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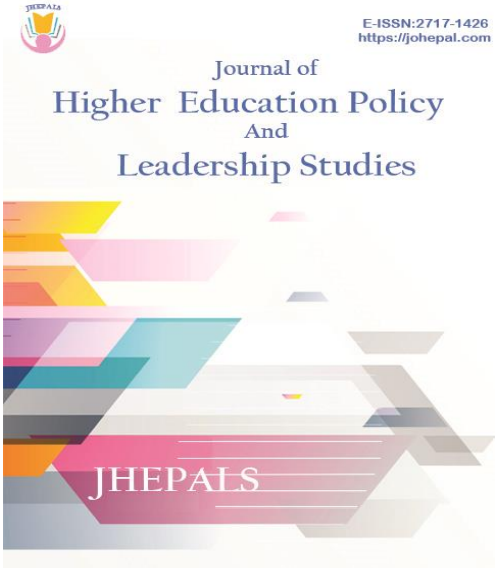

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Abstract

Given the geopolitical tensions involving western nations with China and Russia, this paper investigates the extent to which China and Russia have turned toward one another, or increased their scientific collaboration. It uses bibliometric data to examine trends in China-Russia co-publications from 2013 to 2022 and the value that collaboration has had for each country's scientific output. The findings reveal that China-Russia co-publications increased markedly, and the majority of the growth occurred in multilateral co-publications. Moreover, for Russia, China has emerged as a more important international collaborator, but for China, the importance of Russia has remained relatively the same. Likewise, collaborations with China contributed more to growth in Russia's publication output compared to Russia's contribution to China's growth in output. Finally, China-Russia co-publications tended to occur in physics and astronomy and other applied science fields. These findings have implications for future collaboration between the two countries and potential challenges to the Euro-American dominance in global science.

Keywords: China; Russia; Science Cooperation; Geopolitics of Science; Center-Periphery

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Introduction

Arguably, no two nations embody the apothegm, “the enemy of my enemy is my friend” quite like China and Russia. By virtue of their authoritarian political ideology and anti-capitalism sentiment, the Chinese and Russian partnership “is driven more by their common rivalry with the United States than any natural affinity for each other” (Maizland, 2022). As such, they have been referred to as "reluctant allies” (Korolev & Portyakov, 2019). These observations are especially evident as the US, Europe, and western nations have banded together in opposition to Russia's annexation of Crimea in 2014 (Radin et al., 2021) and most recently its military invasion of Ukraine in early 2022 (Stone, 2022). At the same time, the US, Europe, and other western nations have been increasingly cautious of China’s dramatic rise and have been distancing themselves from international engagement with China (Chen & Lei, 2022; Von der Burchard, 2019).

Geopolitical tensions between these countries are also playing out in their science and technology cooperation. The US has undertaken various measures to limit Chinese interference in its science and technology enterprise to safeguard its economic and national security (Chen & Lei, 2022). The US is not alone in its concern as the EU is renegotiating its approach to science and technology cooperation with China to ensure protections for intellectual property rights as well as academic freedom (Cai, 2022). Regarding measures against cooperation with Russia, after its annexation of Crimea, western countries placed embargos on exports to Russia of high-technology oil exploration and production equipment as well as military and dual-use technologies (Christie, 2015). Furthermore, in response to its invasion of Ukraine, various western countries have cut or froze their ties with Russian science (Stone, 2022).

It has been argued that such measures to limit China’s and Russia’s influence and access to science and technology have brought the two countries closer (Bendett & Kania, 2019). Yet, research collaboration between China and Russia has not been well observed. Cooperative agreements between the two countries are documented (Wagner, 2022), and several empirical studies have investigated their rates of collaboration and subjects in which they collaborate as members of BRICS (e.g., Finardi & Buratti, 2016; Shashnov & Kotsemir, 2018). However, these studies are limited in terms of the foci of their analyses in China-Russia collaboration trends and the time periods utilized in their analyses, i.e., collaboration prior to 2015.

Therefore, this study seeks to contribute to research on China-Russia science and technology cooperation by examining trends over the last decade. It seeks to provide insight into the extent to which the countries have turned toward one another, or increased their collaboration, given the restrictive measures put in place by western countries. Moreover, it examines the value that collaboration has had for the growth of each country’s science and technology enterprises and the subject areas in which they have tended to collaborate.

Literature Review

Scientific and technological development are reliable indicators of economic growth. As a nation’s economy expands so too does its research and development enterprise (Fu et al., 2011). This growth process is particularly salient for middle-income countries, including

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China and Russia. Although their developmental trajectories differ, China and Russia are striving to secure their global positions as leading scientific innovators and research producers. For both countries, international collaboration plays an important role in actualizing their research and development goals, and it has been instrumental in advancing both countries' science and technology enterprises (Fu et al., 2011; Guskov et al., 2018).

Advancing China's Science and Technology Enterprise

Since the beginning of the reform period in the late 1970s, China has emphasized scientific and technological advancement as vital to its economic development and global competitiveness (Benner et al., 2012). It has sought to reduce its dependency on foreign imports and develop domestic innovation capabilities to solve both social and environmental challenges (Schwaag-Serger, 2007; Yang & Welch, 2012). China has recognized that to achieve its modernization goals, it needs a well-developed science and technology enterprise with research institutes and world-class universities capable of engaging in cutting-edge basic and applied scientific research (Schwaag-Serger, 2007; Sun & Cao, 2021). As a result, China has enacted serval initiatives, including the 211 Project, the 985 Project, and the Double World-Class Project, to improve its higher education system to advance its research capabilities, increase its research output, and produce a highly skilled workforce (Wang & Cheng, 2014; Zhao & You, 2021).

Simultaneously, China has recognized the interconnectedness of the global system and the importance of engagement with the outside world. China has prioritized the internationalization of its universities and promoted collaboration between Chinese scientists and international scientists through regional and international scientific cooperation and exchange (Huang, 2015; Yuan et al., 2018). It has sought to attract top global research talent to contribute to its scientific and technological development through programs, such as the Changjiang Scholars Program and the Thousand Talent Program (Cao et al., 2020; Xie et al., 2014). These scientists have positively contributed to China's capacity to produce scientific knowledge and have further connected China to the global scientific community (Cao et al., 2020; Xie et al., 2014).

Trends in China's Research Output and International Collaboration

Success in China's approach to developing its science and technology enterprise can be seen in the dramatic rise in the quantity (Adams et al., 2022) and quality (Brainard & Normile, 2022) of its research output. In 2018, China surpassed the US to become the world's largest producer of science and engineering related article publications, and in 2020, it accounted for 25% of total global output (NSB, 2021). Chinese scientists have been highly productive in engineering and technology related fields with recent research showing that it accounts for 40% of global publications in materials science and 30% of global publications in the fields of computer science, engineering, chemistry, and physics (Adams et al., 2022). Related to quality, a recent report indicated that China accounted for the largest share of the world's most cited papers, 27.2%, in 2018, 2019, and 2020 toping the US for the first time (Brainard & Normile, 2022).

China's rise in publication output has been attributed largely to increases in domestic only publications as opposed to international collaborations, though China has gradually increased its proportion of its international publications over the last decade (Adams et al.,

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2022; NSB, 2021). Regarding the countries with which China collaborates, Chinese scientists tend to collaborate with scientists from economically developed countries with its top partners in recent years including the United States, Germany, the United Kingdom, Canada, Australia, and several Asian countries including, Japan, South Korea, Taiwan, and Singapore (Adams et al., 2022; Haupt & Lee, 2021; Lee & Haupt, 2020; Wang et al., 2013; Yuan et al., 2018; Zhang & Guo, 2017).

Advancing Russia's Science and Technology Enterprise

During the Cold War era, scientific discovery and technological advancement were a top national priority for the Soviet Union, and by the 1980s, the Soviet Union's scientific workforce was 10 to 30 percent larger than that of the United States (Graham & Dezhina, 2008). However, following the collapse of the Soviet Union in 1991, Russia's research infrastructure followed, and there was a stark lack of Russian innovation and funding for decades (Schiermeier, 2020). The collapse resulted in "brain drain" with approximately 80 percent of Russian scientists emigrating to Germany, Israel, or the United States (Gordin, 2009). Further, toward the end of the Soviet Union, many scientists became increasingly critical of the Soviet Academy of Sciences and objected to its centralized administrative model, which controlled the national research agenda (Graham & Dezhina, 2008). This resulted in the enactment of various reforms to democratize its science and technology enterprise and more greatly involve other sectors of Russian society, including higher education (Graham & Dezhina, 2008).

Russia has launched several programs to enhance the research potential of its university system, so that it could play a more central role in the production of basic scientific research (Block & Khvatova, 2017; Gokhberg et al., 2009; Guskov et al., 2018). Beginning in 2006, it engaged in a process of consolidation merging higher education institutions together to form federal universities as well as national research universities (Kosyakov & Guskov, 2019). In 2013, Russia launched Project 5-100 designed to propel five Russian universities into the top 100 globally ranked universities (Block & Khvatova, 2017; Guskov et al., 2018; Kosyakov & Guskov, 2019). Through this project, Russia has sought to increase the quantity and quality of research output and improve linkages between education, science, and industry (Guskov et al., 2018; Lisitskaya et al., 2018). Finally, in 2015, Russia sought to develop "Pillar Universities" to provide strong educational and research centers with missions that support regional needs (Lisitskaya et al., 2018).

As part of its reforms, Russia has also recognized the value in internationalization and engagement with the global scientific community to advance the research potential of its own universities. Project 5-100 is a prominent example. One of the main goals of the project has been to attract the world's leading scientists to Russia to support universities in conducting scientific research (Guskov et al., 2018). This includes recruitment of scientists to permanent positions in Russia as well as temporary ones (Guskov et al., 2018). Additionally, Russian universities designed plans to support academic mobility of faculty and research scientists abroad for conferences, internships, training, and other activities, intended to help boost their capabilities and grow their international networks (Guskov et al., 2018).

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Trends in Russia's Scientific Output and International Collaboration

The trends in Russian research output over the last several decades demonstrate some positive trends in research quantity more so than quality and highlight possible successes of its reforms (Avanesova & Shamliyan, 2018; Kosyakov & Guskov, 2019). Russian output remained relatively flat during the first decade of the 21st century (NSB, 2021), but beginning in 2013, there has been a substantial increase in its annual publications (Avanesova & Shamliyan, 2018; Kosyakov & Guskov, 2019, Moed et al., 2018; NSB, 2021). Much of Russia's publication output has occurred in the subject areas of physics and astronomy, chemistry, materials science, medicine, and mathematics (Avanesova & Shamliyon, 2018). Russia is among the top 10 producers of knowledge within these subject areas, excluding medicine (Avanesova & Shamliyon, 2018). Moreover, in terms of quality, Russian publications have seen small improvements in their citation impact over time, but their impact remains less than that of publications from other scientifically advanced countries (Avanesova & Shamliyon, 2018; Turko et al., 2016).

Like China, the majority of Russia's scientific output is produced domestically and not through international collaborations (NSB, 2021). Over the last decade, the proportion of Russia's papers involving international co-authors has slightly declined though the volume has increased due to increases in total publication output (NSB, 2021; Schiermeier, 2020). Russian scientists have tended to collaborate with scientists from western, more economically advanced countries. Avanesova and Shamliyon (2018) found that from 2012 to 2017, 86% of all of Russia's international publications included authors from the US, Germany, France, the UK, and Italy. However, Russia has steadily increased its rate of collaboration with China. China was Russia's fifth largest collaborating partner between 2017 and 2019 (Gokhberg & Kuznetsova, 2021). From 2020 to 2022, China became Russia's third largest scientific collaborator, while co-publications with western countries declined, the latter of which has been at least partly attributable to Russia's war on Ukraine (Noorden, 2023).

China-Russia Scientific Cooperation

Scientific relations between China and Russia have strengthened with the two countries signing various memorandums of understanding to strengthen bilateral cooperation in science and promote mutually beneficial cooperation between scientists (Wagner, 2022). Moreover, cooperation between the countries has also been strengthened through agreements signed as part of multilateral organizations, such as Shanghai Cooperation Organization (SCO), the Alliance of International Science Organizations (AISO), and BRICS (AISO, 2022; BRICS, 2014; Kamalyan & Egorova, 2020).

Despite this growth in official cooperation between the two countries, to date, few studies have empirically explored the extent of China-Russia cooperation in science. A few studies have examined their collaboration rates and subjects in which they collaborate relative to other countries, especially BRICS countries (Finardi, 2015; Finardi & Buratti, 2016; Shashnov & Kotsemir, 2018). These studies have demonstrated that the annual number of China-Russia scientific publications rose steadily during the first decade and a half of the 21st century (Finardi, 2015; Shashnov & Kotsemir, 2018). Moreover, they have shown that collaboration between the two countries have tended to occur in science and engineering related fields, such as physics, materials science, mathematics, and chemistry (Finardi, 2015;

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Shashnov & Kotsemir, 2018). In terms of relative importance to each country's scientific output, Shashnov and Kotsemir (2018) found that from 2005 to 2015 publications with China contributed to a greater proportion of Russia's scientific output than vice versa. However, it should be noted that a common trend across these studies was the relative lack of collaboration between China and Russia compared to their rates of collaboration with other countries during this time period (Finardi, 2015; Finardi & Buratti, 2016; Shashnov & Kotsemir, 2018).

Given the dearth of studies that have specifically examined China-Russia collaboration and the ever-increasing geopolitical tensions between western countries and China and Russia, this paper seeks to provide an up-to-date in-depth exploration of China-Russia collaboration in science. Both countries have undergone substantial reforms to improve their science and technology enterprises and have recognized the value in international cooperation to achieve their goals and advance their capabilities (Fu et al., 2011; Guskov et al., 2018). Likewise, they represent two countries among others that have the potential to challenge the historic domination of global scientific research by a handful of predominantly western democratic countries (Marginson, 2022). Thus, examining patterns in China-Russia collaboration over the last decade can provide valuable insight into the extent to which cooperation has occurred between the two countries, the value it has had for both countries' science and technology enterprises, and the possible implications for future collaboration between the countries.

Center-Periphery Model of Global Science

To interpret patterns in China-Russia co-publications, this paper employs the center-periphery conceptualization of global science. This conceives global science as a hierarchy with relations between countries predicated on a fixed structure of the global political economy (Olechnicka et al., 2019). In this way, science is a site of power relations in which inequalities exist between countries in the Euro-American center and the periphery (Haupt, 2022; Lee, 2021; Marginson, 2022). These inequalities are associated with disparities in intellectual and financial capital, the use of English as a lingua franca in academic publishing, the presence of journal hierarchies (dominated by English language journals), and the use of evaluation metrics, such as citation counts and rankings, that advantage center countries (Beaver & Rosen 1979; Lee, 2021; Marginson, 2022). Given such inequalities, collaborations between center and periphery countries are largely characterized as asymmetrical with center countries tending to dominate relations between countries allowing them to exert their power and influence over the global science system (Olechnicka et al., 2019; Schott, 1998).

A key component of the center-periphery conceptualization of global science is that the hierarchical structure of the system is highly stable (Schubert & Sooryamoorthy, 2010). In other words, it is difficult for countries to change their positions within the system and move from the periphery to the center (Olechnicka et al., 2019). This is because center-periphery logic downplays the potential for subordinate, periphery countries to promote their own national development (Smith, 1979). A common characteristic among center countries is what Wagner and Jonkers (2017) refer to as its "openness," as measured by international co-authorship and the mobility of each nation's research workforce. Whereas most European countries tend to have high openness and produce high impact studies,

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peripheral countries, including China and Russia tend to be less open and impactful (Wagner & Jonkers, 2017). Thus, despite China's and Russia's efforts to encourage international collaboration, their peripheral status and relative lack of "openness" (or receptiveness to internationally cooperate) further limit their scientific influence.

However, trends over the last several decades suggest tides might be turning with the rise of autonomous science systems in countries, such as China, South Korea, Singapore, Brazil, Iran, and India (Marginson, 2022). The rise of these countries in global science have prompted some scholars to argue that global science is becoming more multipolar, resulting in greater diversification in the locations where science occurs and in the patterns of international collaboration (Marginson, 2022; Wen et al., 2022). Regarding the latter, there has been a growing presence of periphery countries in the global science network which has promoted greater horizontal, periphery-periphery collaboration (Choi, 2012).

Building on these developments, this study investigates China-Russia collaboration as periphery-periphery collaborations that have the potential to advance multipolarity in the global science system. Given the spillover of geopolitical tensions into science – between the Euro-American center countries and Russia as well as between the Euro-American center countries and China – Chinese and Russian scientists may be encouraged or forced to look elsewhere to find international collaboration partners, including with each other. Thus, this paper examines the extent to which China-Russia collaboration in science has grown over the last decade and its potential for supporting both countries in advancing their science and technologies enterprises.

Methodology

Data Source

To examine China-Russia collaboration patterns, China-Russia co-publication data were gathered from Scopus (Elsevier, 2023) on May 2, 2023. Three criteria were utilized to identify co-publications. First, a publication was identified as a China-Russia co-publication if it included at least one author with an institutional affiliation in China and one author with an institutional affiliation in Russia. Next, co-publications were limited to articles, or "original research or opinion," (Elseveir, 2023, p. 10), conference proceedings, or "original article reporting data presented at a conference or symposium (Elseveir 2023, p. 10), and reviews, or "significant review of original research, also includes conference papers" (Elseveir, 2023, p. 11). Finally, co-publications were limited to Scopus defined science and engineering subject areas. Utilizing these criteria, data were gathered on all China-Russia co-publications that occurred from 2013 to 2022.

Additionally, for use in several analyses, data on all China publications and all Russia publications from 2013 to 2022 were downloaded. This data included the number of publications for China and Russia each year during the 10-year period. It also included the number of China and Russia publications that were domestic only publications, or those with only authors from China and Russia, and the number of publications that were international publications, or those that included authors from other countries.

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Data Analyses

Data were analyzed in several ways to examine patterns in China-Russia research collaboration to understand how their relationship has evolved over time and the potential of the relationship for both countries moving forward. First, data were analyzed to determine the extent to which China and Russia collaborated from 2013 to 2022. The total number of publications including both China and Russia affiliated authors were calculated for each year from 2013 to 2022. To measure change during this period, the annual percentage change from year to year was calculated and averaged for the 10-year period. Additionally, China-Russia co-publications were analyzed to determine the number of co-publications that included China and Russian affiliated authors only, or bilateral co-publications, and China, Russian, and other country authors, or multilateral co-publications. The total number of bilateral and multilateral co-publications were calculated for each year, and the annual percentages of all publications and the average annual percentages of all publications that fell into each category were calculated.

Next, data were analyzed to examine the extent of collaboration with the other country as it accounted for each country's overall publication output. To do this, the proportions of China's and Russia's total annual publications which were co-publications with the other country were calculated, and the average annual percentages of each country's publications were calculated for the 10-year period. Then, focusing specifically on international publications, similar calculations were enumerated. The proportions of China's and Russia's international publications from 2013 to 2023 that were co-publications with the other country were calculated along with the average annual percentages of each country's international publications from 2013 to 2022.

Building off these analyses, trends in China-Russia co-publication growth were compared to trends in China and Russia co-publication growth with their other top collaborator countries. The purpose of these comparisons was to explore whether there were any unique characteristics to growth in China-Russia co-publications as well as to better understand the relative importance of collaborations between the two countries. To make the comparisons, the total number of annual co-publications with China's and Russia's other top four collaborating countries over the ten-year period were calculated along with the proportions of China's and Russia's international publications that involved their other top four collaborating countries. These data were compared to data on the annual number of China-Russia co-publications and to data on the proportions of China and Russia's international publications from 2013 to 2023 that were co-publications with the other country.

After these analyses, data were analyzed to determine the extent to which collaboration with the other country may have supported increases in each country's knowledge output from 2013 to 2022. These analyses involved measuring China's and Russia's annual changes in total publications as well as annual changes in international publications. Then, the annual change in China-Russia co-publications was calculated, and the proportions of China's and Russia's increases in annual publication outputs that were China-Russia co-publications were calculated for the 10-year period. These calculations were made for both annual changes in total publications and annual changes in international publications. As the above analyses, the average annual percentages of each country's

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annual total and annual international publication growth that included the other country were calculated.

Lastly, the data were analyzed to investigate the top subject areas in which China and Russia collaborate. The total number of annual publications that fell into each subject area were calculated along with the average number of publications that fell into each category. Then, the percentage of all China-Russia co-publications that fell into each category from 2013 to 2022 were calculated.

Findings

Figure 1 shows China-Russia co-publication trends in STEM fields from 2013 to 2022. The data indicate that there has been a steady increase in China-Russia co-publications. In 2013, there were only 995 co-publications, while in 2021, there were 3,853 co-publications. Moreover, the average annual percentage increase in co-publications over the decade was 17.7%. Lastly, when disaggregating co-publications into bilateral, or only involving Chinese and Russian scientists, and multilateral, or involving Chinese, Russian, and third country scientists, the data show that both types of co-publications steadily increased over the decade. Most of the co-publications over the last decade were multilateral with the average proportion of annual multilateral co-publications being 71.4% of total co-publications compared to 28.6% for bilateral co-publications. However, over the decade, bilateral co-publications steadily represented a larger portion of China-Russia co-publications peaking in 2022 at 37.0% of total co-publications, and from 2021 to 2022, growth in China-Russia multilateral co-publications stagnated and slightly declined.

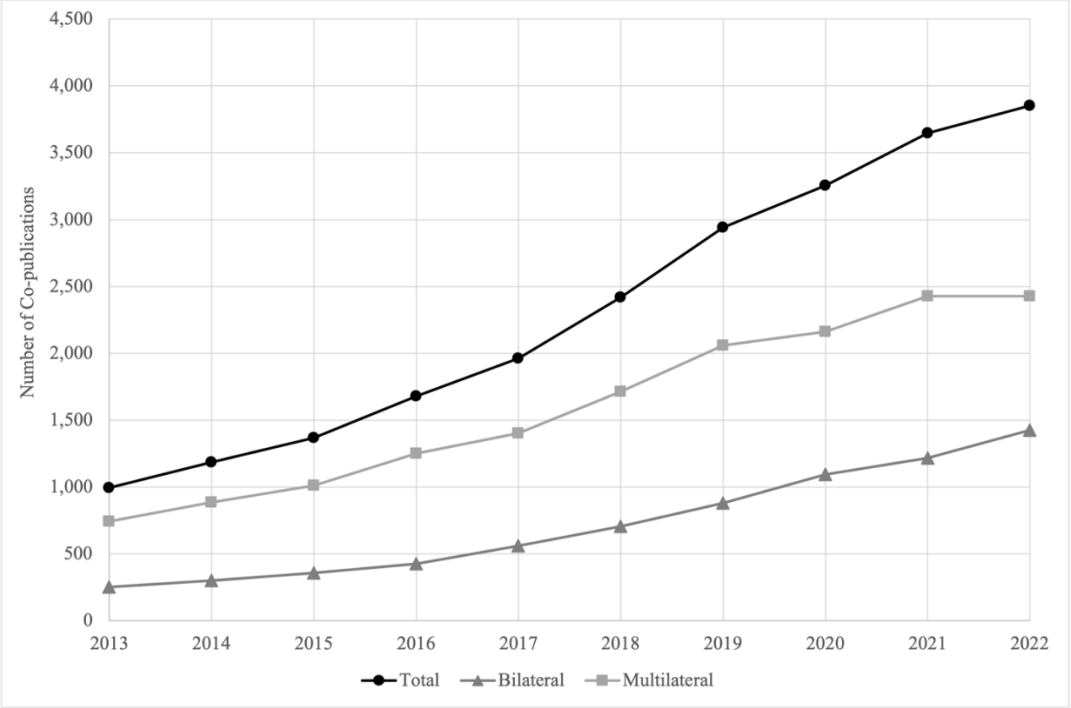

Figure 1. Total China-Russia STEM co-publications from 2013 to 2022

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China-Russia Co-Publications

While scientists from the two countries steadily increased their collaboration activity, the data also indicate that collaboration between the two countries made up only a small portion of both countries' total publication outputs over the decade (See Table 1). For China, the proportion of its annual publications that were co-publications with Russia increased, but co-publications with Russia never accounted for more than 0.47% of its total publications. Over the decade, the average annual percent of China's publications that were co-publications with Russia was only 0.39%. For Russia, co-publications with China accounted for a greater proportion of its publications, and this proportion increased over the decade from 2.19% of Russia's publications in 2013 to 4.37% of Russia's publications in 2022. Further, the average annual percent of Russia's publications that included Chinese authors was 2.87% over the decade.

Table 1.
Percentage of China's and Russia's total publications that involve collaboration with the other country

Year	China-Russia Collaborations	China Publications	% Total (China)	Russia Publications	% Total (Russia)
2013	995	431,496	0.23%	45,466	2.19%
2014	1,187	458,406	0.26%	52,912	2.24%
2015	1,369	433,872	0.32%	59,468	2.30%
2016	1,680	465,979	0.36%	70,899	2.37%
2017	1,963	499,710	0.39%	77,486	2.53%
2018	2,419	558,028	0.43%	89,578	2.70%
2019	2,941	642,629	0.46%	101,551	2.90%
2020	3,256	698,853	0.47%	107,637	3.02%
2021	3,646	778,656	0.47%	107,151	3.40%
2022	3,853	903,785	0.43%	88,226	4.37%

Looking more closely at each country's international publications over the decade, the data show that China has become a more important international collaborator for Russia, while the importance of collaboration with Russia has remained relatively the same for China (See Figure 2b and 2d). As with total publications, the proportion of China's international publications that were co-publications with Russia was small. The percent of China's international publications that included Russia increased by 2.14% from 0.15% in 2013 to 2.29% in 2022. Over the decade, the average annual percent of China's international publications that included Russian authors was only 1.86%. On the other hand, there was a much larger increase in the proportion of Russia's international publications that included Chinese authors. The percent of Russia's international co-publications that included Chinese authors rose by 9.73% from 7.58% in 2013 to 17.31% in 2021. Moreover, the average annual percent of Russia's international publications that included Chinese authors was 10.61%, which is substantially greater than the average annual percent of China's international publications.

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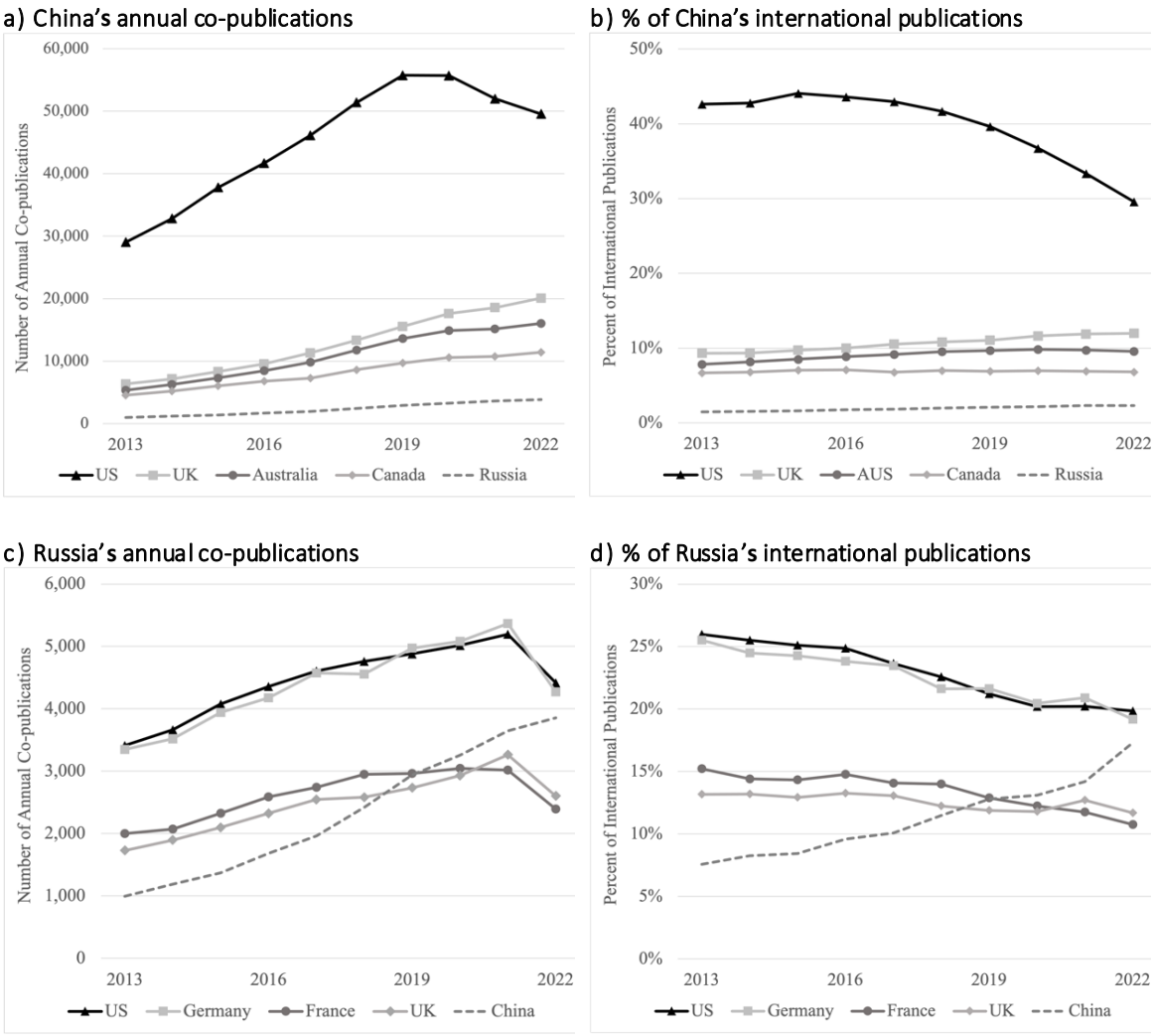

Figure 2. China and Russia co-publications with each other and their other top collaborating countries from 2013 to 2022

Figure 2 also shows data on trends in China and Russia co-publications with their other top collaborating countries from 2013 to 2022. Figure 2a and 2b show that China's top collaborating countries were western, economically developed English-speaking countries, and China produced a substantially larger number of publications in collaboration with these countries than it did with Russia. Comparing the trends in co-publications, despite declines in co-publications between the China and US since 2019, China's overall growth in co-publications with the US, UK, Australia, and Canada were greater than its growth of co-publications with Russia. Moreover, the percentage of China's international publications that included Russia remained lower than the percentage of China's international publications that included the US, the UK, Australia, and Canada even though the percentage of China's international publications with the US declined annually beginning in 2016. Thus, despite positive growth in China-Russia co-publications, Russia did not emerge as one of China's top international collaborators over the last decade.

In contrast, Figure 2c and 2d demonstrate the extent to which China emerged as an important collaborating partner of Russia from 2013 to 2022. The trend lines in Figure 2c show that Russia's overall growth in co-publications with China was greater than its growth

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with the US, Germany, France, and the UK. In 2020, China surpassed France to become Russia's third largest international collaborator. Moreover, from 2021 to 2022, co-publications between Russia and the US, Germany, France, and the UK declined, while co-publications with China continued to increase. Looking specifically at trends in the percentage of Russia's international publications that included its top collaborating countries, there was a gradual decline in the percentage of Russia's international publications that included the US, Germany, France, and the UK over the last decade. On the other hand, the percentage of Russia's international publications that included China steadily increased. Therefore, the evidence demonstrates the growing importance of China relative to Russia's other top collaborating countries, which are all western, economically developed nations.

The next analyses focused on the percent of the growth in annual publications for China and Russia that include co-publications with authors from the other country. When examining the percent of increases in China's total publications as well as international publications that were co-publications with Russia, the data show that co-publications with Russia accounted for only a small percent of China's annual publication growth (Table 2). The percent of increases for which co-publications with Russia accounted fluctuated over the decade increasing in some years, while decreasing in others. The average annual percent of China's total annual publication growth that included Russian authors was only .47%, and the average annual percent of China's annual international publication growth that included Russian authors was only 3.07%.

Table 2.
Percentage of the growth in annual publications for China that were co-publications with authors from Russia

Year	Annual Change in China-Russia Publications	Annual Change in Total China Publications	% of Increase in China Publications	Annual Change China Publications (INT)	% of Increase in China Publications (INT)
2013	10	38,431	0.03%	9,865	0.10%
2014	192	26,910	0.71%	8,565	2.24%
2015	182	-24,534	-	9,027	2.02%
2016	311	32,107	0.97%	9,892	3.14%
2017	283	33,731	0.84%	11,765	2.41%
2018	456	58,318	0.78%	15,924	2.86%
2019	522	84,601	0.62%	17,358	3.01%
2020	315	56,224	0.56%	10,923	2.88%
2021	390	79,803	0.49%	4,343	8.98%
2022	207	125,129	0.17%	11,649	1.78%

Note: INT stands for international publications, or publications that included authors from countries other than China. If annual change was a negative number, then % of increase in China publications was not calculated for that year.

Once again, the same data analyses with Russian publication data demonstrate the greater role that collaboration with China has in Russia's knowledge production output (See Table 3). In terms of the percent of Russia's growth in annual total publications that were co-publications with China, over the decade, there was a general increase in the percent of Russia's growth in total publications that were co-publications with China. The average annual percent of Russia's total annual publication growth that included Chinese authors

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was 3.23%. On the other hand, the increase in Russia's growth in international publications that were co-publications with China fluctuated over the years. The percentages ranged from 1.00% to 48.82%; however, the average annual percent of Russia's annual international publication growth that included Chinese authors was high at 20.51%. Lastly, while China-Russia co-publications increased from 2021 to 2022, Russia's overall research output declined by 18,925 total publications and 3,415 international publications demonstrating the negative impact that its war with Ukraine has had on its science and technology enterprise. The small increase in co-publications with China was not sufficient to counteract the substantial decline in output that Russia experienced in 2022.

Table 3.
Percentage of the growth in annual publications for Russia that were co-publications with authors from China

Year	Annual Change in China-Russia Publications	Annual Change in Total Russia Publications	% of Increase in Russia Publications	Annual Change Russia Publications (INT)	% of Increase in Russia Publications (INT)
2013	10	4,707	0.21%	1,005	1.00%
2014	192	7,446	2.58%	1,235	15.55%
2015	182	6,556	2.78%	1,871	9.73%
2016	311	11,431	2.72%	1,291	24.09%
2017	283	6,587	4.30%	1,959	14.45%
2018	456	12,092	3.77%	1,595	28.59%
2019	522	11,973	4.36%	1,911	27.32%
2020	315	6,086	5.18%	1,850	17.03%
2021	390	-486	-	833	46.82%
2022	207	-18,925	-	-3,415	-

Note: INT stands for international publications, or publications that included authors from countries other than Russia. If annual change was a negative number, then % of increase in Russia Publications was not calculated for that year.

Figure 3 shows the top subject areas in which China and Russia collaborated from 2013 to 2022. The data show that growth in the number of annual publications occurred in all these subject areas, and the top subject areas in which China and Russia collaborated remained consistent over the 10-year period. The greatest number of publications occurred in Physics and Astronomy totaling 10,093 co-publications over the decade and averaging of 1,009 publications per year. Publications within Physics and Astronomy accounted for 43.30% of all China-Russia publications over the decade. Publications in Physics and Astronomy were followed by publications in three closely related fields: Engineering, Materials Science, and Chemistry. Publications within these subject areas ranged between 3,218 to 4,488 and accounted for between 13.81% to 19.25% of China-Russia co-publications over the decade. The remainder of the subject areas in which China and Russia collaborated each accounted for 10% or less of the countries' co-publications and include related fields such as Biochemistry, Genetics, and Molecular Biology; Agriculture and Biological Sciences; and Medicine.

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China-Russia Co-Publications

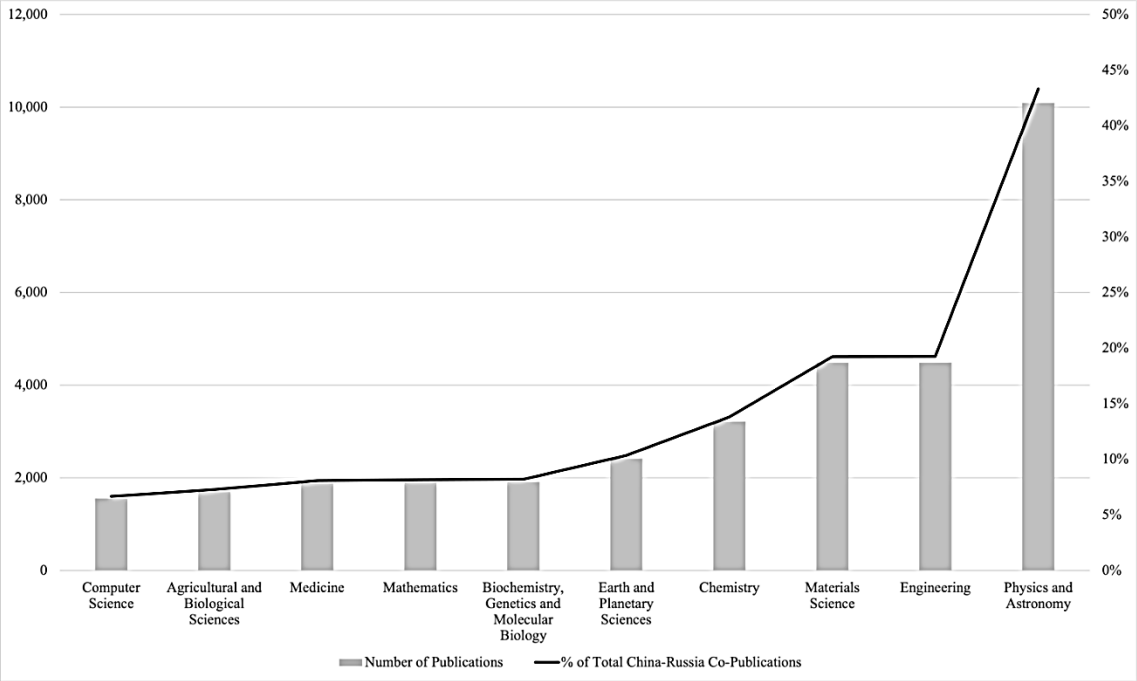

Figure 3. Top subject areas in which China and Russia collaborated from 2013 to 2022

Note: The numbers on the left vertical axis represent total number of publications. The vertical bars represent the total number of publications from 2013 to 2022 in each subject area. The percentages on the right vertical axis represent percentage of total China-Russia co-publications. The black line represents the total percentage of China-Russia co-publications from 2013 to 2022 in each subject area.

Discussion

As the world is polarizing among the top superpowers, there has been increasing attention on the relationship between China and Russia. Despite their volatile history, the two countries have managed to align geopolitically, at least in resistance to the US and its European and other Western allies. While both China and Russia seek to leverage science and technology to expand their economies, each nation takes a unique approach with differing outcomes and degrees of success. As other bibliometric studies indicate, China has emerged as a top global producer of science (Yuan et al., 2018; Zhang & Guo, 2017), while Russia is still in a period of recovery since the collapse of the Soviet Union. Although Russian science has been improving, impact measured by publication output pales in comparison with other top scientific producing countries (Avanesova & Shamliyon, 2018; Turko et al., 2016).

It is curious that despite their respective commitments to scientific development, which in part have encouraged several strategic bilateral and multilateral agreements, there has been a lack of cooperation one might expect from nations with similar political and economic aims (Finardi, 2015; Finardi & Buratti, 2016; Shashnov & Kotsemir, 2018). However, our findings revealed that relations are shifting, and over the last decade, there is a clear upward trend in China-Russia co-publications. Their cooperation was especially strong in physics and astronomy and other applied science fields which have the potential translate to greater military and nuclear power if harnessed towards political ends. While

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our study addresses co-publications between China and Russia across differing academic disciplines, additional research into the nature of collaborative projects as well as governmental support and military contracting warrants additional investigation.

While our data demonstrates growth in China-Russia co-publications over the last decade, the relative importance of collaboration for each country differs, especially regarding their international collaborations. China remains focused on collaborating with other prominent scientific producers, largely from developed Western countries, such as the United States, the UK, and Australia, and collaboration with Russia remains less important to its scientific output. On the other hand, for Russia, collaboration with China has become more important in supporting its nation's research production at the same time as collaboration with its other top collaborators has somewhat declined. China bypassed some of Russia's longstanding European collaboration partners and became one of Russia's top three collaborating countries. The importance of collaboration with China was further exemplified as co-publications between Russia and its other top collaborators declined from 2021 to 2022. Ties between China and Russia strengthened, while ties between Russia and other western countries were severed likely due to these countries' responses to Russia's invasion of Ukraine. In other words, the China-Russia relationship demonstrated resiliency and may operate under different logics than those which guide scientific relationships in the West.

Beyond geopolitical implications, this study also confirms the center-periphery model of global science: Peripheral countries remain in the periphery regardless of collaboration. Despite China's high scientific production, it can neither exclusively nor systematically support Russia's ability to rise above the scientific periphery threshold. Characterized by its highly stable and hierarchical structure (Schubert & Sooryamoorthy, 2010), whereby central dominant countries continually exert power and influence upon periphery countries and the scientific system more broadly (Olechnicka et al., 2019; Schott, 1998), the center-periphery model provides a compelling framework for China-Russia collaborative research. China has managed to emerge from the periphery and approach the center where scientific leaders like the United States comfortably maintain scientific domination. Propelled by rapid growth and strategic investment, China has carved out alternative ways to assert scientific influence (Marginson, 2022). Regardless of its position, collaboration may have limited potential to bring China or Russia closer to the center of power as their combined research accounts for a small proportion of global science and the global science system, as measured by co-publications. Thus, while the two countries have garnered the world's attention based on their challenges to and for the West, their combined role in science is not much greater than working apart.

The scope of our research is limited to English language publications and those submitted to reputable international journals. China-Russia publication trends may differ with the inclusion of other factors. We encourage additional investigations that consider these variables. Additionally, research that expands upon China's and Russia's positions within the center-periphery model may contribute to the current body of knowledge regarding which nations have power, how power is maintained, and what alternative political maneuvers undermine current power structures within the global science system. This study is a launching point into other investigatory areas.

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Conclusion

The 2022 war in Ukraine has led many western nations, including the United States, to enact sanctions against Russia. Isolated and with few trading partners, Russia has relied more heavily on China for economic and political support. Support takes several forms, one of which is through collaborative research and development. Even before Russia's invasion of Ukraine, China-Russia collaborations steadily increased. What factors contribute to this increase and what are the implications for geopolitical relations, as well as for the scientific community?

From 2013 through 2022, this study evaluates the trends in research collaboration, positioning China and Russia as periphery-periphery partners within the center-periphery conceptual model. Pulling several bibliometric datapoints, including shifts in publication rates by individual, bilateral, and multilateral publication types, we explored the ways in which publication patterns have evolved over the last decade. Additionally, by quantifying collaboration type by academic discipline, we identified important development areas that have broader political and social outcomes. Through our research, we found that China and Russia are not as tight knit of collaboration partners as one might expect. Even if they were, neither has the capacity to advance the other's scientific status through collaborative partnerships alone. As we approach ongoing tensions and global polarities, we expect an uptick in China-Russia collaborations, but it is likely that while China will continue to maintain its position as a leading scientific producer, Russia will need to do more to catch up.

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Originality Note

The authors confirm that the manuscript is their original work, and if others' works are used, they are properly cited/quoted.

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