Russian Publications in Web of Science: A Bibliometric Study

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Abstract: This article presents a bibliometric study of 1.38 million Russian publications indexed in Web of Science as of May 2022 without any restrictions as to document types, time periods, scientific disciplines, etc. From this perspective, the present analysis reflects the true presence and visibility of Russian research in the most prestigious database of scientific literature. The main results obtained are the following: a) There was a rapid increase in research production in the 2010s, but the share of the Russian output in the global research production is still below 3%. b) International collaborative publications account for about 30% of Russian papers but around 70% of Russian citations. c) Physics, chemistry, and engineering are the most productive Russian research areas, but their citation impact is below the world average in those respective fields. d) The most frequently collaborating countries are the United States, Germany, and France, but it is Canada and Switzerland that consistently contribute to the greatest relative citation impact of collaborative papers in the top ten research areas.

Keywords: Russia; Web of Science; publications; citations; productivity; impact

1. Introduction and Related Work

After the dissolution of the Union of Soviet Socialist Republics (USSR) on 26 December 1991, Russian Federation as the biggest out of its constituent republics became the legal successor state. Following the struggles of the 1990s related to the collapse of centrally planned economy and thus lack of funding, huge societal changes in the post-Soviet space, and the disintegration of the whole former Eastern Bloc, Russian science has gradually begun gaining foothold in the 2000s and 2010s again. As a result, the development of Russian science from a scientometric (bibliometric) point of view has become the focus of numerous research papers, which will be briefly discussed in the next paragraph.

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There have been quite a few bibliometric studies of the Russian research output in the literature, as we will show in the following rough overview, but none of them can be considered a duplicate of this present analysis. Some studies have focused specifically on the Russian nanotechnology research [17, 51, 24], limnology [57], enology and viticulture [1], psychology [47, 25], organic chemistry [7], composite materials [6], energy and fuels [28, 40], cancer research [23], scientometrics [13], or computer science [9, 56, 60]. Russian research performance in general or in a certain scientific field has often been investigated in the context of a group of other countries, most frequently the so-called BRICS countries, which in addition to Russia also include Brazil, India, China, and South Africa [57, 1, 60, 12, 11, 10, 48, 55, 59, 4], but also of Eastern European [47, 9, 21] or post-Soviet nations [25, 5] as well as Western countries [60, 54, 58, 30, 45]. Analyses of the research performance of Russian scientific institutions include [2, 14, 36, 53, 3, 34, 38, 46, 15, 26], investigations into their collaboration patterns are presented in [38, 46, 37], and the effects of the university excellence initiative (Project 5-100) on them are examined in [38, 26, 37]. Other studies of Russian science dealt with the participation of women in research [22], correlation between standard and alternative bibliometric indicators [27], particular Russian regions [36, 35, 33], Russian Index of Science Citation or Russian Science Citation Index [44, 18], funding and funding organizations [34, 15, 31, 49], Russian Academy of Sciences [15, 32, 29], publication languages [20], use of open-access journals [16], research performance in individual scientific disciplines [42, 43], or international collaboration [19]. Most of the papers in this overview of related work reported using Web of Science (WoS) data for their analyses, but some of them based their investigation also or exclusively on Scopus data [47, 13, 56, 48, 2, 14, 49, 41, 50, 39, 52].

Unlike the aforementioned works, the analysis presented in this article is unique in the fact that it is concerned with all Russian publications indexed in the prestigious Web of Science database "as is", i.e. without any restrictions as to document types, time range, scientific discipline, citation index, specific regions, citations thresholds, etc. Briefly put, everything that was indexed in WoS at the time of data collection and connected to Russia was included in our study. In this respect, this analysis reflects the true picture of Russia's visibility in Web of Science as of May 2022.

2. Data and Methods

The data set analyzed in this study was acquired from the standard web interface of Web of Science from 27 April 2022 to 10 May 2022. The query we used to retrieve bibliographic records in plain-text files from WoS was simply "CU=(Russia)" (i.e. where country data field contains "Russia") and we did not impose any further limitations whatsoever as to time range, document type, citation index, etc. in order to submit as general a query as possible. (The "exact search" option was turned off as by default.) The

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section of WoS data searched was the flagship "Core Collection", which contains these eight most important citation indices: Science Citation Index Expanded (articles since 1945), Social Sciences Citation Index (since 1977), Arts & Humanities Citation Index (since 1977), Conference Proceedings Citation Index – Science (since 1990), Conference Proceedings Citation Index - Social Science & Humanities (since 1990), Emerging Sources Citation Index (since 2005), Current Chemical Reactions (since 1985), and Index Chemicus (since 1993). Consequently, we retrieved 1,383,996 bibliographic records in total on Russian publications (papers) indexed in WoS, whose description will follow in the next section. It should also be noted that the citation indices mentioned above are not mutually exclusive but sometimes overlap each other in terms of the coverage of research publications. For instance, based on the data we acquired, Science Citation Index Expanded was the largest with 966,615 records overall, but only 840,096 (86.9%) belonged exclusively to it with the rest being shared with some of the other indices.

For the examination of the data we applied the same methodology as in [9] and [8], consisting in importing the downloaded plain-text files with bibliographic records into a relational database, carrying out some data curation, and submitting well formulated structured query language (SQL) queries to the database. The results of these SQL queries then formed the basis of our analysis. As for the data curation, we performed some necessary unifications regarding upper-case and lower-case letters in names and titles and made adjustments especially in addresses associated with authors of papers. For example, we assigned "United States" (USA) as the affiliation country to all addresses without an explicit country that included a state code of a US state such as TX or CA. Also, we merged England, Scotland, Wales, and Northern Ireland into "United Kingdom", but otherwise made intentionally no attempts to standardize or adapt the names of now defunct countries such as the Soviet Union, Czechoslovakia, or Yugoslavia. Neither did we try to reflect the territorial changes of some countries in the past. Therefore, with the exceptions mentioned above, we adopted WoS data "as is" and will show the results of our inspection in the next section.

3. Results and Discussion

We will first present and discuss the document types appearing in our data collection, the overall production as it evolves over time, and the document languages used in the publications under study, then international collaboration and its impact in the second subsection, research areas and their citedness in the third subsection, collaborating countries in the top research areas in the fourth subsection, and finally the top publication sources and the most frequently cited papers in the last subsection.

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3.1 Document Types, Production over Time, and Languages Used

The 20 most frequent document types occurring in our data set are shown in Table 1, along with their number of occurrences, percentage share in the data, citations received (as of May 2022), percentage share in overall citations (i.e. total citation count of all citations), and the average number of citations per paper (*CPP*). We can observe that the top document type is "Article" with almost one million occurrences and a share of 72%, followed by "Proceedings Paper" appearing almost 200 thousand times and having a 14% share and "Article; Proceedings Paper" with over 60 thousand appearances and a 4.5% share in total publications. We may thus claim that Russia's visibility in Web of Science is to the extent of 90% formed by original journal articles, conference proceedings papers, and conference proceedings papers reprinted as journal articles.

Table 1. Top 20 document types and their counts, share in total production, citations, share in total citations, and citations per paper (*CPP*).

Document Type	Count	% Papers	Citations	% Citations	*CPP*
Article	995,954	71.96%	9,895,022	82.29%	9.9
Proceedings Paper	192,014	13.87%	269,794	2.24%	1.4
Article; Proceedings Paper	62,523	4.52%	683,963	5.69%	10.9
Meeting Abstract	60,336	4.36%	16,334	0.14%	0.3
Review	31,638	2.29%	998,579	8.30%	31.6
Editorial Material	13,073	0.94%	38,910	0.32%	3.0
Letter	6,617	0.48%	54,633	0.45%	8.3
Book Review	6,240	0.45%	480	0.00%	0.1
Note	5,525	0.40%	36,503	0.30%	6.6
Correction	2,883	0.21%	4,722	0.04%	1.6
Article; Early Access	2,791	0.20%	1,585	0.01%	0.6
Biographical-Item	1,674	0.12%	649	0.01%	0.4
Article; Data Paper	480	0.03%	2,988	0.02%	6.2
News Item	419	0.03%	1,913	0.02%	4.6
Review; Book Chapter	310	0.02%	11,830	0.10%	38.2
Discussion	233	0.02%	222	0.00%	1.0
Item About an Individual	222	0.02%	151	0.00%	0.7
Review; Early Access	198	0.01%	207	0.00%	1.0
Poetry	180	0.01%	0	0.00%	0.0
Article; Book Chapter	142	0.01%	2,061	0.02%	14.5

Other document types that exceed the 10,000 mark are "Meeting Abstract", "Review", and "Editorial Material" with only reviews (out of these three) being so-called "citable items", whose counts contribute to the calculation of the famous Journal Impact Factor. As far as citations are concerned (more on them

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later), over 82% of them (nearly 10 million) were received by journal articles and only about 2% by proceedings papers, which, given their respective shares of 72% and 14% in total publications, clearly confirms the well-known fact that journal articles usually attract more citations than conference papers. By contrast, review articles representing only about 2.3% of total publications managed to garner almost one million citations, which is 8.3% of total citations and 31.6 citations per paper (*CPP*) on average. The only document type that has a greater *CPP* than reviews is "Review; Book Chapter" (38.2), but its share in total publications is negligible (only 0.02%). Journal articles and proceedings papers reprinted as journal articles have both *CPP* around 10 (9.9 and 10.9, respectively) whereas this indicator is smaller almost by an order of magnitude for simple conference papers (only 1.4). Therefore, it can be recommended to Russian authors that in order to increase the impact of their publications they should aim for journal articles rather than conference papers or target those conferences that reprint their proceedings papers as journal articles. In addition, publishing more review articles may also augment the influence of Russian research in terms of greater citedness.

Journal articles and conference proceedings papers are thus by a large margin the two most common types of documents (co-)authored by Russian scientists as reflected in WoS and it might be interesting to have a closer look at the production of articles and papers by Russian researchers in the course of time. Figure 1 shows graphically how many of such publications have been indexed in WoS each year since 1992. Of course, 2022 is an incomplete year and most likely also 2021 and 2020 are still not yet fully indexed given the indexation delay in WoS (especially with conference proceedings) and the time of data collection (May 2022). We set 1992 as the start year of the time period under investigation because of the creation of the Russian Federation as a sovereign state in December 1991 and because the counts of publications affiliated with "Russia" were very tiny in prior years. (For example, 2,134 in 1991, 1,541 in 1990, 309 in 1989, etc.) As explained in Section 2, we did not attempt to do any mapping between Russia and the Soviet Union as affiliation countries of authors but generally treated the country data fields in WoS records "as is". It should also be noted that the document type "Article; Proceedings Paper" contributes equally to both articles and proceedings papers in Figure 1.

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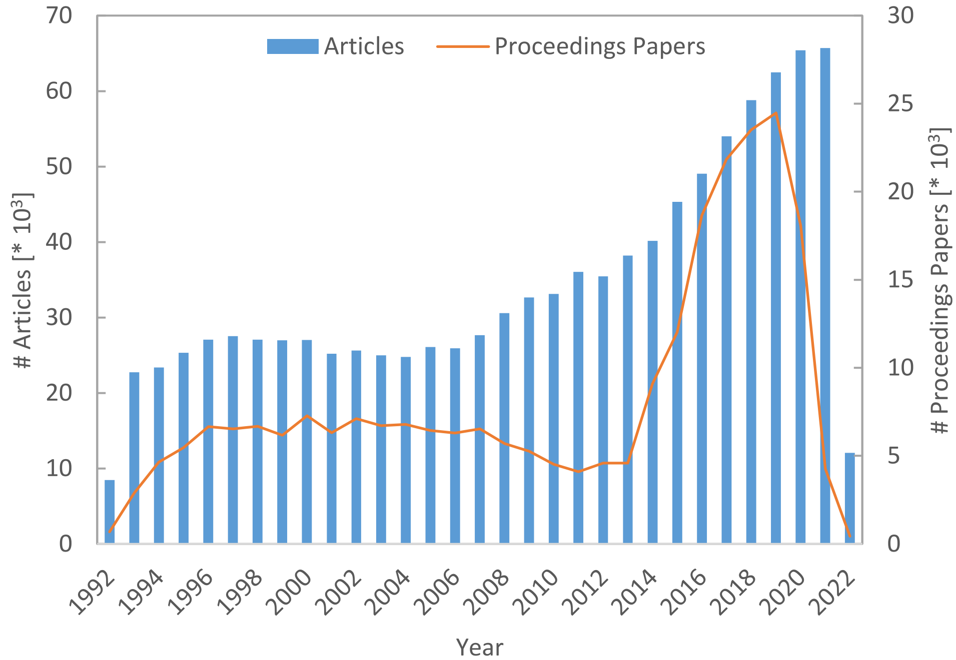

Figure 1. Number of Russian articles (left) and proceedings papers (right) published over time.

As we can see in Figure 1, the production of journal articles by Russian scholars indexed in WoS was quite stable between 1993 and 2007 with about 20 to 30 thousand articles per year. Starting in 2008 this productivity began rising sharply and reached its peak with 65,680 articles in 2021, which is more than a two-fold increase in journal articles production in the course of 13 years. In addition, the peak number of articles is very likely not final as a large amount of articles published in 2021 had certainly not yet been indexed in WoS as of May 2022. As far as conference proceedings papers are concerned, we may observe a steep rise in their publication from 1992 to 1996 (with 682 and 6,656 papers, respectively), a further stable period until 2007, then a slight decline and stagnation until 2013 (with a local minimum of 4,091 papers in 2011), afterwards a very sharp increase until 2019 (a maximum of 24,475 papers), and finally a sudden drop in the most recent years. While the decline after 2007 may be explained by a lack of resources for attending (and organizing) conferences due the 2008-2009 financial crisis in a significant portion of the world's banking sector or perhaps also by some changes in the indexation policy of conference proceedings in WoS, the extreme fall in the number of conference papers in the last years of the time period under study is most obviously just a result of the slow indexation process in WoS, which is very unfavourable towards conference proceedings compared to journals. Therefore, what really stands out in Figure 1, is the truly remarkable growth of the production of conference proceedings papers from 2013 to 2019, which is an increase by 433% in a short period of just six years!

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We have thus observed a rapid growth of the Russian scientific production in the 2010s (generally speaking), but an important question needs to be asked here: Is the Russian growth greater than the global growth? And to answer this let us have a look at the chart in Figure 2, which shows the Russian share in the global research production as indexed in WoS. We can notice that the Russian production share was about 2.5% in the 1990s, below 2.0% in the 2000s, and climbed up to almost 3.0% in the 2010s (2.88% in 2018). However, there are indications that the percentage of the global research publications with a Russian contribution may start shrinking again, although this may be obscured by the indexation issues relevant for the most recent years as mentioned earlier and it remains to be seen what happens in the next years before any precise conclusions can be drawn in this respect. So, yes, Russian research output was growing in both absolute and relative terms in the 2010s, but compared to the 1990s, the share of the Russian research publications in global publications increased only modestly and the future is uncertain.

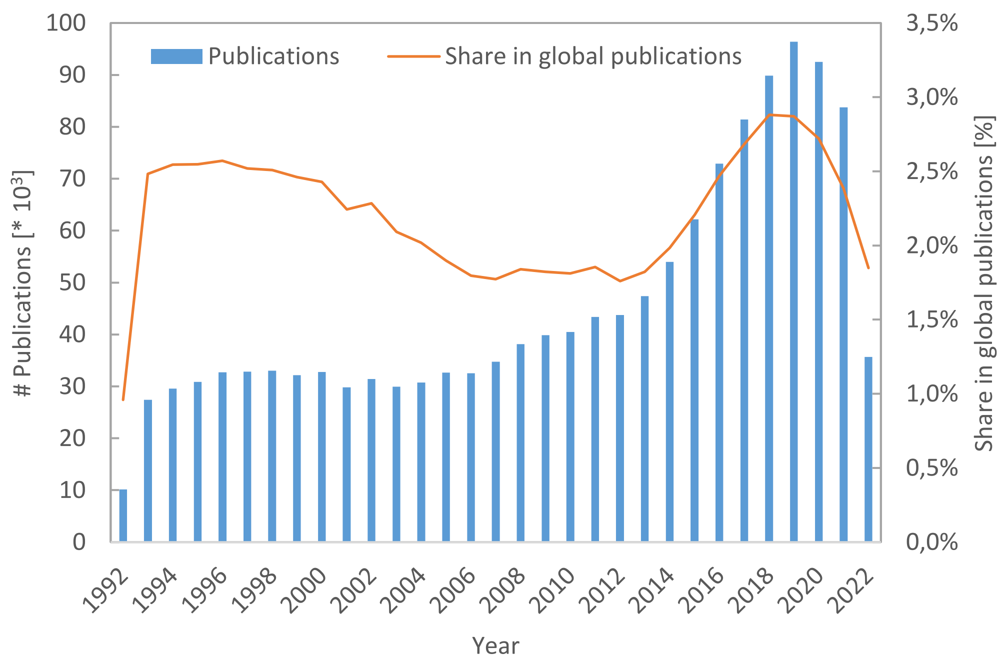

Figure 2. Development of the Russian production indexed in Web of Science and the share of Russian publications in global publications over time. (Data as of 6 September 2022.)

The last part of this section will be briefly devoted to the languages used in the Russian publications. Table 2 lists the 20 most frequent languages in which papers by Russian (co-)authors were written. The dominant language is English with 84.4% of papers and 97.3% of citations (*CPP* = 10.0), followed by Russian with 15.4% of papers and just 2.6% of citations (*CPP* = 1.5). Thus, the relative citation impact of English-language publications is almost seven times greater than the same

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impact of those written in Russian and it would thus be advisable for Russian scholars to publish their papers in English in order to attract citations more frequently. (In fact, it was a requirement of the Russian Academic Excellence Project “5-100”, taking place from 2012 to 2020, for academic and research institutions to publish a certain number of papers in international journals indexed in WoS and Scopus, which highly motivated Russian researchers to write their papers in English.) The presence of other languages (of which German and French are the most common) is close to negligible, but there are two striking facts that we would like to mention. First, it is the position of the Bulgarian language, which can be considered as a “small” language but is the seventh most frequently used language in Russian publications. However, the absolute number of such papers (in Bulgarian) is small (162) and appears to be largely driven by a single journal called *Chuzhdoezikovo Obuchenie-Foreign Language Teaching* indexed in WoS only since 2020 (not shown in Table 2). And second, there is a markedly larger mean number of citations per paper (*CPP*) of publications written in French or Chinese (2.9 and 3.1, respectively), which contrast with the lower *CPP*s of papers authored in German or Spanish, for example (1.5 and 1.2, respectively). Of course, the different *CPP*s could be explained by distinct scientific disciplines having various citation practices (and this seems to be indeed the case with Chinese-language sources from the fields of physics known to have high citation rates), but the difference between the publications written in French and German from similar research disciplines of the humanities and social sciences is less clear and would require further investigation, which is not the topic of this article. On the other hand, even if it is a well-known fact that languages other than English still play a marginal part in the coverage of publication sources in WoS, an inspection of our data revealed that Russian-language papers represented more than 30% of all Russia-affiliated publications in the first half of the 1990s, then fell below 10% at the beginning of the 2000s and have been around the non-negligible 15% since 2010, which is also close to the total share of 15.4% shown in Table 2.

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Table 2. Top 20 document languages and their papers, share in total papers, citations, share in total citations, and citations per paper (*CPP*).

Document Language	Papers	% Papers	Citations	% Citations	*CPP*
English	1,168,042	84.4%	11,700,778	97.3%	10.0
Russian	212,615	15.4%	318,593	2.6%	1.5
German	1,019	0.1%	1,572	0.0%	1.5
French	709	0.1%	2,021	0.0%	2.9
Spanish	429	0.0%	511	0.0%	1.2
Ukrainian	306	0.0%	224	0.0%	0.7
Bulgarian	162	0.0%	66	0.0%	0.4
Chinese	148	0.0%	462	0.0%	3.1
Unspecified	70	0.0%	99	0.0%	1.4
Italian	63	0.0%	19	0.0%	0.3
Serbian	63	0.0%	4	0.0%	0.1
Polish	60	0.0%	52	0.0%	0.9
Portuguese	43	0.0%	80	0.0%	1.9
Japanese	33	0.0%	60	0.0%	1.8
Slovak	30	0.0%	24	0.0%	0.8
Czech	29	0.0%	26	0.0%	0.9
Croatian	27	0.0%	18	0.0%	0.7
Turkish	25	0.0%	13	0.0%	0.5
Estonian	17	0.0%	2	0.0%	0.1
Korean	14	0.0%	6	0.0%	0.4

3.2 International Collaboration and Its Impact

Before examining the international collaboration in Russian papers in more detail, let us have a look at the overview in Table 3. The total number of citations received by all 1.38 million publications in the data set ("Times Cited" in WoS terminology) is roughly 12 million, which yields 8.7 citations per paper (*CPP*) on average. About a million papers (73.1%) out of all publications did not have any co-authors affiliated with an institution from outside of Russia, but these papers attracted only one third of all citations, which is thus a much lower share than expected. On the other hand, papers with co-authors from foreign institutions (based outside of Russia) represented only 26.9% of all publications but received two thirds of all citations, having a *CPP* of 21.5, which is more than five times larger than the *CPP* of Russia-only papers (4.0). Thus, international collaboration can be warmly recommended to Russian scholars because internationally co-authored publications have a clearly larger citation impact.

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Table 3. Paper counts and their citations and citations per paper (*CPP*) per collaboration type.

Collaboration Type	# Papers	% Papers	# Citations	% Citations	*CPP*
All papers	1,383,996	100.0%	12,024,740	100.0%	8.7
Russia-only papers	1,011,612	73.1%	4,002,847	33.3%	4.0
International collaborative papers	372,384	26.9%	8,021,893	66.7%	21.5

How the percentage of papers produced in international collaboration developed over time is shown in the following figure (Figure 3), where the number of Russian papers published in the individual years from 1992 to 2022 and the number of their all-time citations are displayed on the left-hand Y-axis in thousands whereas the right-hand Y-axis depicts the percentage share of international collaborative papers in all papers in a given year and the share of the citations of such papers in all all-time citations of all papers published in a certain year. We can immediately grasp that the percentage share of international papers' citations is consistently higher than the publication share of such papers over the whole period under study. While the share of international papers in total production is about 30%, citations of international papers account for around 70% of all citations, with local maxima in 2006 (33.17% share of international papers) and 2004 (73.35% share of international papers' citations). Both percentage shares (of international papers and their citations) tend to increase in the most recent years, but this trend needs to be confirmed in a future analysis due to incomplete data. By contrast, the rise of the percentage of international publications (and correspondingly also of their citations) in the early years is undisputable: from 7.18% in 1992 and 16.83% in 1993 it exceeded 30% as early as in 2001. After the peak in 2006, however, it slightly declined and stabilized at around 25%.

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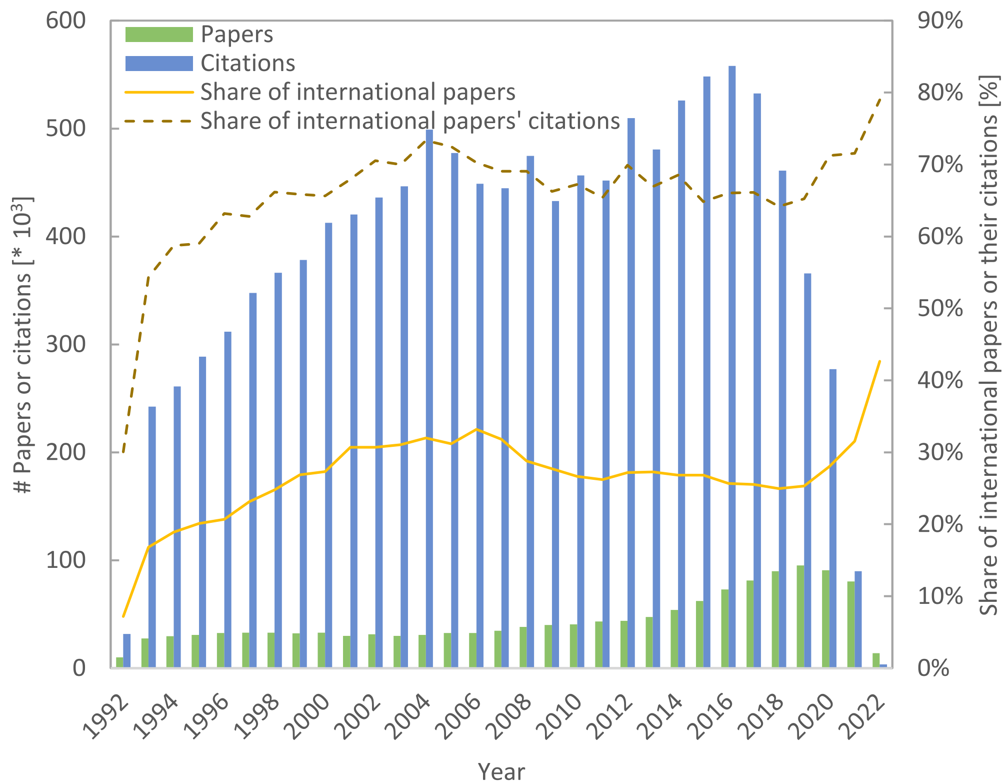

Figure 3. Number of Russian papers published in individual years and of all-time citations of those papers (left) and the share of international collaborative papers in the published papers and of their citations in the all-time citations over time (right).

Finally, we will inspect more closely the individual collaborating countries in this subsection. Table 4 shows the 40 most frequently collaborating countries with the number of papers published jointly with researchers affiliated with institutions based in these countries, share of such papers in all papers, number of citations received by these papers, share of such citations in all citations, average number of citations per paper (*CPP*) of these papers, and relative average number of citations per paper (*RCPP*), which is calculated as *CPP* divided by 4.0 (*CPP* of Russia-only publications) and gives a factor of improvement over papers authored by scholars from only Russian institutions. Let us note that we use the so-called full counting method when recording the countries contributing to international publications, i.e. each country is counted exactly once for any non-zero contribution to an international collaborative paper. As a result, the percentages in Table 4 may add up to more than 100% and we can observe that the two most frequently collaborating nations, United States (USA) and Germany, both participated in more than 6% of Russia's publications, which means over 90 thousand papers. These first two countries are followed by

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France and the United Kingdom (UK), having each exceeded a 3% share in Russia's research production indexed in WoS. Italy and China contributed both to over 2% of Russian papers and all the other states in Table 4 remained below this threshold.

Table 4. Top 40 collaborating countries and their number of papers, citations, citations per paper (*CPP*), and relative citations per paper (*RCPP* – related to 4.0, which is *CPP* of Russia-only publications).

	Collaborating Country	# Papers	% Papers	# Citations	% Citations	*CPP*	*RCPP*
1	United States	93,955	6.79%	3,507,623	29.17%	37.3	9.43
2	Germany	90,311	6.53%	2,954,013	24.57%	32.7	8.27
3	France	51,604	3.73%	1,896,275	15.77%	36.7	9.29
4	United Kingdom	45,626	3.30%	2,003,226	16.66%	43.9	11.10
5	Italy	37,059	2.68%	1,525,747	12.69%	41.2	10.40
6	Peoples R China	28,801	2.08%	1,067,235	8.88%	37.1	9.36
7	Japan	25,759	1.86%	1,100,699	9.15%	42.7	10.80
8	Spain	24,612	1.78%	1,221,811	10.16%	49.6	12.55
9	Poland	24,078	1.74%	935,683	7.78%	38.9	9.82
10	Switzerland	21,267	1.54%	1,083,747	9.01%	51.0	12.88
11	Netherlands	20,095	1.45%	1,120,240	9.32%	55.7	14.09
12	Sweden	19,499	1.41%	881,606	7.33%	45.2	11.43
13	Ukraine	19,409	1.40%	428,462	3.56%	22.1	5.58
14	Canada	18,106	1.31%	1,083,627	9.01%	59.8	15.13
15	Finland	16,840	1.22%	718,180	5.97%	42.6	10.78
16	Czech Republic	16,122	1.16%	568,048	4.72%	35.2	8.90
17	South Korea	13,562	0.98%	682,353	5.67%	50.3	12.72
18	Belgium	13,554	0.98%	680,776	5.66%	50.2	12.69
19	India	13,469	0.97%	679,564	5.65%	50.5	12.75
20	Austria	13,309	0.96%	568,186	4.73%	42.7	10.79
21	Australia	13,219	0.96%	837,004	6.96%	63.3	16.00
22	Brazil	12,439	0.90%	670,919	5.58%	53.9	13.63
23	Belarus	10,502	0.76%	214,494	1.78%	20.4	5.16
24	Israel	10,207	0.74%	531,015	4.42%	52.0	13.15
25	Norway	9,817	0.71%	546,247	4.54%	55.6	14.06
26	Denmark	9,320	0.67%	575,613	4.79%	61.8	15.61
27	Greece	9,209	0.67%	468,065	3.89%	50.8	12.85
28	Portugal	9,072	0.66%	449,165	3.74%	49.5	12.51
29	Hungary	8,827	0.64%	490,303	4.08%	55.5	14.04
30	Turkey	8,518	0.62%	369,458	3.07%	43.4	10.96
31	Taiwan	8,375	0.61%	499,525	4.15%	59.6	15.07
32	Romania	7,647	0.55%	370,445	3.08%	48.4	12.24
33	Mexico	7,493	0.54%	425,099	3.54%	56.7	14.34
34	Slovakia	7,154	0.52%	297,959	2.48%	41.6	10.53
35	Kazakhstan	6,658	0.48%	77,729	0.65%	11.7	2.95
36	Bulgaria	6,165	0.45%	256,254	2.13%	41.6	10.50
37	Ireland	5,747	0.42%	361,876	3.01%	63.0	15.91

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38	South Africa	5,651	0.41%	383,422	3.19%	67.9	17.15
39	Armenia	5,393	0.39%	218,205	1.81%	40.5	10.23
40	Serbia	5,113	0.37%	275,803	2.29%	53.9	13.63

What deserves our attention is the fact that former USSR's republics as well as former Eastern Bloc countries have all relatively tiny shares in Russia's publications: Ukraine 1.40%, Belarus 0.76%, Kazakhstan 0.48%, and Armenia 0.39% representing the first group of nations and Poland 1.74%, Czech Republic 1.16%, Hungary 0.64%, Romania 0.55%, Slovakia 0.52%, Bulgaria 0.45%, and Serbia 0.37% representing the latter. (For the sake of simplicity, we now consider former Yugoslavia as a former Eastern Bloc country.) This indicates that in Russian scientific research, the presence of scientists from Eastern Europe is visible, but only modest. Russian science as represented by its publications in WoS is oriented more globally and the West is preferred to the East.

As far as the citation impact of Russia's internationally collaborative papers is concerned, almost 30% of that impact is made up of citations received by papers co-published with authors from the United States (29.17%) and nearly 25% by publications written jointly with German researchers (24.57%). In both cases, the total number of citations obtained is about three million. The other collaborating countries with more than 10% of citations are (in descending order) the United Kingdom, France, Italy, and Spain followed by the Netherlands, Japan, Switzerland, Canada, and China that all exceeded the threshold of one million citations. However, the *CPP* indicator is surprisingly low for Germany with just 32.7 citations per paper on average, which is lower than that of all other Western nations in Table 4, but also of China (*CPP* = 42.7), India (50.5), and of some Eastern European countries like Poland (38.9), Czech Republic (35.2), or Hungary (55.5). On the contrary, not so surprising are the small *CPP*s of the former USSR's republics Ukraine (22.1), Belarus (20.4), and Kazakhstan (11.7), with the notable exception of Armenia (*CPP* = 40.5). These extreme values are even more visible in the last column of Table 4, in which *RCPP* means a factor of improvement in *CPP* over papers published by only Russia-based authors. For instance, *RCPP* of 16.00 for Australia (rank 21) signifies that, on average, papers co-published with researchers from Australian institutions get 16 times more citations than Russia-only (domestic) publications. (Remember that *CPP* of Russia-only papers is 4.0 as shown in Table 3.) The only nation better than Australia in terms of *RCPP* is South Africa (17.15) and the other top-performing countries are Ireland (15.91), Denmark (15.61), Canada (15.13), and Taiwan (15.07). By contrast, Kazakhstan, Belarus, and Ukraine have the lowest *RCPP*s (2.95, 5.16, and 5.58, respectively). Therefore, from a general point of view, it might be tempting to recommend Russian scientists to publish with South African, Australian, or Irish researchers and advise them against publishing with co-authors from Kazakhstan, Belarus, or Ukraine, but it is important to realize that the underlying citation indicators supporting such a

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recommendation are affected not only by the absolute number of papers produced in collaboration with a certain country, but also by the different citation practices of the various scientific disciplines in which such collaboration took place. We will deal with this topic in Section 3.4.

3.3 Research Areas and Their Impact

Based on the fields and subfields of science they are concerned with, papers indexed in Web of Science are categorized into research areas which themselves consist of one or more subject categories. These areas and categories are not immutable but can change over time as they are split, merged, added, removed, renamed, etc. As of May 2022, there were 152 research areas and 254 subject categories in the data we investigated and it should be noted that the areas and categories are not mutually exclusive and a paper may be classified into multiple subject categories and even research areas. The top 40 research areas most frequently associated with Russian publications in WoS are displayed in Figure 4 along with the number of papers they are assigned to, number of citations these papers accumulated, percentage of papers and citations in total papers and citations (which may add up to more than 100% due to the mutual non-exclusivity of research areas mentioned earlier), average number of citations per paper (*CPP*), global baseline *CPP* known for a specific research area, and relative world impact calculated as the ratio of *CPP* to global baseline *CPP*.

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Research Area	# Papers	% Papers	# Citations	% Citations	Citations per Paper (*CPP*)	Global Baseline *CPP*	Relative World Impact
Physics	312,691	22.59%	3,882,663	32.29%	12.4	20.7	0.60
Chemistry	193,254	13.96%	1,818,742	15.13%	9.4	24.4	0.39
Engineering	147,973	10.69%	649,578	5.40%	4.4	11.0	0.40
Materials Science	108,843	7.86%	1,141,204	9.49%	10.5	19.1	0.55
Mathematics	75,664	5.47%	412,132	3.43%	5.4	12.3	0.44
Optics	66,376	4.80%	450,628	3.75%	6.8	10.8	0.63
Science & Technology - Other Topics	56,419	4.08%	818,048	6.80%	14.5	20.9	0.69
Biochemistry & Molecular Biology	46,845	3.38%	732,505	6.09%	15.6	35.6	0.44
Astronomy & Astrophysics	46,713	3.38%	985,712	8.20%	21.1	26.8	0.79
Computer Science	39,746	2.87%	195,772	1.63%	4.9	9.8	0.50
Geology	34,508	2.49%	369,288	3.07%	10.7	20.1	0.53
Instruments & Instrumentation	31,124	2.25%	215,312	1.79%	6.9	11.2	0.62
Metallurgy & Metallurgical Engineering	29,176	2.11%	187,530	1.56%	6.4	12.2	0.53
Mechanics	26,282	1.90%	161,642	1.34%	6.2	16.1	0.38
Environmental Sciences & Ecology	25,853	1.87%	280,844	2.34%	10.9	23.4	0.46
Business & Economics	22,839	1.65%	65,699	0.55%	2.9	16.5	0.17
Geochemistry & Geophysics	22,704	1.64%	243,699	2.03%	10.7	27.8	0.39
Neurosciences & Neurology	21,720	1.57%	177,648	1.48%	8.2	24.0	0.34
Cardiovascular System & Cardiology	19,715	1.42%	87,191	0.73%	4.4	16.9	0.26
Nuclear Science & Technology	19,289	1.39%	186,017	1.55%	9.6	8.7	1.11
Research & Experimental Medicine	18,644	1.35%	77,540	0.64%	4.2	17.8	0.23
History	18,365	1.33%	9,983	0.08%	0.5	1.1	0.51
Psychology	17,565	1.27%	56,535	0.47%	3.2	22.2	0.14
Energy & Fuels	17,116	1.24%	116,895	0.97%	6.8	17.6	0.39
Automation & Control Systems	16,310	1.18%	57,987	0.48%	3.6	10.0	0.35
Education & Educational Research	15,601	1.13%	18,832	0.16%	1.2	7.1	0.17
Meteorology & Atmospheric Sciences	15,285	1.10%	169,623	1.41%	11.1	27.3	0.41
Spectroscopy	15,183	1.10%	112,051	0.93%	7.4	14.8	0.50
Polymer Science	14,516	1.05%	151,557	1.26%	10.4	21.2	0.49
Thermodynamics	14,364	1.04%	104,367	0.87%	7.3	16.4	0.44
Telecommunications	14,220	1.03%	38,089	0.32%	2.7	7.2	0.37
Pharmacology & Pharmacy	13,827	1.00%	139,821	1.16%	10.1	19.2	0.53
Biophysics	13,762	0.99%	192,972	1.60%	14.0	23.6	0.59
Crystallography	13,573	0.98%	115,846	0.96%	8.5	13.0	0.66
Agriculture	12,998	0.94%	77,847	0.65%	6.0	14.4	0.41
Genetics & Heredity	12,825	0.93%	179,688	1.49%	14.0	31.1	0.45
General & Internal Medicine	12,662	0.91%	285,046	2.37%	22.5	11.7	1.92
Zoology	12,068	0.87%	79,481	0.66%	6.6	16.0	0.41
Cell Biology	11,641	0.84%	243,027	2.02%	20.9	34.3	0.61
Microbiology	11,543	0.83%	161,650	1.34%	14.0	31.0	0.45

Figure 4. Top 40 Web of Science research areas with the number of papers and citations, their percentage shares in all papers and citations, citations per paper (*CPP*), global baseline *CPP*, and the relative world impact, which is a ratio of the two preceding indicators. Background colours tend towards green (positive) for high values and red (negative) for low values in their respective columns. The source of

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global baseline *CPP*, which has been recalculated from WoS subject categories to WoS research areas, is *InCites* (Clarivate, 2022) based on Web of Science documents including Emerging Sources Citation Index since 1980 until 30 April 2022 with a data update on 27 May 2022.

In Figure 4 we can see that *physics* is by far the "largest" research field in Russia with 22.59% of papers and 32.29% of citations, followed by *chemistry*, *engineering* and *materials science* that also exceeded the 100,000 publications threshold. All other WoS research fields are much "smaller". *Physics* is the most impactful field in absolute citation terms too, having attracted close to 3.9 million citations and only *chemistry* and *materials science* got also over one million cites. (*Astronomy & astrophysics* is slightly below this significant mark.) However, the *CPP* indicator (supported by a "heat map" with background colours tending towards green for high values and red for low values) is the largest for *general & internal medicine* (22.5), *astronomy & astrophysics* (21.1), and *cell biology* (20.9) and the smallest for *history* (0.5), *education & educational research* (1.2), and *telecommunications* (2.7). Nevertheless, when we relate the *CPP*s of individual disciplines to the world average of citations in a certain field (for the source of these global baseline *CPP*s see the caption of Figure 4), the relative world impact shown in the last column also as a "heat map" looks a little different and more grim for Russian science. For instance, *physics* has a relative world impact of 0.60, which means that, on average, the publications (co-)authored by Russian researchers in the field of physics received only 60% of the mean number of citations attracted by physics papers globally. And this is even worse for *chemistry* and *engineering* with a relative world citation impact of 0.39 and 0.40, respectively, which causes their background colour to be reddish. But in fact, the relative citation impact of all the research areas in Figure 4 is below the world average with two notable exceptions: *nuclear science & technology* (1.11) and, particularly, *general & internal medicine*, which is 92% above the world average. A third research area, *astronomy & astrophysics*, is at least somewhat close to the global average (0.79). On the other hand, there are a number of fields at the opposite end of the spectrum with very tiny citation impacts as compared to the world average and *psychology* (0.14), *education & educational research* (0.17), and *business & economics* (0.17) certainly belong to them. Therefore, in order to boost their relative global citation impact in some underperforming research areas, a good strategy for Russian scientists may be to co-publish their papers with authors from the countries which contribute to collaborative papers with a greater citedness. This aspect will be discussed in the next subsection. (A figure analogous to Figure 4 with WoS subject categories is Figure A1 in the appendix.)

3.4 Collaborating Countries and Their Impact in Top Research Areas

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The top 10 research areas from Figure 4 and the top 30 countries from Table 4 are juxtaposed in Figure 5 in the form of a "heat map" to show the relative *CPP*s of papers related to the baseline *CPP* values of Russia-only publications: 5.7 (*physics*), 6.2 (*chemistry*), 2.9 (*engineering*), 5.3 (*materials science*), 3.6 (*mathematics*), 3.7 (*optics*), 3.4 (*science & technology – other topics*), 7.9 (*biochemistry*), 7.2 (*astronomy & astrophysics*), and 2.7 (*computer science*). The numbers 10 and 30 were deliberately chosen to obtain a reasonably-sized matrix for visualization. For example, the number 6.60 in the cell for the United States and *physics* means that Russia's papers in the field of *physics* co-published with scientists affiliated with institutions from the USA received 6.6 times more citations on average than Russian domestic papers, which would be 6.6 times 5.7 yielding 37.7 mean citations per paper (not shown in Figure 5). Considering the global baseline *CPP* for *physics* of 20.7 (see Figure 4), the relative world citation impact of Russian *physics* papers produced in collaboration with the USA is 1.82, i.e. 82% above the world average in this research area. The relative global citation impacts are not shown in Figure 5 either, but the actual exact counts of joint publications with specific countries in particular research areas are displayed in Figure A2 in the appendix.

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	Physics	Chemistry	Engineering	Materials Science	Mathematics	Optics	Science & Technology - Other Topics	Biochemistry & Molecular Biology	Astronomy & Astrophysics	Computer Science
United States	6.60	4.01	5.39	5.62	4.87	5.79	21.11	5.51	6.29	8.55
Germany	5.48	3.56	4.22	4.25	3.02	5.17	14.68	4.72	5.91	4.51
France	6.19	3.42	5.67	3.83	2.88	5.59	16.17	3.87	6.82	5.78
United Kingdom	7.19	4.37	4.89	5.33	3.12	5.90	29.00	5.06	7.28	6.43
Italy	6.86	4.12	5.59	3.94	3.36	5.13	17.57	4.21	6.82	5.41
Peoples R China	7.08	3.11	3.62	3.32	1.65	3.56	13.22	3.32	6.31	4.68
Japan	7.11	3.40	5.40	4.55	2.50	4.72	18.61	5.28	7.31	4.19
Spain	7.95	3.74	6.01	3.87	2.67	4.06	17.91	5.50	8.25	3.91
Poland	6.26	2.25	3.59	2.53	1.72	4.76	24.58	2.96	7.15	3.66
Switzerland	7.90	4.51	6.32	4.70	3.62	6.30	28.46	6.32	8.20	8.98
Netherlands	8.41	5.65	7.51	7.10	4.24	7.29	36.16	7.09	7.72	4.67
Sweden	6.70	3.81	5.94	3.85	2.85	4.91	19.63	4.72	7.45	3.86
Ukraine	3.84	1.87	1.65	2.40	1.62	2.95	5.50	2.41	4.29	6.80
Canada	9.77	4.20	6.77	5.73	3.53	10.23	38.66	6.08	9.30	8.30
Finland	7.26	3.12	5.32	3.15	3.03	3.30	19.38	4.22	8.52	3.08
Czech Republic	5.92	2.42	3.26	2.53	1.90	2.81	14.53	6.42	5.31	3.20
South Korea	8.25	4.09	3.94	3.65	1.74	3.14	15.51	3.34	6.62	3.50
Belgium	7.69	3.38	5.39	4.47	3.85	8.80	25.68	5.28	7.79	7.15
India	9.00	1.98	3.77	2.17	1.87	3.35	13.30	2.12	7.74	4.78
Austria	6.83	3.54	2.55	4.63	2.11	5.07	20.88	8.07	6.01	2.13
Australia	9.26	3.96	4.74	5.23	2.49	6.57	26.67	8.96	9.33	4.50
Brazil	7.61	3.00	4.90	3.65	2.21	5.25	20.55	7.13	6.68	6.33
Belarus	5.09	1.95	2.07	2.39	1.09	2.38	3.42	1.62	7.88	1.99
Israel	8.48	2.92	3.44	3.48	2.70	4.46	16.03	5.77	9.12	4.21
Norway	7.27	3.35	5.13	2.95	2.41	4.00	29.17	4.08	9.31	4.77
Denmark	7.32	5.07	6.54	5.54	3.38	4.92	30.83	7.13	10.50	4.56
Greece	6.97	3.28	6.22	3.54	2.84	3.32	19.14	6.76	6.02	3.74
Portugal	6.76	3.87	9.39	2.99	2.25	8.29	19.42	6.33	7.71	6.84
Hungary	9.14	3.49	11.18	2.68	3.05	12.09	26.86	4.68	7.57	4.24
Turkey	6.85	2.60	4.67	3.27	1.28	2.15	10.65	3.62	6.69	2.67

Figure 5. Top 30 collaborating countries and their relative *CPP*s in the top ten research areas related to the baseline *CPP*s of Russia's domestic papers (i.e. without foreign co-authors) in those areas. Background colours tend towards green (positive) for high values and red (negative) for low values in their respective columns.

Regarding *physics*, the greatest improvement over Russia-only papers in terms of relative citedness is achieved in collaboration with Canada, Australia, and Hungary with a factor of improvement of 9.77, 9.26, and 9.14, respectively, so USA does not necessarily appear to be the best potential collaborator in this most productive research area. On the other hand, Ukraine (3.84), Belarus (5.09), and, surprisingly, Germany (5.92) contribute the least to the increase in citations, but Germany is by far the most frequently collaborating nation in *physics* as can be seen in Figure A2. However, the unexpectedly weak citation contribution of Germany in *physics* is repeated in *engineering*, *science & technology – other topics*, *biochemistry & molecular biology*, and *astronomy & astrophysics*, which is an interesting phenomenon

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and should be further explored in follow-up studies. By contrast, Canada and Switzerland are consistently among the best performers in all scientific fields in Figure 5 (only greenish cells in their respective rows) while Ukraine and Belarus stand out negatively with all reddish cells except *computer science* (Ukraine) and *astronomy & astrophysics* (Belarus). In general, green cells (high relative *CPP* values) are often present with developed Western nations and red cells (low relative *CPP*s) appear more frequently with Eastern European and developing countries. Nevertheless, there is one notable exception with respect to Hungary, which is the best impact contributor in two research areas and raises the *CPP* of Russian publications 11.18 times in engineering and 12.09 times in optics, although with quite small numbers of joint papers (see the corresponding entries in Figure A2). This observation and the fact that Russia (Soviet Union) had played a very specific part in the research collaboration of Eastern European countries lead us to the need for a more detailed inspection of the citation contribution of the former Eastern Bloc countries with the basis in another "heat map" depicted in Figure 6.

	Physics	Chemistry	Engineering	Materials Science	Mathematics	Optics	Science & Technology - Other Topics	Biochemistry & Molecular Biology	Astronomy & Astrophysics	Computer Science
Poland	6.26	2.25	3.59	2.53	1.72	4.76	24.58	2.96	7.15	3.66
Ukraine	3.84	1.87	1.65	2.40	1.62	2.95	5.50	2.41	4.29	6.80
Czech Republic	5.92	2.42	3.26	2.53	1.90	2.81	14.53	6.42	5.31	3.20
Belarus	5.09	1.95	2.07	2.39	1.09	2.38	3.42	1.62	7.88	1.99
Hungary	9.14	3.49	11.18	2.68	3.05	12.09	26.86	4.68	7.57	4.24
Romania	6.45	1.79	4.87	2.23	3.21	2.12	10.85	3.03	9.55	1.95
Slovakia	6.02	3.25	2.20	1.93	1.29	3.04	12.29	3.53	4.82	1.53
Kazakhstan	1.93	0.89	1.15	1.52	0.81	1.09	2.70	1.50	4.50	0.87
Bulgaria	7.10	2.34	1.83	1.79	1.11	4.36	16.56	2.96	6.47	2.81
Armenia	7.57	1.42	1.40	1.37	0.80	2.18	12.45	2.24	7.39	0.51
Serbia	8.35	1.65	1.89	1.22	2.22	2.43	16.53	2.43	7.60	2.79
Slovenia	7.35	2.70	4.36	3.31	2.48	4.07	16.10	6.26	5.96	3.37
Estonia	6.92	2.53	2.29	2.11	2.27	2.59	29.79	11.84	7.49	2.36
Georgia	7.67	1.57	2.49	1.97	1.27	1.02	48.76	4.83	7.51	1.38
Croatia	8.51	1.62	1.88	2.24	1.50	2.77	37.57	6.30	7.34	1.35
Lithuania	6.16	1.49	2.61	1.64	3.05	2.33	22.37	5.24	7.93	2.20
Latvia	2.82	1.45	1.99	1.60	1.47	2.74	23.96	2.76	2.59	1.41
Azerbaijan	6.51	1.84	2.88	2.23	1.08	2.26	8.11	1.78	6.71	0.45
Uzbekistan	2.54	0.75	1.38	1.09	0.57	3.84	14.67	2.76	4.66	0.64
Moldova	1.77	1.86	1.56	2.67	0.15	2.09	5.76	1.32	4.57	0.74

Figure 6. Top 20 Eastern European collaborating countries and their relative *CPP*s in the top ten research areas related to the baseline *CPP*s of Russia's domestic papers (i.e. without foreign co-authors) in those areas. Background colours tend towards green (positive) for high values and red (negative) for low values in their respective columns.

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And indeed, among Eastern European countries (in the broad sense of the term), Hungary is clearly the leader in *physics*, *chemistry*, *engineering*, and *optics* and among the top-performing collaborators in all other research areas. Other well-performing countries include Poland, which is consistently good but excels in no particular field, Estonia, which is the best in *biochemistry & molecular biology* (11.84), and Slovenia, which is the top citation contributor in *materials science* (3.31) but has a weakness in *astronomy & astrophysics* (5.96). This time, Ukraine and Belarus are rather mediocre in the context of Eastern European nations and the former is even the best country in *computer science* (6.80), but at the other end of the impact spectrum there are three former Soviet republics Kazakhstan, Uzbekistan, and Moldova with many reddish cells and relative *CPP*s even less than 1 (unlike those in Figure 5) indicating that they actually decrease the citedness of Russian research papers. The absolute minimum to be seen in Figure 6 is 0.15 in *mathematics* for Moldova, which means that mathematics papers co-published with authors from Moldovan institutions receive on average only 15% of the mean number of citations garnered by domestic Russian papers in that discipline, although this calculation is based on an extremely small number of common publications as may be seen in Figure A3 in the appendix. To conclude this subsection, for a greater citation impact Russian scholars may generally be advised to co-publish their papers with researchers from Western nations rather than from Eastern Europe or developing countries and if they need to produce publications with scientists from the former Eastern Bloc nations, their best choice would likely be Hungary, Poland, or Estonia whereas Kazakhstan, Uzbekistan, or Moldova could actually be detrimental to their efforts.

3.5 Top Publication Sources and Cited Papers

In this last subsection we will first discuss the results of an examination of the publication sources indexed in WoS that are used by Russian scientists for the dissemination of their research outcomes. Table 5 presents the 20 most often used publication sources, all of which are journals, along with their country of origin, number of Russian papers published in them, percentage share of these papers in the total number of Russian publications, number of citations received by these papers, percentage share of these citations in the total number of citations received by all Russian publications, average number of citations per paper (*CPP*), journal citation indicator (*JCI*), and average journal impact factor percentile (*AJIFP*). Let us note that the last two indicators are adopted from the 2021 *Journal Citation Reports* by Clarivate and their meaning is the following: *JCI* is a new category-normalized citation impact calculated also for journals with no impact factor and a journal with a *JCI* of 1.19 has 19% more citation impact than the average in its category, but a journal with a *JCI* of 0.76 is 24% below the average. On the other hand, *AJIFP* is the mean impact factor of a journal across all WoS subject categories in which it is indexed and

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an *AJIFP* greater than 0.75 means a Q1 journal (i.e. a quartile 1 journal in a list of journals in a particular category sorted by their impact factor in descending order), *AJIFP* less than 0.75 but greater than 0.5 means a Q2 journal, etc. Obviously, Q1 journals may be considered prestigious and so can be those with a *JCI* greater than 1.0.

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Table 5. Top 20 publication sources and their paper counts, citations, citations per paper (*CPP*), journal citation indicator (*JCI*), and average journal impact factor percentile (*AJIFP*).

Publication Source	Country	# Papers	% Pap.	# Citations	% Cit.	*CPP*	*JCI*	*AJIFP*
Russian Chemical Bulletin	Russia	11,561	0.84%	62,357	0.52%	5.4	0.21	23.74
Bulletin of Experimental Biology and Medicine	Russia	10,945	0.79%	27,151	0.23%	2.5	0.18	4.68
Physical Review B	USA	9,258	0.67%	258,737	2.15%	27.9	0.76	62.77
Doklady Akademii Nauk	Russia	9,128	0.66%	24,101	0.20%	2.6	*NA*	25.96*
Russian Journal of Applied Chemistry	Russia	8,741	0.63%	17,987	0.15%	2.1	0.14	15.97
Physics of the Solid State	Russia	8,635	0.62%	51,787	0.43%	6.0	0.15	9.42
JETP Letters	Russia	8,160	0.59%	81,600	0.68%	10.0	0.35	30.81
Russian Journal of General Chemistry	Russia	7,744	0.56%	23,835	0.20%	3.1	0.13	10.34
Technical Physics Letters	Russia	7,428	0.54%	28,486	0.24%	3.8	0.15	5.28
Doklady Earth Sciences	Russia	6,702	0.48%	27,718	0.23%	4.1	0.16	1.74
Semiconductors	Russia	6,695	0.48%	33,815	0.28%	5.1	0.11	3.62
Terapevticheskii Arkhiv	Russia	6,328	0.46%	6,363	0.05%	1.0	0.10	4.36
Technical Physics	Russia	6,230	0.45%	25,109	0.21%	4.0	0.11	0.31
Inorganic Materials	Russia	6,160	0.45%	26,047	0.22%	4.2	0.14	9.71
Tomsk State University Journal	Russia	6,126	0.44%	1,876	0.02%	0.3	0.10	*NA*
Russian Journal of Inorganic Chemistry	Russia	6,077	0.44%	23,678	0.20%	3.9	0.41	27.17
Physical Review D	USA	6,076	0.44%	219,294	1.82%	36.1	1.19	77.56
Physical Review Letters	USA	5,869	0.42%	418,018	3.48%	71.2	2.34	91.28
Physics of Atomic Nuclei	Russia	5,512	0.40%	25,964	0.22%	4.7	0.12	2.18
Russian Journal of Organic Chemistry	Russia	5,426	0.39%	23,451	0.20%	4.3	0.19	13.39

* *AJIFP* of *Doklady Akademii Nauk* is given for 1999, which is the last available year for that journal. All other *JCI* and *AJIFP* indicators as well as journal countries (locations) were retrieved from the 2021 *Journal Citation Reports* (Clarivate, 2022) on 7 September 2022. *NA* means the unavailability of an indicator.

There are only two Q1 journals in Table 5 and these are *Physical Review Letters* (*AJIFP* = 91.28) and *Physical Review D* (*AJIFP* = 77.56) with *JCI*s of 2.34 and 1.19, respectively. The third most prestigious journal is *Physical Review B* with *AJIFP* = 62.77 and *JCI* = 0.76. In is not without interest that these three most prestigious journals are based in the USA, have the highest mean numbers of citations per paper (71.2, 36.1, and 27.9) and also the largest shares in citations (over 1% each), although with relatively small shares in published papers (around 0.5% each). All other journals in Table 5 are Russia-based and have much lower *CPP*, *JCI*, and *AJIFP* indicators, with only *JETP Letters* achieving a two-digit *CPP* of 10.0 and boasting an *AJIFP* of 30.81. However, the largest *JCI* of Russia-based journals is attributed to *Russian Journal of Inorganic Chemistry* (0.41) and the journal publishing the highest number of Russian papers is *Russian Chemical Bulletin* with 0.84% of papers and 0.52% of citations, whose indicators of prestige are rather modest but still greater than those of the second journal by papers, which is *Bulletin of*

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Experimental Biology and Medicine. Russian researchers thus still tend to publish more frequently in journals based in Russia but may be encouraged to disseminate their knowledge in foreign journals (particularly those from the USA), which have a much larger citation impact.

Finally, let us have a look at the most cited papers co-authored by Russian scientists as reflected by Web of Science in May 2022. Table 6 shows the titles of the 20 publications with the highest "times cited" along with the first author's name, publication year, number of co-authors, and abbreviated journal title (since the sources are all research journals). As we can see, the publication years range from 2000 (Valiev's article on nanostructured materials) to 2020 (Hoffmann's paper on SARS-CoV-2) and the number of co-authors (including the first author) varies between 3 (Valiev's paper again) and 2,891 (Chatrchyan's 2012 work on bosons). There are no papers from the 1990s and no single-author articles. The most frequently cited Russian publication by a wide margin is Novoselov's 2004 paper on electric field effects with over 46,000 citations, which was published in the prestigious journal *Science*, followed by another Novoselov's paper from 2005 on Dirac fermions, which appeared in the top journal *Nature* and attracted more than 16,000 citations. Interestingly, there is one more paper by Novoselov from 2005, which dealt with atomic crystals. In addition, what makes Novoselov's articles even more impressive is the relatively very low number of co-authors (eight or seven), which is in stark contrast with the other papers in Table 6 from the fields of physics, biology, and medicine boasting of up to hundreds or even thousands of co-authors. However, the absolute minimum number of co-authors (three) and thus the greatest contribution by each of them can be found in Valiev's 2000 article published in *Progress in Materials Science*. To conclude, some papers co-authored by Russian scientists achieved remarkably high citation rates and, in particular, physics articles published in the prestigious multidisciplinary journals *Science* and *Nature* are extremely influential.

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Table 6. Top 20 papers by citations with first author name, publication year, number of coauthors, article title, publication source in abbreviated form, and number of citations.

First Author	Year	# Coauthors	Article Title	Source	Citations
Novoselov, K.S.	2004	8	Electric field effect in atomically thin carbon films	*SCIENCE*	46,402
Novoselov, K.S.	2005	8	Two-dimensional gas of massless Dirac fermions in graphene	*NATURE*	16,395
Agostinelli, S.	2003	127	GEANT4-a simulation toolkit	*NUCL INSTRUM METH A*	14,888
Bankevich, A.	2012	16	SPAdes: A New Genome Assembly Algorithm and Its Applications to Single-Cell Sequencing	*J COMPUT BIOL*	11,485*
Novoselov, K.S.	2005	7	Two-dimensional atomic crystals	*P NATL ACAD SCI USA*	8,697
Adzhubei, I.A.	2010	8	A method and server for predicting damaging missense mutations	*NAT METHODS*	8,555
Ade, P.A.R.	2014	264	Planck 2013 results. XVI. Cosmological parameters	*ASTRON ASTROPHYS*	8,209*
Hoffmann, M.	2020	13	SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2 and Is Blocked by a Clinically Proven Protease Inhibitor	*CELL*	8,112*
Koboldt, D.C.	2012	357	Comprehensive molecular portraits of human breast tumours	*NATURE*	7,470*
Lozano, R.	2012	189	Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010	*LANCET*	7,311*
Ng, M.	2014	140	Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013	*LANCET*	6,262*
Chatrchyan, S.	2012	2,891	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC	*PHYS LETT B*	6,212*
Schedin, F.	2007	7	Detection of individual gas molecules adsorbed on graphene	*NAT MATER*	6,120
Abbott, B.P.	2016	1,011	Observation of Gravitational Waves from a Binary Black Hole Merger	*PHYS REV LETT*	6,051*
Olive, K.A.	2014	209	REVIEW OF PARTICLE PHYSICS Particle Data Group	*CHINESE PHYS C*	5,939*
Beringer, J.	2012	192	REVIEW OF PARTICLE PHYSICS Particle Data Group	*PHYS REV D*	5,762*
Borghaei, H.	2015	28	Nivolumab versus Docetaxel in Advanced Nonsquamous Non-Small-Cell Lung Cancer	*NEW ENGL J MED*	5,745*

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Abe, O.	2005	438	Effects of chemotherapy and hormonal therapy for early breast cancer on recurrence and 15-year survival: an overview of the randomised trials	*LANCET*	5,593
Granger, C.B.	2011	32	Apixaban versus Warfarin in Patients with Atrial Fibrillation	*NEW ENGL J MED*	5,521
Valiev, R.Z.	2000	3	Bulk nanostructured materials from severe plastic deformation	*PROG MATER SCI*	5,430

* This is a highly-cited paper that received enough citations to place it in the top 1% of its respective research field based on a highly-cited threshold for the field and publication year as of May/June 2022 (retrieved from WoS on 10 October 2022).

4. Conclusions and Future Work

In this article we presented a bibliometric study of 1.38 million publications co-authored by researchers from Russian institutions that were indexed in the flagship Core Collection of the Web of Science (WoS) database as of May 2022. Unlike related works, the main contribution of this analysis is that it was concerned with the complete contents of WoS without any restrictions as to document types, time periods, research disciplines, etc. Therefore, in this respect our study reflects the true presence and visibility of Russian science in the most prestigious WoS database at the time of data collection. Among other things, our study investigates the overall distribution of document types and the development of the Russian scholarly production over time, international collaboration and its citation impact, the most productive research areas and their citedness, and the top publication sources and cited papers. It also attempts to give some general recommendations to Russian researchers to make their publications more impactful.

The main results we showed in our analysis are the following:

- Russian publications in WoS are primarily journal articles and conference proceedings papers whose production stagnated or declined in the 2000s but began growing sharply in the 2010s. However, even this increased research productivity still yields only less than a 3% share in the global research output (as indexed in WoS) and it is currently uncertain whether the recent Russian growth will continue in the 2020s.

- The percentage share of international papers in Russia's production is relatively stable at around 30%, but these papers are consistently cited much more frequently and accrue about 70% of all Russian citations. International collaborators are most often from the United States, Germany, and France, but these countries do not necessarily bring about also the greatest relative impact of the collaborative publications.

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- The most Russian papers were produced in the fields of *physics*, *chemistry*, *engineering*, and *materials science*, but the mean citedness of these publications is below the world average in these disciplines. From among the most productive research fields, it is only *general & internal medicine* and *nuclear science & technology* that have a greater citation impact than the global average.
- The contribution of scientists from foreign nations to the publications in the ten most productive research areas varies considerably, but the greatest relative citation impact is consistently achieved in collaboration with scholars from Canada and Switzerland, and regarding Eastern Europe, from Hungary, Poland, and Estonia.

The present study has several limitations some of which will be tackled in our future work. First, we deliberately did not include any institutional analysis and thus completely ignored the research production and impact of individual Russian institutions (organizations) for the simple reason that, in the raw Web of Science data we have, there is currently no straightforward way of unambiguously attributing papers to research institutions using their standardized names. Therefore, any attempt at analyzing the Russian research organizations would yield misleading results at this stage. Such analysis would first require a careful and thorough unification of institutional names (their merging and disambiguation), which is a very tedious and time-consuming task that we may address in the future. Second, in our paper there is almost no investigation into the nature of references and citations present in the Russian publications under study, nor is there any examination of Russia's collaboration pattern evolution over time, which is a topic we would like to deal with in a whole new article of ours. And third, we intentionally did not carry out any network analysis (of citations and collaborations) of the data set at our disposal because this remains to be the goal of our ongoing and future efforts. Finally, it must be noted that the Russian scientific output is by far not limited to the WoS database and more Russian articles in international journals are actually indexed in Scopus, while the vast majority of papers are present in the national electronic library eLibrary.

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Appendix

Subject Category	# Papers	% Papers	# Citations	% Citations	Citations per Paper (*CPP*)	Global Baseline *CPP*	Relative World Impact
Physics, Applied	109,092	7.88%	978,020	8.13%	9.0	19.4	0.46
Materials Science, Multidisciplinary	86,203	6.23%	1,006,505	8.37%	11.7	21.1	0.55
Physics, Multidisciplinary	67,639	4.89%	967,143	8.04%	14.3	21.7	0.66
Optics	66,376	4.80%	450,628	3.75%	6.8	10.8	0.63
Physics, Condensed Matter	65,529	4.73%	735,174	6.11%	11.2	22.7	0.49
Chemistry, Physical	64,137	4.63%	784,305	6.52%	12.2	31.4	0.39
Chemistry, Multidisciplinary	63,753	4.61%	567,684	4.72%	8.9	22.5	0.40
Engineering, Electrical & Electronic	61,788	4.46%	238,847	1.99%	3.9	9.1	0.42
Astronomy & Astrophysics	46,713	3.38%	985,712	8.20%	21.1	26.8	0.79
Mathematics	46,190	3.34%	199,125	1.66%	4.3	8.2	0.52
Biochemistry & Molecular Biology	43,138	3.12%	631,946	5.26%	14.6	36.7	0.40
Physics, Particles & Fields	42,058	3.04%	902,617	7.51%	21.5	21.0	1.02
Multidisciplinary Sciences	32,896	2.38%	571,000	4.75%	17.4	13.4	1.30
Instruments & Instrumentation	31,124	2.25%	215,312	1.79%	6.9	11.2	0.62
Physics, Nuclear	30,385	2.20%	564,272	4.69%	18.6	15.9	1.17
Mathematics, Applied	29,292	2.12%	175,237	1.46%	6.0	11.0	0.54
Metallurgy & Metallurgical Engineering	29,176	2.11%	187,530	1.56%	6.4	12.2	0.53
Chemistry, Organic	28,793	2.08%	244,149	2.03%	8.5	22.6	0.38
Geosciences, Multidisciplinary	28,371	2.05%	322,072	2.68%	11.4	20.4	0.56
Chemistry, Inorganic & Nuclear	27,626	2.00%	227,623	1.89%	8.2	19.5	0.42
Mechanics	26,282	1.90%	161,642	1.34%	6.2	16.1	0.38
Physics, Atomic, Molecular & Chemical	24,277	1.75%	325,037	2.70%	13.4	25.2	0.53
Geochemistry & Geophysics	22,704	1.64%	243,699	2.03%	10.7	27.8	0.39
Engineering, Chemical	22,256	1.61%	164,676	1.37%	7.4	16.9	0.44
Physics, Mathematical	21,409	1.55%	236,959	1.97%	11.1	17.5	0.63
Physics, Fluids & Plasmas	20,470	1.48%	242,571	2.02%	11.9	19.9	0.60
Nanoscience & Nanotechnology	19,385	1.40%	226,776	1.89%	11.7	27.7	0.42
Nuclear Science & Technology	19,289	1.39%	186,017	1.55%	9.6	8.7	1.11
Engineering, Mechanical	18,877	1.36%	85,656	0.71%	4.5	9.3	0.49
Medicine, Research & Experimental	18,644	1.35%	77,540	0.64%	4.2	17.8	0.23
History	18,365	1.33%	9,983	0.08%	0.5	1.1	0.51
Engineering, Multidisciplinary	17,523	1.27%	56,373	0.47%	3.2	7.6	0.42
Computer Science, Theory & Methods	17,521	1.27%	52,205	0.43%	3.0	7.7	0.38
Energy & Fuels	17,116	1.24%	116,895	0.97%	6.8	17.6	0.39
Economics	16,463	1.19%	37,142	0.31%	2.3	14.6	0.15
Automation & Control Systems	16,310	1.18%	57,987	0.48%	3.6	10.0	0.35
Environmental Sciences	15,680	1.13%	185,960	1.55%	11.9	21.5	0.55
Meteorology & Atmospheric Sciences	15,285	1.10%	169,623	1.41%	11.1	27.3	0.41
Spectroscopy	15,183	1.10%	112,051	0.93%	7.4	14.8	0.50
Neurosciences	15,091	1.09%	146,614	1.22%	9.7	29.4	0.33

Figure A1. Top 40 Web of Science subject categories with the number of papers and citations, their percentage shares in all papers and citations, citations per paper (*CPP*), global baseline *CPP*, and the relative world impact, which is a ratio of the two preceding indicators. Background colours tend towards

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green (positive) for high values and red (negative) for low values in their respective columns. The source of global baseline *CPP* is *InCites* (Clarivate, 2022) based on Web of Science documents including Emerging Sources Citation Index since 1980 until 30 April 2022 with a data update on 27 May 2022.

	Physics	Chemistry	Engineering	Materials Science	Mathematics	Optics	Science & Technology - Other Topics	Biochemistry & Molecular Biology	Astronomy & Astrophysics	Computer Science
United States	31,613	8,120	5,173	6,530	3,972	3,857	4,643	5,740	10,675	1,859
Germany	39,997	10,616	4,487	9,838	2,739	4,034	4,167	3,183	10,340	1,310
France	22,549	5,124	2,700	4,639	2,441	2,220	2,138	1,850	6,162	977
United Kingdom	16,494	3,413	2,518	2,916	1,919	1,721	2,207	1,721	5,846	955
Italy	17,059	2,538	1,538	1,861	1,373	926	1,214	981	6,533	569
Peoples R China	11,306	3,116	2,372	3,068	1,186	1,212	1,815	690	3,763	688
Japan	12,807	2,150	1,177	2,804	469	1,076	1,015	622	3,609	291
Spain	10,945	2,084	948	1,805	716	692	1,220	518	4,524	365
Poland	11,747	2,195	1,023	1,776	497	512	669	570	3,472	284
Switzerland	11,347	1,078	692	1,038	350	397	752	476	3,702	290
Netherlands	8,630	1,187	886	1,049	414	430	797	611	3,289	368
Sweden	8,048	1,696	942	1,415	591	425	982	937	2,413	296
Ukraine	7,701	2,803	1,127	2,103	388	638	733	388	2,206	201
Canada	6,226	1,036	719	721	658	578	740	654	2,713	318
Finland	6,080	1,330	1,250	1,039	362	778	777	657	2,443	462
Czech Republic	7,889	933	686	1,018	347	398	501	279	2,347	238
South Korea	7,447	972	812	1,129	251	352	550	176	2,805	247
Belgium	5,323	1,273	529	831	284	394	529	349	1,612	133
India	6,430	1,262	877	1,120	283	212	503	315	2,856	344
Austria	5,627	731	454	615	512	286	536	325	2,303	144
Australia	4,440	767	701	867	483	632	822	320	1,741	222
Brazil	6,949	425	424	566	505	172	340	178	2,415	218
Belarus	4,788	1,244	773	1,400	204	684	534	349	823	100
Israel	4,509	784	493	700	601	372	459	274	1,176	179
Norway	3,535	418	357	367	330	67	374	240	1,438	132
Denmark	3,662	544	359	392	152	295	461	313	1,331	114
Greece	4,890	477	306	307	223	109	258	103	1,795	134
Portugal	4,626	836	444	525	287	165	337	186	1,243	243
Hungary	4,598	459	161	360	187	100	201	198	1,584	74
Turkey	3,937	386	322	416	347	100	257	121	1,391	103

Figure A2. Top 30 collaborating countries and their counts of joint publications with Russia in the top ten research areas. Background colours tend towards green (positive) for high values and red (negative) for low values in their respective columns.

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	Physics	Chemistry	Engineering	Materials Science	Mathematics	Optics	Science & Technology - Other Topics	Biochemistry & Molecular Biology	Astronomy & Astrophysics	Computer Science
Poland	11,747	2,195	1,023	1,776	497	512	669	570	3,472	284
Ukraine	7,701	2,803	1,127	2,103	388	638	733	388	2,206	201
Czech Republic	7,889	933	686	1,018	347	398	501	279	2,347	238
Belarus	4,788	1,244	773	1,400	204	684	534	349	823	100
Hungary	4,598	459	161	360	187	100	201	198	1,584	74
Romania	4,283	394	215	390	154	123	218	80	1,249	52
Slovakia	4,099	345	280	281	53	71	166	124	1,290	73
Kazakhstan	1,547	899	659	579	479	107	567	115	266	170
Bulgaria	3,218	326	299	233	120	208	185	80	1,102	82
Armenia	3,903	188	92	115	64	142	123	88	1,198	38
Serbia	2,603	163	210	131	131	74	142	83	896	40
Slovenia	2,581	141	80	151	181	22	85	58	915	71
Estonia	1,577	227	184	277	55	110	215	114	453	61
Georgia	2,618	116	58	26	46	12	49	32	1,021	10
Croatia	2,320	63	45	48	121	22	96	69	679	16
Lithuania	1,729	143	187	234	77	101	120	62	407	26
Latvia	1,353	200	220	277	21	127	114	59	244	99
Azerbaijan	1,620	432	130	156	93	9	47	34	466	9
Uzbekistan	749	275	95	110	79	95	64	30	184	11
Moldova	451	234	75	156	9	38	77	22	11	20

Figure A3. Top 20 Eastern European collaborating countries and their counts of joint publications with Russia in the top ten research areas. Background colours tend towards green (positive) for high values and red (negative) for low values in their respective columns.

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