.78
9	Poland	497	1.48
10	Spain	495	1.48
11	Netherlands	483	1.44
12	Belarus	423	1.26
13	Finland	390	1.16
14	South Korea	324	0.97
15	Israel	300	0.89
16	Switzerland	296	0.88
17	Belgium	290	0.86
18	China	267	0.80
19	Canada	261	0.78

Analysis of Russian Web of Science nanotechnology publications, 1990-2012.

Figure 22. Time Series Data on the Top-6 Collaborating Countries, Russian Nanotechnology Publications

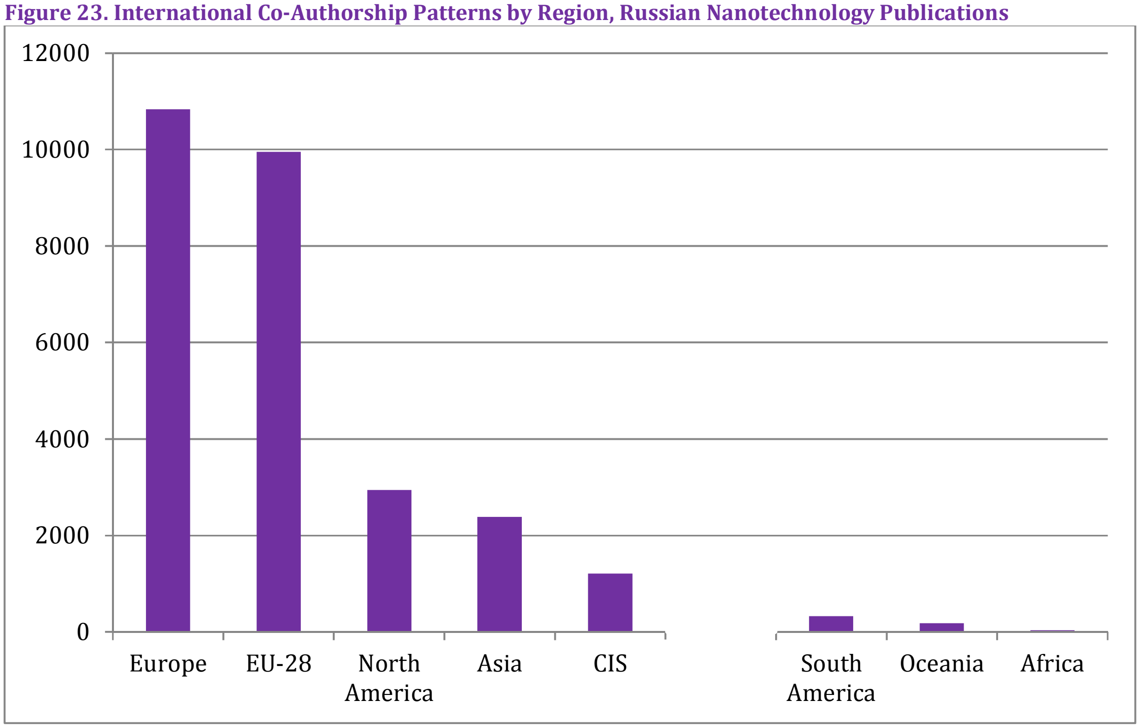


Analysis of Russian Web of Science nanotechnology publications, 1990-2012.

3.1.13 International co-authorship patterns by Region

Russia's European orientation in international collaboration is asserted when the international partners are grouped according to larger regions. Russian scientists predominantly collaborate with European Union member states: the share of all publications together amounts to 69% of all international collaborations (Figure 28). In the chart the North American contribution is predominantly the USA, which constitute 92% of all North American collaborations. In Asia 40% of all collaborations are made with Japanese participation, but such countries as South Korea, China and Taiwan have almost equal share of contributions following Japan, each amounting to 8-10%. In recent years there has been an increase in Russian nanotechnology research involving Asia. The CIS is a group uniting the countries of the former Soviet Union; Ukraine and Belarus are the primary collaborators there, with 50% and 35% of all CIS collaborations.

Figure 23. International Co-Authorship Patterns by Region, Russian Nanotechnology Publications



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, co-authorship by regional blocs.

3.1.14 Leading International Partners, Russian Nanotechnology Publications

Russian nanotechnology scientists collaborate with a range of international partners, although the top 20 international partners are all in Europe (see Table 13). The first three leading organisation make up 11% of all internationally collaborated papers. These are the Max Planck Society, a German umbrella research organisation; the French CNRS that has analogous structure; and the Ukrainian Academy of Sciences, which used to be a branch of the Soviet Academy of Sciences. Together the Top 20 International Partners make up just over 28% of all internationally collaborated publications.

There are organisations from 8 countries represented in the table of the top 20 International partners, half of which are based in Germany. Three partner organisations are located in Sweden, with two in Belarus. By type of the organisation 11 of the top 20 international partner organisations are universities, 4 are the Academy of Sciences type organisations (Ukraine, Belarus, Poland, and Czech Republic), and 5 are public research organisations.

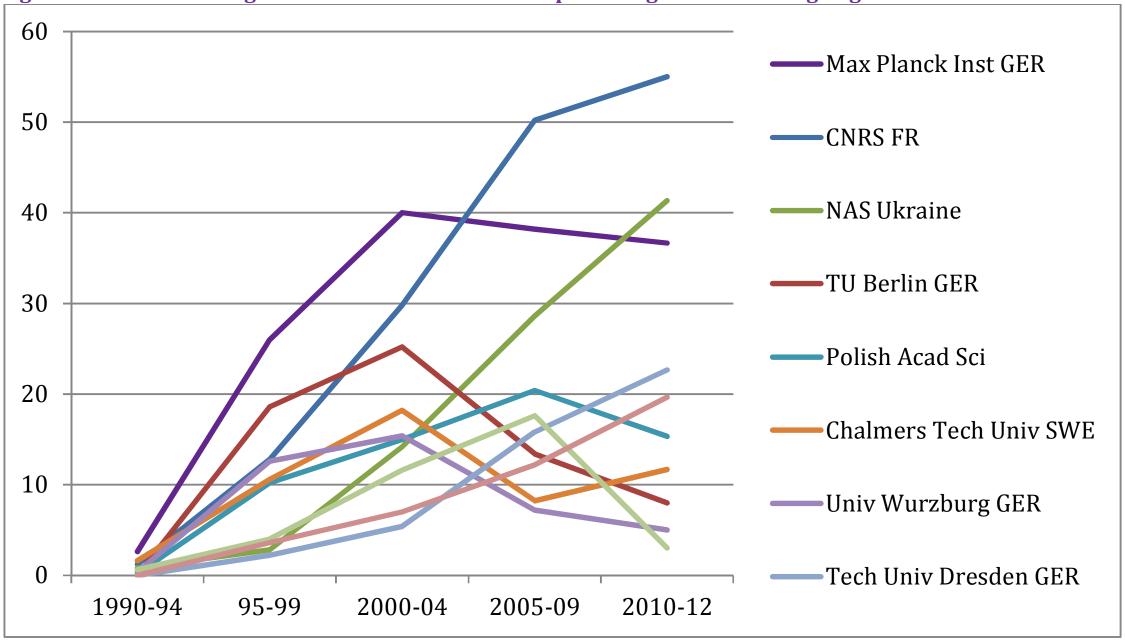
Table 13. Leading International Partners

Organisation name	Number of Records	Share of total International records
Max Planck Inst GER	644	4.49%
CNRS FR	635	4.43%
NAS Ukraine	356	2.48%
TU Berlin GER	310	2.16%
Polish Acad Sci	275	1.92%
Chalmers Tech Univ SWE	228	1.59%
Univ Wurzburg GER	193	1.35%
Tech Univ Dresden GER	185	1.29%
Forschungszentrum Karlsruhe GER	178	1.24%
NAS Belarus	173	1.21%
Belarusian State Univ	150	1.05%
Helmholtz Zentrum GER	139	0.97%
Leibniz Inst Solid State & Mat Res Dresden GER	139	0.97%
Univ Nottingham UK	139	0.97%
Humboldt Univ GER	137	0.96%
Univ Ulm GER	134	0.93%
Linkoping Univ SWE	131	0.91%
Acad Sci Czech Republic	126	0.88%
Lund Univ SWE	124	0.86%
Tech Univ Munich GER	124	0.86%

Analysis of Russian Web of Science nanotechnology publications, 1990-2012, co-authorship by affiliated institutions of international co-authors.

The leading three foreign organisations that publish nanotechnology research in collaboration with Russia form a distinctive cohort, not only in the all-time contributions, but also in the time-series perspective. Although the all-time shares place Max Planck Society Institutes in first place, the time series data (Figure 29) demonstrates the decline of the contribution of this research organisation in collaboration with Russian authors. The French CNRS became the leader in the annual publishing in 2006, and the Ukrainian Academy of Sciences overtook the Max Planck Society, pushing it into third place in terms of the annual publication output. The Technical University of Berlin also featured strongly in the 1990s in terms of the annual publications output, but then its collaborations with Russia declined substantially throughout the 2000s.

Figure 24. 5-Year Average Time Series Data for the Top 7 Foreign Collaborating Organisations

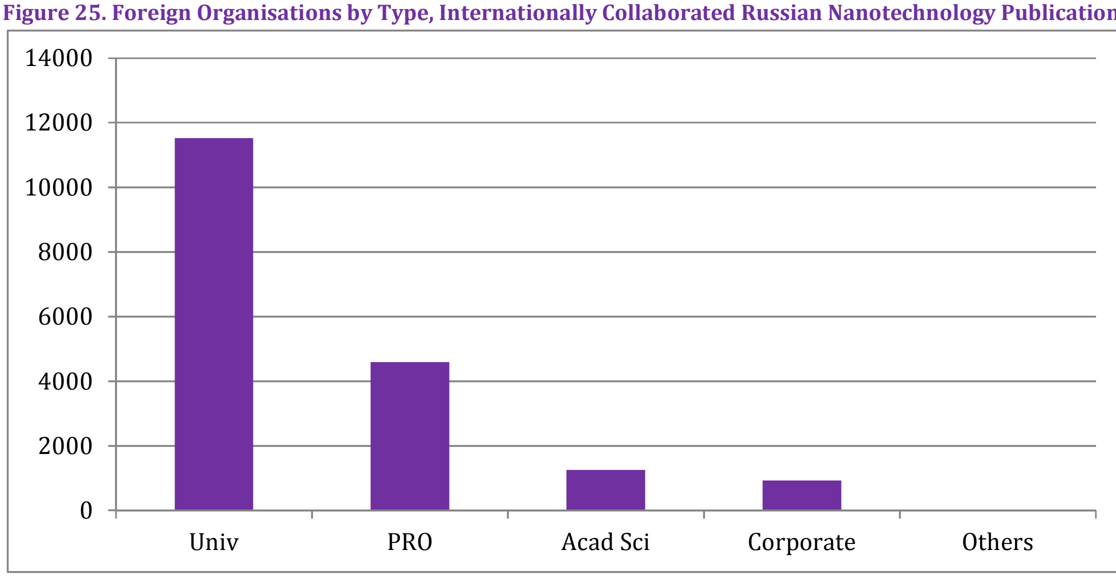


Analysis of Russian Web of Science nanotechnology publications, 1990-2012, co-authorship by affiliated institutions of international co-authors. Y-axes = internationally collaborated papers for time periods on X-Axis

3.1.15 International Collaboration by the Type of Organisation

80% of all foreign organisations that collaborate with Russian researchers were classified as university actors, and 32% of the publications were collaborated with public research organisations. 8.7% and 6.47% of the publications were collaborated with Academy of Sciences type organisations and with corporate actors respectively (see Figure 30).

Figure 25. Foreign Organisations by Type, Internationally Collaborated Russian Nanotechnology Publications



Analysis of Russian Web of Science nanotechnology publications, 1990-2012, co-authorship by affiliated institutions of international co-authors. Y-Axis = number of collaborated papers with foreign organisations.

3.2 Funding Trends

3.2.1 Main Russian Funders

The research funding data available in the WoS covers the period from mid-2008-2012 in our data set. (The WoS first made funding acknowledgements data available in mid-2008, for further details on WoS funding acknowledgements see Wang and Shapira, 2011.[12])

The overwhelming majority of the top 20 funders in Russian nano research are public bodies and large domestic universities (Figure 31). PICS and ARCUS are programmes which involve international co-operation and yet have close ties to government policy. Russian funders are dominated by public bodies as the top three funders cover over 90% of the top 20 funding bodies (

[12] Wang, J., and Shapira, P. "Funding Acknowledgement Analysis – An Enhanced Tool to Investigate Research Sponsorship Impacts: The Case of Nanotechnology," *Scientometrics*, 2011, 87, 3, 563-586.

Table 14. Top 20 Domestic Funding Sponsors of Russian Nanotechnology Publications, mid-2008-2012

Rank	Funding Sponsor	Records	Percentage of total Funding Instances in dataset	Sector
1	Russian Foundation for Basic Research	5360	63.0	Public
2	Russian Academy of Science	2109	24.8	Public
3	Russian Federal Target Program	1559	18.3	Public
4	Ministry of Education and Science RU	1495	17.6	Public
5	Dynasty Foundation	173	2.0	PRO
6	Federal Agency for Science and Innovation Rosnauka	144	1.7	Public
7	Russian Science Support Foundation	101	1.2	Public
8	Government of St-Petersburg	39	0.5	Public
9	National University of Science and Technology (MISiS) RU	31	0.4	Univ
10	St. Petersburg State University RU	30	0.4	Univ
11	Joint Institute for Nuclear Research RU	19	0.2	Public
12	Ural Federal University RU	13	0.2	Univ
13	Russian Academy of Medicine RU	12	0.1	Public
14	ARCUS RU	9	0.1	Public
15	Government of Moscow RU	9	0.1	Public
16	Government of Tatarstan RU	9	0.1	Public
17	Moscow State University	8	0.1	Univ
18	UMNIK RU (of FTP)	8	0.1	Univ
19	PICS RU	7	0.1	Public
20	Government of Sverdlovsk Oblast RU	6	0.1	Public

Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

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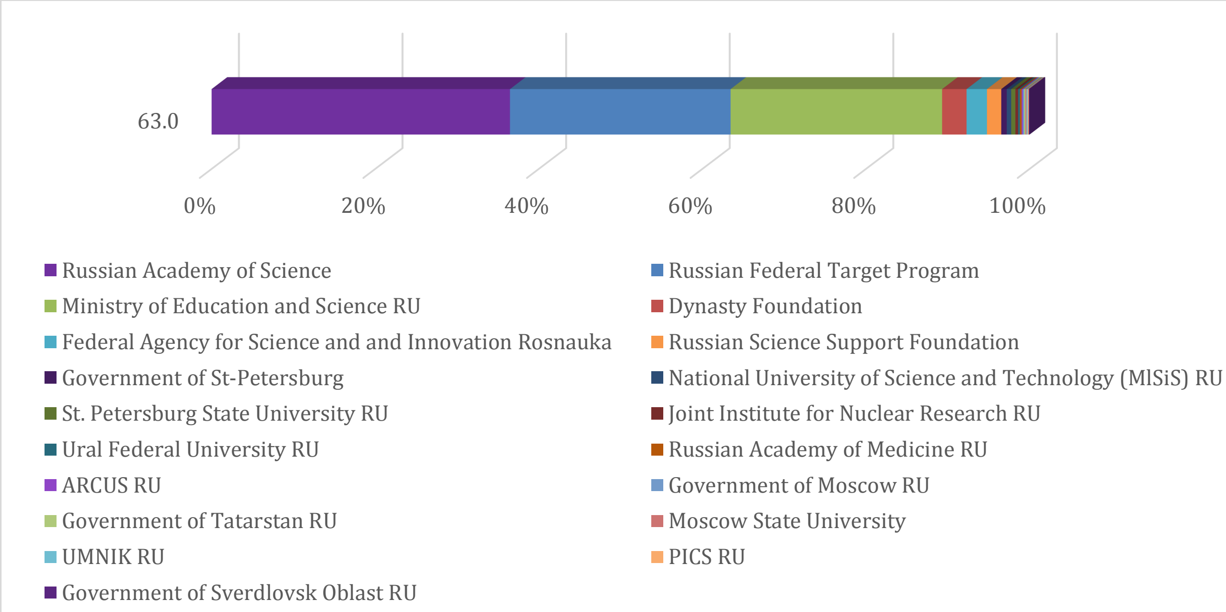
Figure 26. Percentage Cover of Top 20 Funders (Domestic)



Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

The structure of Russian funding for nanotechnology research demonstrates the prevalence of the public sector (RFBR, FTPs, Ministry of Education and Science). The internal funding programmes of the Russian Academy of Sciences have constituted a quarter of all funded papers since 2008. However, this internal RAS funding comes from public sources.

Table 14. Top 20 Domestic Funding Sponsors of Russian Nanotechnology Publications, mid-2008-2012

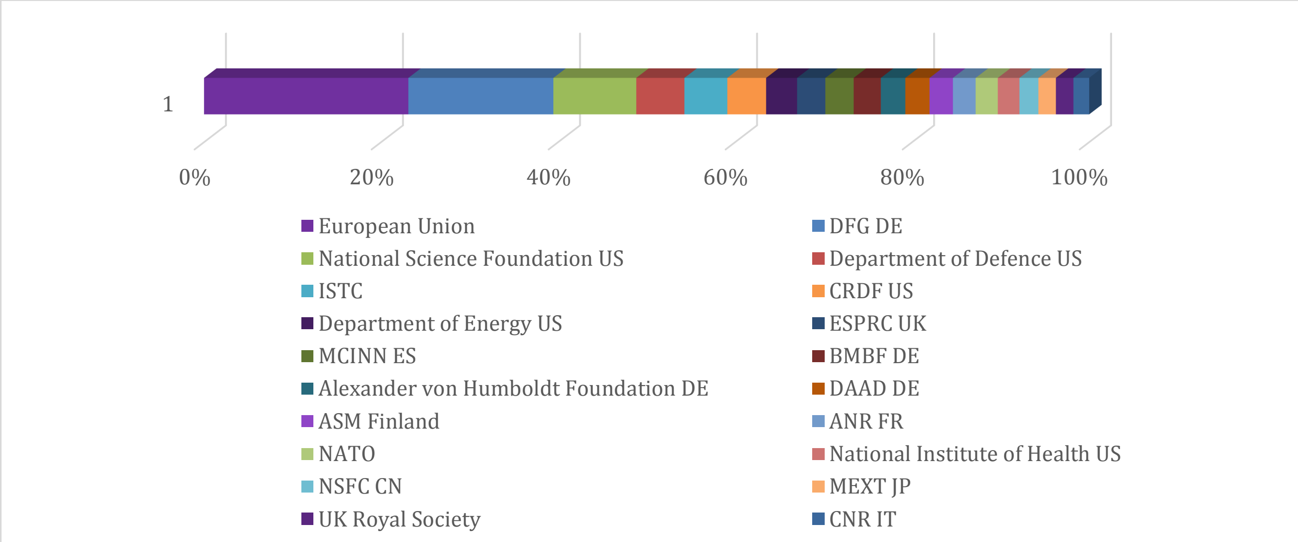
Rank	Funding Sponsor	Records	Percentage of total Funding Instances in dataset	Sector
1	Russian Foundation for Basic Research	5360	63.0	Public
2	Russian Academy of Science	2109	24.8	Public
3	Russian Federal Target Program	1559	18.3	Public
4	Ministry of Education and Science RU	1495	17.6	Public
5	Dynasty Foundation	173	2.0	PRO
6	Federal Agency for Science and Innovation Rosnauka	144	1.7	Public
7	Russian Science Support Foundation	101	1.2	Public
8	Government of St-Petersburg	39	0.5	Public
9	National University of Science and Technology (MISiS) RU	31	0.4	Univ
10	St. Petersburg State University RU	30	0.4	Univ
11	Joint Institute for Nuclear Research RU	19	0.2	Public
12	Ural Federal University RU	13	0.2	Univ
13	Russian Academy of Medicine RU	12	0.1	Public
14	ARCUS RU	9	0.1	Public
15	Government of Moscow RU	9	0.1	Public
16	Government of Tatarstan RU	9	0.1	Public
17	Moscow State University	8	0.1	Univ
18	UMNIK RU (of FTP)	8	0.1	Univ
19	PICS RU	7	0.1	Public
20	Government of Sverdlovsk Oblast RU	6	0.1	Public

Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

3.2.2 Leading Foreign Funders

The foreign funding element of the database is more distributed between groups compared to the domestic funding structure. Once again, the majority of funders appear to be large national public bodies or quasi-independent funders. The European Union (EU) represents the largest single foreign funder (Figure 27) covering 20% of the papers supported by the top 20 funders. The nature of the EU may render funding to larger projects with many different affiliations easier and more likely to occur.

Figure 27. Top 20 Funders (International) of Russian Nanotechnology Publications, mid-2008-2012



Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

The structure of foreign funding corresponds with the top-collaborating countries. In addition to the EU, two intergovernmental organisations – ISTC and NATO – have provided nanotechnology research sponsorship in papers involving Russian authors. The International Science and Technology Center (ISTC) is based in Moscow and supports research collaborations involving scientists from Russia, CIS (former Soviet) countries, the US, South Korea, Japan, the European Union and Norway (under the umbrella goal of supporting Russian and CIS nuclear and weapons scientists to pursue peaceful research and commercialization pathways).[13] The other leading foreign sponsors of Russian nanotechnology research papers are affiliated with particular host countries. Of all papers (mid-2008-2012) that report funding acknowledgement information, German national funders sponsor 12.9%, US organisations fund 13%, and UK organisations sponsor 2.7%.

Funding instances appear to be dominated by public bodies both in international and domestic records. Following this group, University funding is the second most influential group, which can be linked to the public funding as many universities have strong links with government policy.

[13] See: http://www.istc.ru/

Table 15. Top 20 (Foreign) Sources of Research Sponsorship, mid-2008-2012

Rank	Funding Sponsor	Records	% of Total Funding Organisation Instances	Sector
1	European Union	700	11.9	Public
2	DFG DE	497	8.5	Public
3	National Science Foundation US	284	4.8	Public
4	Department of Defence US	165	2.8	Public
5	ISTC	147	2.5	Public
6	CRDF US	133	2.3	Public
7	Department of Energy US	106	1.8	Public
8	ESPRC UK	97	1.7	Public
9	MCINN ES	97	1.7	Public
10	BMBF DE	93	1.6	Public
11	Alexander von Humboldt Foundation DE	84	1.4	PRO
12	DAAD DE	83	1.4	Public
13	ASM Finland	80	1.4	Public
14	ANR FR	78	1.3	Public
15	NATO	76	1.3	Public
16	National Institute of Health US	74	1.3	Public
17	NSFC CN	65	1.1	Public
18	MEXT JP	60	1.0	Public
19	UK Royal Society	60	1.0	Public
20	CNR IT	54	0.9	Public

Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

3.2.3 Recent Developments in Funding

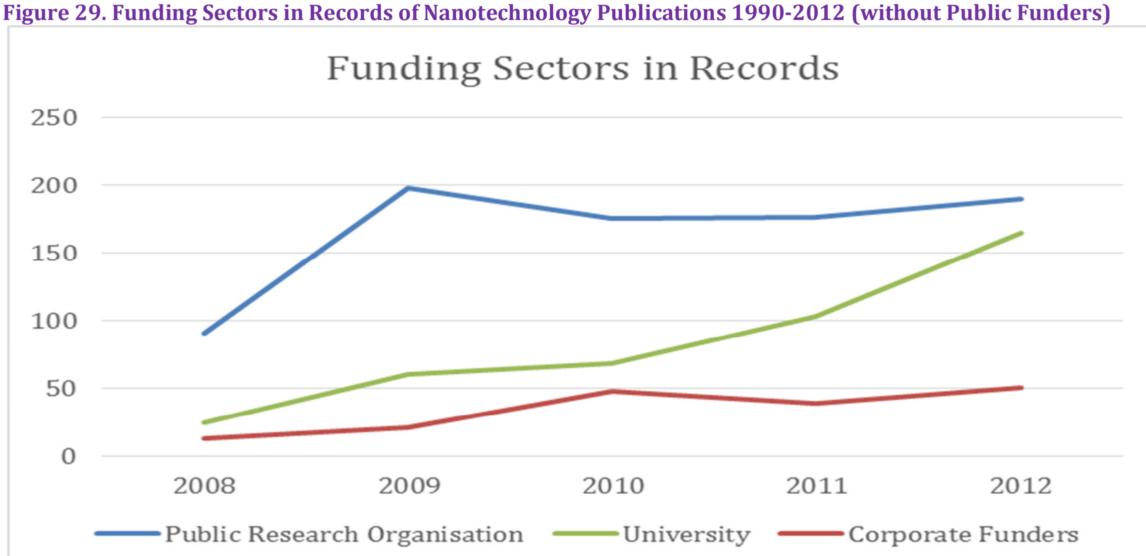
WoS information on funding acknowledgments begins in mid-2008. This allows about 3.5 years of publications (through to the end of 2012) in our data base to analyse funding trends (Figure 33). Public funders dominate the top 20 leading research sponsors for all Russian nanotechnology publications reporting funding acknowledgments. The other three sectors (universities, PRO, and corporate) are more nominal funders of research of nanotechnology. Each sector has an increasing number of instances, although universities appear to be the only one to increase funding in the technology year on year since records began (Figure 34). While the sectors are independent, one could argue that large university grants are largely influenced by government policy in an environment where 90% share of the top 20 funders are public bodies. As funding instances are not mutually exclusive, many research articles may be funded from multiple sources.

Figure 28 Funding Sectors of Russian Nanotechnology Publications mid-2008-2012

Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

Looking closer at the three minor funders, it is noticeable that corporate and PRO funding have been on a plateau since the beginning of the observation period, whereas the university funding shows an increasing trend (Figure 34). This may be a consequence of a recent policy introduced by the Russian Government to facilitate university research. Federal Universities that enjoy privileged funding were established in 2006-2009, and National Research University system was introduced in 2008.

Figure 29. Funding Sectors in Records of Nanotechnology Publications 1990-2012 (without Public Funders)



Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

3.2.4 Funding distribution across the subject areas

Top 10 subject categories of the publications in different sectors offer some insight into the funding influences of different sectors. Three out of four of the sectors have the largest percentage in Physics. Corporate funding provides the largest funding in Science & Technology-Other Topics.

The majority of top 10 subject categories are similar. Public and Non-Governmental funders (Figure 30, Figure 31) have the most distributed funding types, whereas University and Corporate funders especially are more targeted, with over 75% of the top 10 taken up by four publication subject categories (Figure 32 and Figure 33).

Figure 30. Top 10 Subject Areas for Public Funding, Russian Nanotechnology Publications, mid-2008-2012

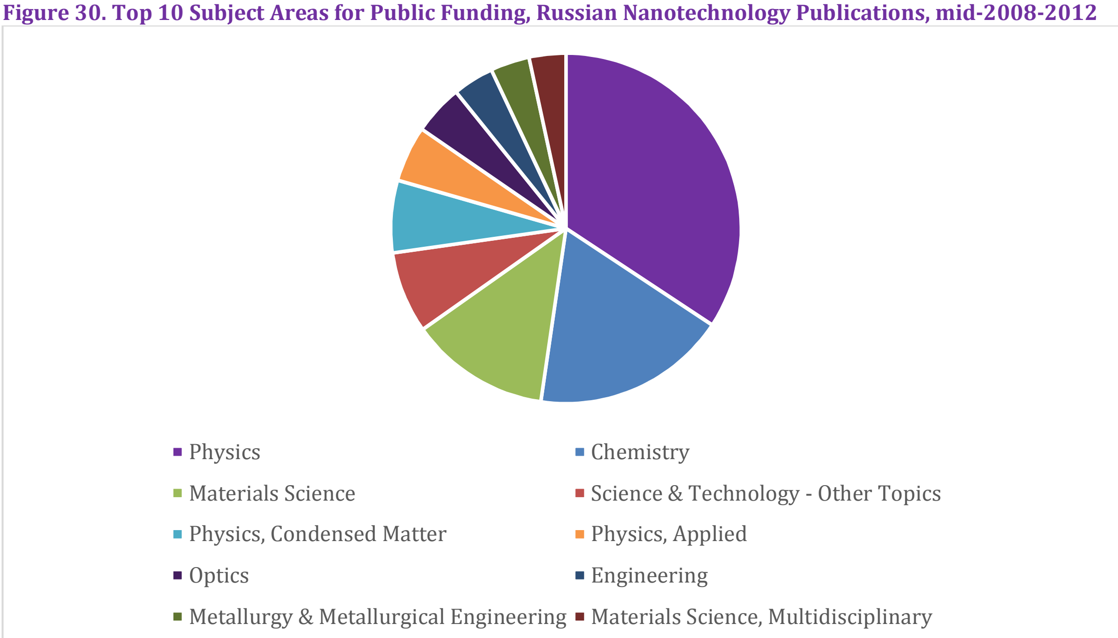


Figure 31. Top 10 Subject Areas for Public Research Organisation Funders, Russian Nanotechnology Publications, mid-2008-2012

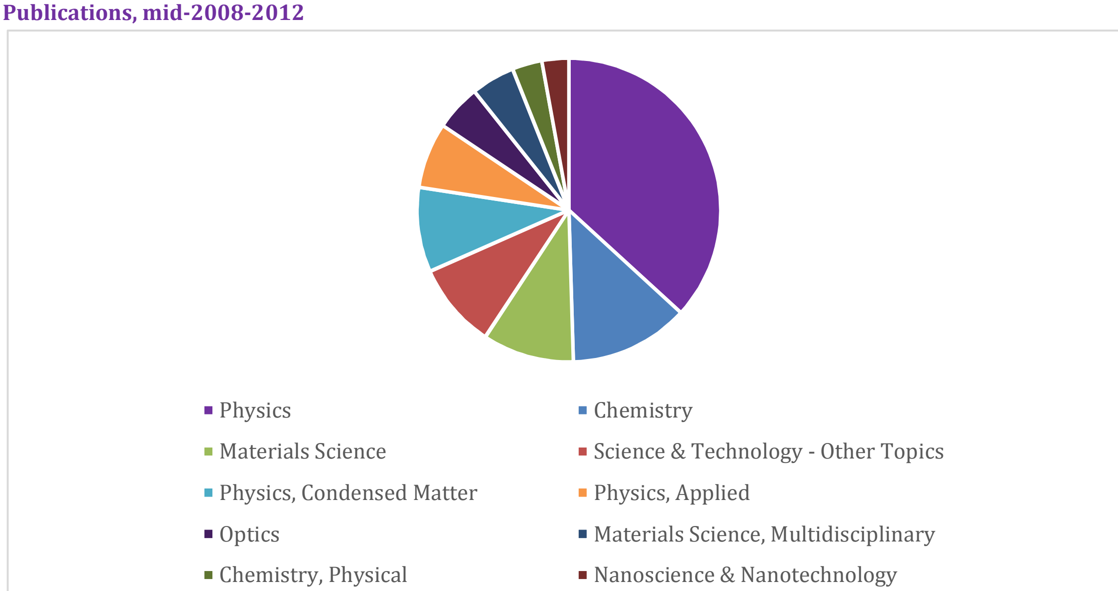
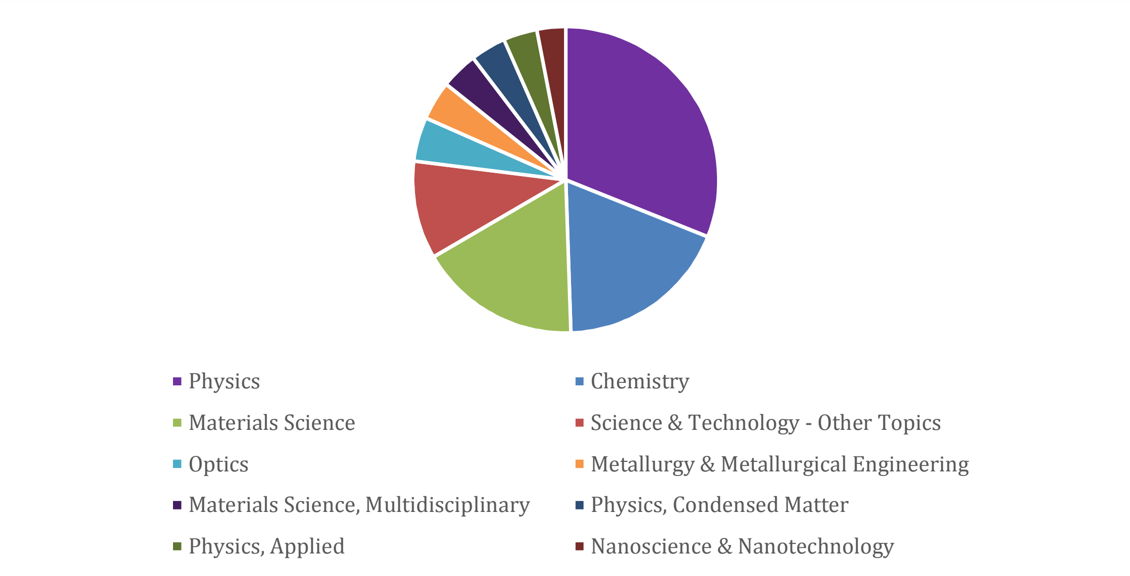


Figure 32. Top 10 Subject Areas for University Funders, Russian Nanotechnology Publications, mid-2008-2012

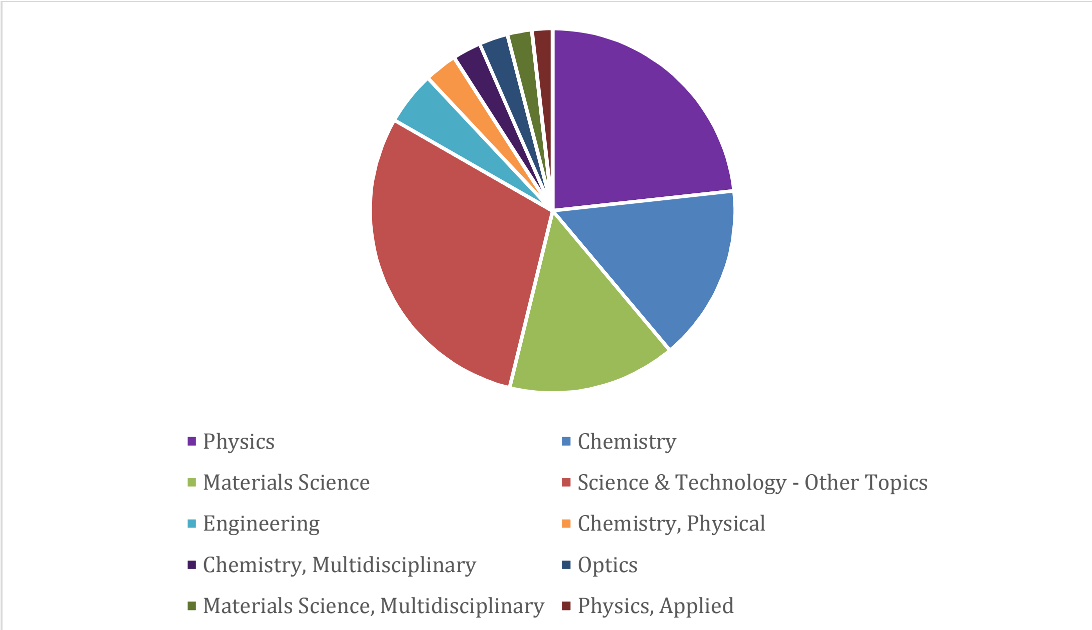


Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

The subject categories of research appear to show a leaning towards particular topics in research. Within these subject categories there are many different research areas. Corporate research appears to be the most focussed on the top 10 subject categories, implying that that the market influence is less varied and the application of research is more closed when involved in the corporate sector. Public funding appears to offer the most distributed view of research across its top 10 research subjects. Whereas the state has larger financial assets and no explicit shareholders to appease, the research may be more distributed since short term "profits" are exchanged for longer term goals of national research agendas.

Three out of four categories show Physics and Chemistry as covering approximately 50% of the Top 10 subject categories through all sectors (Figure 30, Figure 31, Figure 32, and Figure 33).

Figure 33. Top 10 Subject Areas for Corporate Funders, Russian Nanotechnology Publications, mid-2008-2012



Analysis of funding acknowledgements in Russian Web of Science nanotechnology publications, mid-2008-2012.

The funding of research may offer some insight into the direction and type of research made in the different sectors. As the public funding sector far outstrips the other sectors, we may consider the largest volume of research to be focussed in the same area. Unfortunately the database has limited data prior to 2008 which coincides with the National Nanotechnology Initiative in the Russian Federation and the 2008 Modernisation Initiative. However, in this prior period, it is evident the public funding bodies were major players in the early development of nanotechnology research.

The publication of research may be vastly larger than the other sectors, however the spread of topics will be more focussed according to top 10 research categories (Figure 30). Research funding may be linked with the research output, but performance of the work also needs to be addressed as quantity may not necessarily produce quality. Inferences can be made from the citations of PRO publications by authors and shows the institutes associated with the RAS are frequently cited and involve the star publishers of nanoscience and technnology (see section 3.1).

3.3 Indicators of Research Performance

3.3.1 Research Performance Analysis Based on Publications Data

For the period 1990-2010, nanotechnology publications that only have Russian authors are cited on average 2.5 times per publication. Out of all organisation types, the Russian Academy of Sciences publications collect the highest number of citations: 4.55 per publication. PRO publications, albeit being smaller in number, collect 3.86 citations per publication and occupy the second place. Universities collect on average 3.24 citations, and publications produced by corporate actors collect 2.44 citations per publication.

The average number of citations for international co-authored Russian nanotechnology publications is 4.33, with Dutch and UK international collaborated papers (ICPs) attracting the highest mean citations (Table 16). This indicator suggests that international collaboration increases the number of times that a Russian nanotechnology paper is cited by a factor of 1.7 compared with purely domestic-authored Russian papers. There are some regional variations in collaboration performance outputs (Table 17). Overall, the North American collaborations result in an average of 9 citations, followed by about 7 for collaborations with European Union countries.

Table 16. Average Number of Citations in Internationally Collaborated Russian publications by Country

Collaborating Country	Average Citations Per Paper
Netherlands	18.9
UK	12.2
Canada	9.4
USA	9.2
Switzerland	9.0
Germany	7.7
Belgium	7.3
Japan	6.9
China	6.7
Sweden	6.0
France	5.8
Italy	5.3
Spain	5.1
Israel	4.7
Finland	4.1
South Korea	4.0
Poland	4.0
Belarus	3.8
Taiwan	2.9
Ukraine	2.4
Average (all ICP)	4.3

Analysis of Russian Web of Science nanotechnology publications, 1990-2012

Table 17. Average Number of Citations in Internationally Collaborated Russian Publications by Region

Region	Average Citations Per Paper
North America	9.0
EU-28	7.0
Europe	6.8
Oceania	5.7
Asia	5.3
South America	5.1
Africa	3.7
CIS	3.1

Analysis of Russian Web of Science nanotechnology publications, 1990-2012

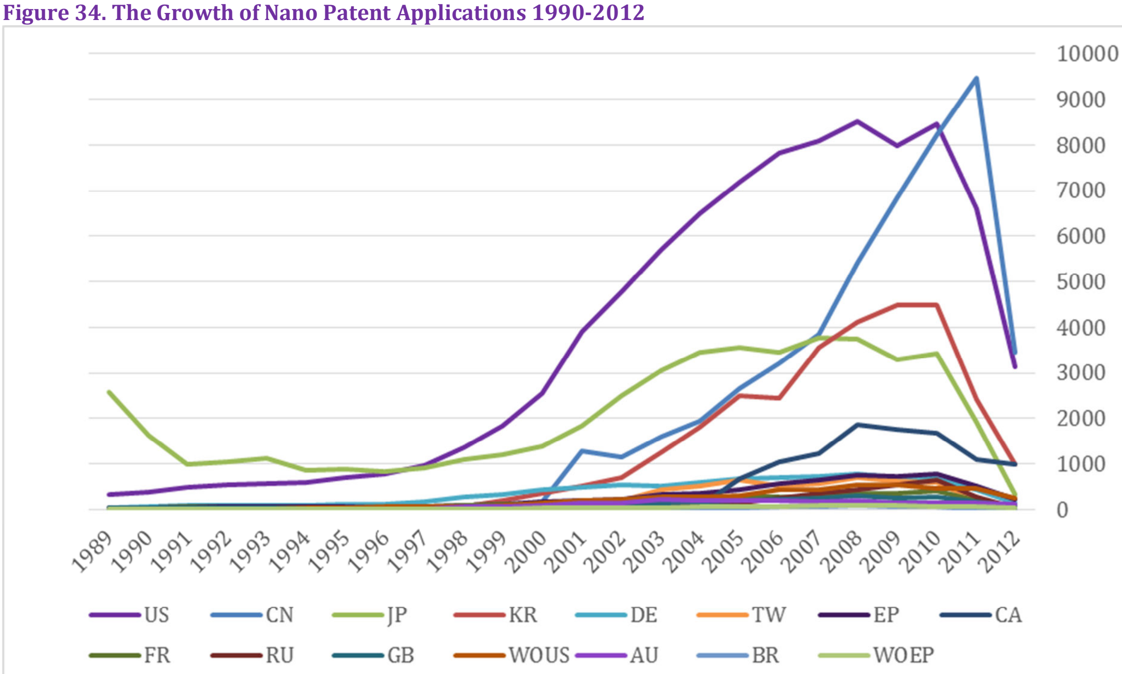
The lowest citations from foreign collaborations result from collaborations with CIS countries. Given that some of the CIS countries are among the most frequent foreign collaborations, the average citation rate is lower than that of an average paper produced within Russian Academy of Sciences. Such collaborations may be viewed as academic path–dependencies from Soviet times, when local Academies of Sciences used to be a part of the Soviet Union Science and Technology system. Present day collaborations at the current level of intensity with these CIS organisations lowers average citation rates. On the other hand, collaborating with Netherlands garners an average of 19 citations per publication, but this country is 12th in the top-20 foreign collaborators list, and only 1.44% of foreign nanotechnology paper collaborations in Russia are made with Dutch researchers.

3.4 Patenting Patterns

With nanotechnology research achieving the Nobel Prizes for Fullerene in 1996 and Graphene in 2010, academic research in nanotechnology has gained a higher profile. As we have seen through publications, there has been increased output of research in academic journals on nanotechnology. We would expect an increase in nanotechnology patents as basic research is adapted into inventions that inventors (in public and private sectors) anticipate there may be novel use value. We identified nanotechnology patent application records using the Derwent Patent Database. The nanotechnology search algorithm was as in Porter et al., 2008, and updated in Arora et al., 2012.[14]

There is a distinct upward trend in patents produced within the WoS definition of nanotechnology illustrated earlier between 1990 and 2012 across different priority countries (Figure 34). The US has led the way in patenting of Nanotechnology for over a decade, although China overtook the US in 2011 by the sheer numbers of patent applications. The drop in patent applications recorded for 2012 is an artefact of the data, due to time lags of 1-2 years in public reporting or patent applications.

Figure 34. The Growth of Nano Patent Applications 1990-2012

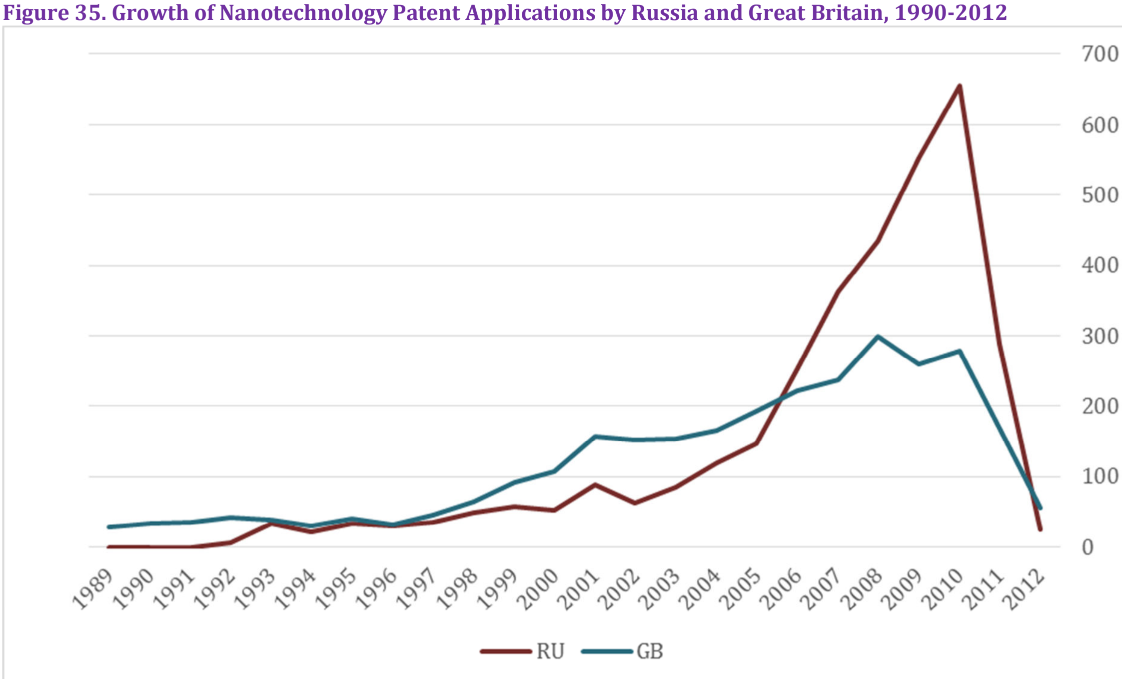


Analysis of nanotechnology patent applications in Derwent Patents, 1990-2012

[14] See footnotes 2 and 3.

Russian patents in Nanotechnology have increased since 2005 and overtook Great Britain in volume of patents in the same year (Figure 35). Although increasing, the number of Russian nanotechnology patents remains far below the US and Chinese volumes.

Figure 35. Growth of Nanotechnology Patent Applications by Russia and Great Britain, 1990-2012

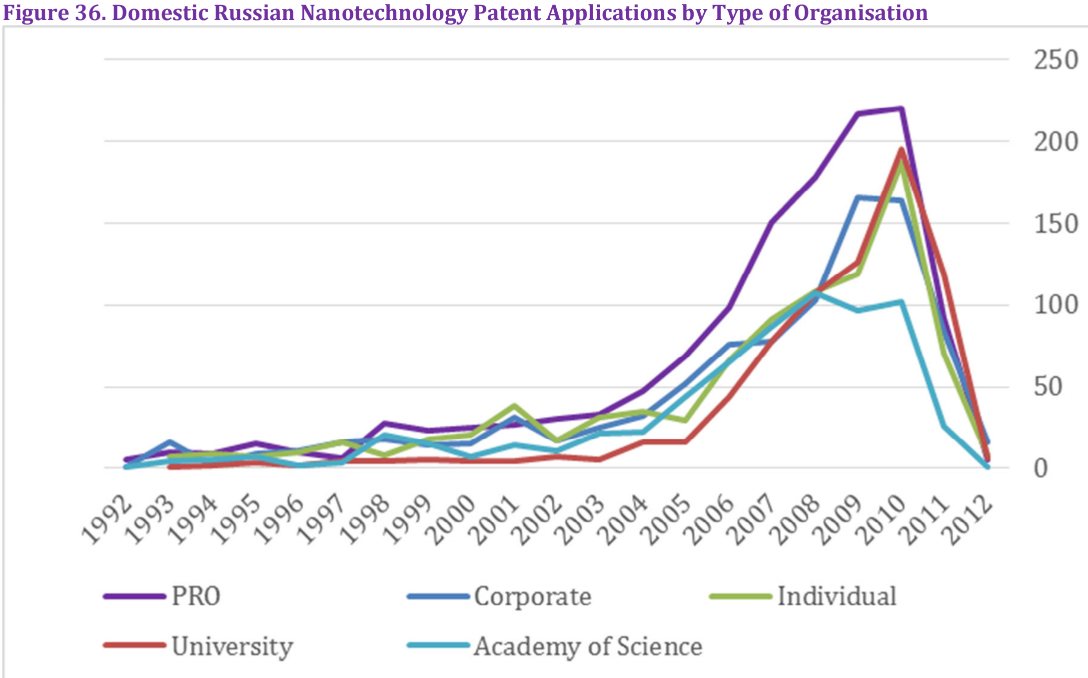


Analysis of nanotechnology patent applications in Derwent Patents, 1990-2012

Russian patenting in nanotechnology has fluctuated over the past two decades, with the highest peak increase in patents occurring in 2007. In comparison, the UK has proved to show a more uniform patenting numbers with smaller peaks and troughs. Russian Nanotechnology patenting appears to be influenced year on year rather than part of a general direction of nanotechnology patenting in the country (Figure 35) The drop after 2009 can be attributed to underreporting of nanotechnology patents and incomplete records received at time of collection.

3.4.1 Proportion of Domestic/Collaborated Patenting

Figure 36. Domestic Russian Nanotechnology Patent Applications by Type of Organisation



Analysis of Russian nanotechnology patent applications in Derwent Patents, 1990-2012.

As a sectoral approach, the patenting of innovations has shown typical upward trend in each sector with Public Research Organisations (PRO) outstripping other sectors. Within that, over half of the total patents produced by PROs were from the Russian Academy of Sciences. All sectors appear to have an increase in activity from the middle of the 2000's and the drop off in 2012 could well be put down to under reporting in the database up to time of writing. There has been some plateauing of patents as of 2008 onwards, and noticeably RAS has dropped in number of patents. The question is whether the research partaken by RAS has been adopted by other sectors, such as the Corporate and the Academy has instead focussed on the development of research articles rather than patent based output.

3.4.2 Top Russian Nanotechnology Patent Assignees

Russian domestic patents are distributed amongst various bodies. Patent production appears in the top 20 led by the Russian Academy of Sciences. The university sector is also prominent. The leading organisations for Russian nanotechnology patent applications are strongly in the public sector, but there are a number of corporations involved in nanotechnology patenting. One individual is prominent as a nanotechnology patent assignee. The patent applications by "Fond Salvatore…" appear to have international origins, however the initial patent of the family is assigned to a Russian source, so we denote this in the domestic classification.

Table 18. Top 20 Russian Nanotechnology Patent Assignees (Domestic) 1990-2012

Rank	Top Domestic Patent Assignees	Patents	Percentage of Total	Sector
1	RAS RUSSIA PETROCHEM CATALYSIS INST	47	1.40	Acad
2	RAS SIBE CATALYSIS INST	41	1.22	Acad
3	NUCLEAR ENERGY AGENCY	39	1.16	Public
4	RAS SIBE SEMICONDUCTORS PHYS INST	34	1.01	Acad
5	SOKOLOV S V	33	0.99	Individual
6	UNIV PEOPLES'S FRIENDSHIP	29	0.87	Univ
7	KAMENSKII V V	26	0.78	Individual
8	UNIV SARAT CHERNYSHEV	26	0.78	Univ
9	NT MDT COMPANY	25	0.75	Corp
10	UNIV TAMBOV TECH	25	0.75	Univ
11	RAS RUSSIA URALS APPLIED MECHANICS INST	24	0.72	Acad
12	PROMETEI CONSTR MATERIALS RES INST	24	0.72	Univ
13	UNIV DAGESTAN TECH	23	0.69	Univ
14	UNIV URALS FEDERAL ELTSIN	23	0.69	Univ
15	APPLIED NANOTECHNOLOGY INST STOCK CO	22	0.66	Corp
16	UNIV MOSC ELECTRONICS&AUTOMATION INST	22	0.66	Univ
17	UNIV TOMSK POLY	22	0.66	Univ
18	FOND SALVATORE MAUGERI CLINICA DEL LAVOR	19	0.57	Corp
19	SIB LAB LTD	19	0.57	Corp
20	UNIV ST PETERSBURG AEROCOSMIC INSTR	19	0.57	Univ

Analysis of Russian nanotechnology patent applications in Derwent Patents, 1990-2012.

4 Summary of Findings

From a selection of observations and findings from this preliminary analysis we can note the following.

- There is an upward trend of research paper outputs in Russian nanotechnology. The publishing activity is highly concentrated. The Russian Academy of Sciences (RAS) dominates publishing in nanotechnology, although there is a tendency of decline of the annual contribution of RAS, and a transition away from monocentrism in nanoscience publishing. RAS still has the biggest regional structure of all research organisations.
- In the WoS database, English is the predominant language for Russian nanotechnology publications, and rate of publishing in Russian decreases. However, there is a prevalence of publications in translated versions of domestic journals rather than in international journals for all types of publishing entities.
- The most productive researchers in nanotechnology increased outputs during the key formative years in the development of nanoscience, aided by domestic policies to encourage development in nanotechnology. More recently, productivity among this research group is declining: peak productivity for current "star scientists" is over.
- The leading international collaborations for Russian nanotechnology researchers are with Western Europe and the former Soviet Union republics, and the USA. Collaboration rates with Asian countries are low, with the exception of Japan.
- Russian nanoscientists co-author with a diversity of international organisations. Russian university nanotechnology authors are relatively more likely to collaborate with foreign organisations that for the Russian Academy of Science or other Russian research actors.
- Corporate Research appears to collaborate with universities and RAS to a higher degree than other types of publishers, and also shows leaning towards collaborating domestically.
- The RAS dominates nanotechnology research in the subject areas of physics and chemistry. Other types of actors contribute to other subject areas relatively more than found in the RAS. There is a clear specialisation according to the traditional subject areas within RAS institutes, inhibiting multidisciplinary research within institutes.
- RAS publications are the most highly cited among domestic publications. Internationally collaborated Russian nanotechnology publications garner the highest number of citations on average.
- The distribution of research funding for nanotechnology in Russia is overwhelmingly dominated by the public sector. International research appears to be most linked with funding coming from large national public bodies or quasi-independent funders, as well as international sponsors.
- Russian nanotechnology patenting is increasing year on year, although Russia ranks significantly below China and the USA for patenting activity.
- Russian nanotechnology patent production is led by the Russian Academy of Science, with a strong role from the university sector. Russian corporate patenting of nanotechnology is represented but at relatively lower levels.

5 Appendix

The following sections provide additional methodological notes and explanation.

5.1 Publication Database

Publication data is drawn from the Web of Science (SCI), using the nanotechnology search algorithm in Porter et al., 2008, and updated in Arora et al., 2012.[15] VantagePoint text mining software was used to aid data cleaning, management, and analysis. 33,538 Russian nanotechnology publication records were identified (1990-2012).

5.1.1 Cleaning of Fields

The data in affiliations and funding fields were cleaned to combine duplicate records and deal with misspellings and variations in the raw data. The cleaning was first run through an algorithm and then reviewed in person to pick up on records which were missed by the programme.

5.1.2 Domestic (NCP) and International (ICP)

Russian publications were identified if they had at least one author with a Russian institutional affiliation. Domestic (NCP) publications ought to have had all authors affiliated with Russian organisations. International (ICP) publications ought to have at least one author with foreign affiliation. The two types of publications are mutually exclusive. The Soviet Union in the early publications (1990-1992) is classified as belonging to "Domestic" publications, although the affiliations belonging to the countries of the former Soviet Union (including Belarus and Kazakhstan that have formed a confederation entity with Russia) were then classified as "International".

This classification grouping was applied to the affiliation and funding categories to show the spread of NCP and ICP in both of these categories.

5.1.3 Affiliations

Affiliation data in the dataset is available for 100% of the data and includes 4065 separate Russian and international affiliations. The basic grouping of the affiliations was based on 5 categories that are mutually exclusive:

- Academy of Science organisations – specific research entities that have wide government affiliations and heavily rely on government funding, that have a wide regional structure and hierarchical administrative division;
- Universities – without distinguishing into private and public;
- Public Research Organisations – private and state-owned research institutes that are neither academy of science institutions, nor universities. These also include research foundations and ministries;
- Corporate – privately and state-owned company affiliations. Organisations were usually labelled as "corporate" actors if they had a distinctive property type word in their names (LLC, Ltd, GmbH, ZAO etc.);

[15] See footnotes 2 and 3.

- Other – all other organisations that cannot be attributed to any other category (such are high schools, vet clinics etc.).

In the domestic regional mapping only Universities, PROs and corporate actors were counted, as the academy of science groupings were aggregate of all academy organisations in all regions. The grouping of Russian organisation by regions was carried out in the accordance with the administrative division of Russia into 83 federal subjects (21 republics, 9 krais, 46 oblasts, 2 federal cities, 1 autonomous region). The current administrative division is valid from 2008, publications from the time previous to 2008 were classified according to the modern dividing lines. The bigger picture is provided by aggregating the 83 federal subjects into 8 Federal Districts. They were set up by the President of Russia in 2000, and each includes the federal districts with similar economic and demographic conditions. As an anomaly, since July 2013 Troitsk was adjoined with Moscow. The dataset precedes this, therefore Troitsk is classified as a Moscow Region unit.

Internationally Collaborated Publications are grouped in accordance with the established regional classifications: North America, EU-28, the rest of Europe, Asia, Oceania, and BRICSK. Russia is excluded from BRICSK, South Korea is added. Also, CIS as a distinct group of states that used to be included into the Soviet Science System is separated from their usual Europe/Asian classification categories.

These groupings have given an insight into the sectoral approach of innovation in the Nano sector. There are grey areas with each of these grouping. For example, such as joint stock companies and other state-owned enterprises, which are notable in Post-Soviet Russia and comprise government corporate influences. Many of such corporate actors were established as spin-offs of State Research Centres, so in the late Soviet Union era, and never quite got detached from their state-owned mother organisations. They are obviously different in structure, organising principles and the purposes of functioning from more conventional (especially Western) corporate actors, and there may be doubts as whether these should be grouped and studied separately. This hypothesis is a subject to further investigation.

There were no notable civil society actors, such as NGOs or charities, in the dataset, so the separate grouping was not created. The phenomenon may be attributed to the lack of civil society concerns regarding research in Russia, and the lack of specialised NGOs, including Russian branches of international NGOs. This is yet another point of inquiry for further research.

5.1.4 Funding Information.

The funding data available covers the period mid-2008-2012. A total of 8512 records with funding sources were identified.

The Domestic (NCP) and Foreign (ICP) groupings were applied to the funding sponsors, which showed the overall spread. All records had at least 1 Russian author, however foreign links were found in 5872 articles.

A secondary grouping was created to show the sectoral make-up of the funding organisations involved in nanotechnology research. The groupings were the following.

- Universities – both private and public;

- Public Funders – National and local government bodies as well as national target programmes;
- Public Research Organisations – Research institutes that were neither Universities nor Government Ministries. They include Research Foundations formed from charities and businesses;[16]
- Corporate – privately and state-owned company affiliations. Organisations were usually group as ‘corporate’ actors if they had a distinctive property type word in their names (LLC, Ltd, GmbH, ZAO etc).

5.2 Patent Database

The source of the patent data is the ThomsonReuter Web of Knowledge Derwent Patent Database. The nanotechnology search algorithm was as in Porter et al., 2008, and updated in Arora et al., 2012.[17] VantagePoint text mining software was used to aid data cleaning, management, and analysis. Russian patents were identified as those patents listing Russia as the patent priority country. In total, 3,350 Russian nanotechnology patent families were identified (1990-2012).

After cleaning the dataset was grouped into Domestic (NCP) and International (ICP) categories. “Domestic” implies a patent priority registered only in Russia. “International” denotes at least one international link in priority countries of the patent.

Similar to the publication database, patent assignees were grouped into sectors covering

- Universities - National and Private Higher Education bodies;
- Public Research Organisations – private and state-owned research institutes that were neither academy of science institutions, nor universities. They also include research foundations and ministries;
- Academy of Science – This covers Russian Academy of Sciences assignees from different regions of the Russian Federation. This grouping is a subset of of the PRO category as this is a particularly common occurrence in the database;
- Corporate – privately and state-owned company affiliations. Organisations were usually group as ‘corporate’ actors if they had a distinctive property type word in their names (LLC, Ltd, GmbH, ZAO etc);
- Individual- Patent assignees with for individuals.

5.3 Limitations

Publications used in the analysis were collected from the Web of Science Database. Therefore, there is a database bias in the data. One of the effects of this bias shows in the overall growth of publications: it is a ‘jump’ in the annual publication output in 1998, which also features in graphs and tables further along the text. Second, it is the language of publications. Although the majority of publications are in English, there is a small portion of publications in Russian. A small percentage of inflation may be expected regarding that, as the majority of publications in Russian are then translated into the English version of the peer-reviewed journal. The third

[16] This grouping is distinct from “Universities” and diverges from the OECD definition of PRO/ PRI as we felt that the category could limit analysis of some intermediate bodies such as Foundations and charities which may have some similar characteristics but different goals and management approaches.
[17] See footnotes 2 and 3.

limitation of the database is that information on funders is only available starting from 2008. Finally, the Web of Science only recently started to associate each author with their affiliation, opening some more advanced opportunities for research, but the too recent opening made it impossible to carry out further analysis on this topic in the report.

Russia has a publication database eLIBRARY.ru that contains over 15 million records in Russian and English covering all areas of science. Possible overlaps or complementarities between the records in the WoS and eLIBRARY remain to be investigated.

Manchester Institute of Innovation Research

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