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Scientific Collaboration in Top Five Chinese Universities

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Abstract

Scientific collaboration in the top five Chinese Universities is studied in the paper. According to the types of geographical collaboration from 2014 to 2023, the results show that the percentage of domestic collaboration articles among the five universities is high, while organizational collaboration among these universities is low. The international collaboration trend of five universities during this period is different. Tsinghua University and Peking University show similar levels, as do Zhejiang University and Fudan University, while Nanjing University exhibits a different level compared to the others. The quartiles with journal impact factors (JIF) are used to analyze the articles, the percentage of articles in quartile 1 (Q1) of all five universities is relatively high, and that of Q4 is the lowest. Therefore, international collaboration can publish high-quality articles. The scientific impact of articles in Q1 is positive in five universities. Additionally, five universities have three common research areas, though there is a slight difference in the ranking of research areas. Domestic collaboration articles remain prevalent among all five universities. Articles with international funding show higher levels of collaboration, with the United States emerging as the most significant scientific collaborator for these Chinese universities.

Subject Areas

Information Science, Library, Intelligence and Philology

Keywords

Scientific Collaboration, Chinese University, International Research, Scientific Impact

1. Introduction

Economic growth, industrial innovation, quality improvement, cost reduction,

and the measurement of a country's educational level depend on scientific research [1]. In modern times, it is difficult for an individual scientist to complete scientific research alone, and scientific research has become a collective endeavor. Numerous projects are now carried out by teams of scientists. International research collaboration is crucial, as articles increasingly involve authors from multiple countries worldwide. Furthermore, these collaborations facilitate knowledge exchange with leading global researchers [2].

The primary outcomes of international collaborations are publications and patents. Teamwork in research significantly enhances knowledge production. There are numerous benefits to collaboration, such as increased scientific productivity, innovative capacity, and research quality, *et al*. Researchers can improve their performance through participation in international collaborations. In the United Kingdom, researchers with international experience tend to be more productive than those without. Thus, mobile researchers who engage internationally may demonstrate higher productivity. Additionally, international networks result in a higher frequency of co-authored papers. Binary logistic regression was employed to analyze the presence of international papers and their impact on productivity. Furthermore, an ordered logistic model was used to assess the extent of internationalization [3].

The link between the extent of internationalization of scientific products was examined. Both research productivity and the average quality of output had positive effects on the degree of international collaboration. Correlation analysis revealed a strong link between productivity and the intensity of international collaboration. As researchers' scientific output increased, so did their cross-national articles. However, the correlation between the intensity of international collaboration and the average quality of research products from scientists was not strong. Productivity had a much larger impact on the intensity of international collaboration than the average quality of scientific products [4].

For co-authorship, there were different types, including top-top, top-ordinary, and ordinary-ordinary scientist co-authorships. The top-ordinary category also included three sub-types: strong, moderate, and weak co-authorships. Strong and moderate co-authorships provided mutual benefits for both top and ordinary scientists [5]. Collaborating with top scientists can significantly benefit researchers' career advancement, as top scientists possess superior skills and academic impact. Scientific research resources are the result of years of accumulation. Junior scientists collaborating with top scientists can leverage previous achievements and accelerate their career progression, thus shortening the time needed to establish themselves. Co-authorship with highly cited scientists enhances the impact of junior researchers' work, as academic success tends to build upon itself. Less prestigious academic institutions could unlock latent potential by enhancing collaboration with top scientists. Over time, there exists a positive correlation between institutional prestige and the likelihood of producing highly cited scientists [6]. Furthermore, while research collaboration with highly productive scientists generally

yields high productivity, collaboration with low-productivity scientists tends to have the opposite effect. Those less fluent in English are less likely to be invited to collaborate. On average, scientists born in the USA are less productive than their foreign-born counterparts [7]. The Triple Helix model considers international collaboration as a fourth element of the system. It proposes three levels of analysis to evaluate the impact of international collaboration on innovation systems. Results suggest that international collaboration enhances knowledge sharing at the domestic level [8].

Allometric models were employed to analyze the evolution of international research collaboration. The findings revealed that fields primarily focused on applied sciences, such as medical and agricultural sciences, experienced accelerated collaboration patterns [9]. In contrast, some predominantly basic fields, such as physics and mathematics, showed comparatively slower growth in international scientific collaboration. Despite this, physics and mathematics find widespread applications across various domains, underscoring their omnipresence in practical applications.

The prevalence of single-author, single-address, and single-country papers declined across natural and medical sciences, social sciences, and humanities. On average, papers with fewer authors consistently garnered lower citation rates. Conversely, an increase in the average number of authors correlated with higher scientific impact [10]. Generally, collaborative research contributed to enhanced research quality, with papers involving more authors and organizations often receiving more citations. Productive scientists tended to collaborate with others of similar productivity. Multi-authored papers may achieve greater success due to broader dissemination through personal networks. Moreover, international collaboration, as opposed to national collaboration, was found to increase a paper's citation impact [11].

International research collaboration continues to play a prominent role in global capacity building. The emergence of the knowledge economy has resulted from global economic restructuring, emphasizing intellectual capabilities over physical or natural resources. Research laboratories, universities, and other educational institutions create, disseminate knowledge, and innovate new products and processes. Science and technology serve as primary drivers of economic growth. Collaborating with academics from different regions can bring novel or complementary skills and capabilities, enhancing countries' academic capacity and addressing economic challenges. Countries have implemented policies to attract scientific talent from abroad to bolster domestic research capabilities. International collaboration helps prevent redundant research efforts. European countries, in particular, exhibit diverse collaboration patterns within the region compared to global collaborations. Researchers within regions are motivated to address specific economic, social, and political concerns. For instance, the Horizon 2020 initiative in Europe plays a crucial role in enhancing local research capacity through international collaborations, particularly with lower and middle-income countries. These

collaborations are essential as these countries often lack research capacity and struggle to translate research into impactful outcomes [12].

The limited availability of high-skilled human resources has hindered economic development. Excellent doctors and postdoctoral students gain profound professional knowledge and acquire advanced skills in high-level laboratories abroad. Governments have established universities with distinct missions that include an international dimension, thus internationalizing institution building. The regional economy is also integral to the institutional mission, necessitating the enrollment of foreign students and the inclusion of foreign faculty to enhance the university's international reputation [13].

South American universities were examined in terms of the relationship between international collaboration and scientific impact. Publications in Q1 journals showed a higher component of international collaboration compared to the total number of publications. Field Weighted Citation Impact (FWCI) values increased with the number of countries participating in publications. Encouraging collaboration between universities and their national or international peers is essential. Collaboration with research institutes, scientific societies, and even basic education institutions should also be encouraged. Such collaborations can lead to better formulation of research problems, both basic and applied, resulting in greater scientific impact [14].

The number of faculties and funding levels varied across universities, influencing their publication and patent outputs. Older universities tended to collaborate more due to their established expertise, in contrast to younger institutions striving to seek guidance from their more experienced counterparts. In less developed regions, factors like geographical, institutional, and social proximity play a crucial role in explaining scientific collaborations among Spanish universities. These findings underscored the significance of proximity in fostering scientific collaboration. Additionally, universities with limited financial resources sought partnerships with better-funded counterparts, indicating a quest for synergies through collaboration [15]. In contrast to Southeast Asian countries, top Indonesian universities showed a preference for collaboration with developed nations. They published fewer joint works with neighboring countries compared to collaborations with leading global research hubs renowned for their research and development prowess. To enhance the quality of higher education institutions, governments could facilitate scholarships enabling visits and collaborations with advanced institutions. Indonesian scholars often hold international degrees across various academic fields, a key driver of current research productivity among Indonesia's top universities. Moreover, Indonesian researchers frequently contribute to high-impact articles published in prestigious journals and conferences indexed in foreign databases. The government's ambition to elevate national universities to world-class status emphasizes the importance of partnerships with advanced nations, while collaborations with local industries and institutions can further benefit universities [16]. Research team size typically correlates positively with international

collaboration. A study analyzed the input-output dynamics of international research collaboration involving five U.S. public universities using quantitative metrics. Sixteen metrics, encompassing inputs, outputs, and outcomes such as international faculty, research funding, research influence, and academic impact, highlighted their role as predictors of international research collaboration [17]. Furthermore, multi-university collaborations yield high-impact papers, particularly when involving top-tier institutions, thus increasingly stratifying by university rank within collaborative groups [18].

Universities aim to achieve world-class status and attract international talent for study. Therefore, university researchers aspire to gain global recognition. How can university researchers achieve global renown? They must meet international standards, which require them to publish internationally recognized articles or secure patents, gaining recognition from the global scientific community. Collaborations with international faculty can also enrich courses with global perspectives, thereby enhancing the quality of teaching and research [19].

From the previous scholars' research, we can see that scientific collaboration is a complex matter. Scientific collaboration has certain advantages, increasing both the productivity and quality of articles. Although researchers have conducted in-depth studies on the degree of internationalization, using mathematical models to analyze international articles and their impact on productivity, as well as employing logistic models to estimate the extent of internationalization, correlation analysis revealed a link between productivity and the intensity of international collaboration. Allometric models analyzed the evolution of international research collaboration. However, allometric models have limitations, as they were only employed to analyze applied sciences. Therefore, quantitative research on scientific collaboration still needs to be further deepened.

2. Method

In the above context, measuring the relationship between collaboration efforts and scientific research outcomes is crucial for university research programs and science policy management. Due to the lack of research on the collaboration behavior and impact of Chinese universities, this study utilizes data from networks and the InCites database to clearly understand the results and trends generated by this data. The study hypothesizes that: First, it investigates three types of geographical collaboration for articles published by the top five Chinese universities from 2014 to 2023 to determine which type is predominant. Second, it analyzes the state of international collaboration over the decade to see if such collaboration is necessary for becoming a top international university. Third, it examines the quality of published articles through an impact analysis of articles from the five universities over ten years to understand which type of collaboration enhances article quality. Fourth, it analyzes articles in major research areas and their impact to determine the different types of collaboration among the top five universities over the decade. Fifth, it analyzes articles funded by foreign funding agencies and

their impact to determine the different types of collaboration among the top five universities over the decade. Sixth, it analyzes articles from the countries with the most collaborations with the top five universities to determine whether collaborating with developed countries is necessary.

In this paper, the author exclusively presents data from five universities in China sourced from SCIEs (Science Citation Index-Expanded). A comprehensive university was selected for this study, thereby excluding Shanghai Jiao Tong University.

All data were retrieved from the InCites database, a research evaluation and analysis tool that collects and analyzes citation data from the Web of Science Core Collection. The InCites database is a comprehensive resource based on Web of Science (WoS) that offers extensive data on research outputs, publication impacts, and collaborations. It includes information on institutions, researchers, countries, research areas, publication sources, and funding agencies, with data available dating back to 1980. The database provides valuable indicators of research performance (https://incites.help.clarivate.com/Content/Indicators-Handbook/ih-about.htm). In the WoS database, journals are divided into four quartiles based on impact factor. Journals in the top 25% are in Q1, those in the 26% - 50% are in Q2, those in the 51% - 75% are in Q3, and those in the 76% - 100% are in Q4. Q1 - Q4 refers to the first, second, third, and fourth quartiles of journals in the WoS database according to their impact factor, which is an indicator of journal quality. Category Normalized Citation Impact is widely recognized as one of the most valuable and unbiased impact indicators. CNCI values are usually compared with global CNCI values to gauge publication impact. A CNCI value equal to 1 indicates performance at the world average, while a value higher than 1 indicates performance above the world average, and a value below 1 indicates performance below the world average.

Data retrieval was conducted on April 4, 2024, and the study period is limited to 2014-2023. The data obtained were processed using Excel, and images were modified using Photoshop software. The search encompassed institutions, research areas, funding agencies, and the country with the most collaborations. The article types analyzed were research articles and reviews, and we specifically focused on funded research agencies. It should be noted that the original indexing date for funding agencies was April 4, 2024, but was later updated to August 3, 2024, for accuracy. Therefore, it will have some impact on the analysis results. Since the analysis focuses on universities, the institution type is restricted to "academic". We identified three types of collaborations: international, domestic, and organizational. International collaboration refers to articles with one or more international co-authors. Domestic collaboration involves articles with two or more authors whose addresses are all within the same country. Organizational collaboration includes articles with more than two authors where addresses are not exclusively marked as international or domestic.

Table 1 presents the abbreviated names of five universities, along with the year of their earliest articles and the total number of articles published from 2002 to

Table 1. Top five Chinese universities based on articles of web of science.

No	University	Abbreviation	First year/ in Web of Science	Total Number of Articles	Teaching and Administrative Staff	Full time Teacher	Deadline for Statistics
1	Tsinghua University	THU	1991	137,515	16,270	3738	2022.08
2	Peking University	PKU	1986	131,510	21,183	7317	2017.12
3	Zhejiang University	ZJU	1986	159,038	9746	4557	2022.12
4	Fudan University	FDU	1985	106,977		3602	2022.10
5	Nanjing University	NJU	1987	84,967	4794	2197	2022.11

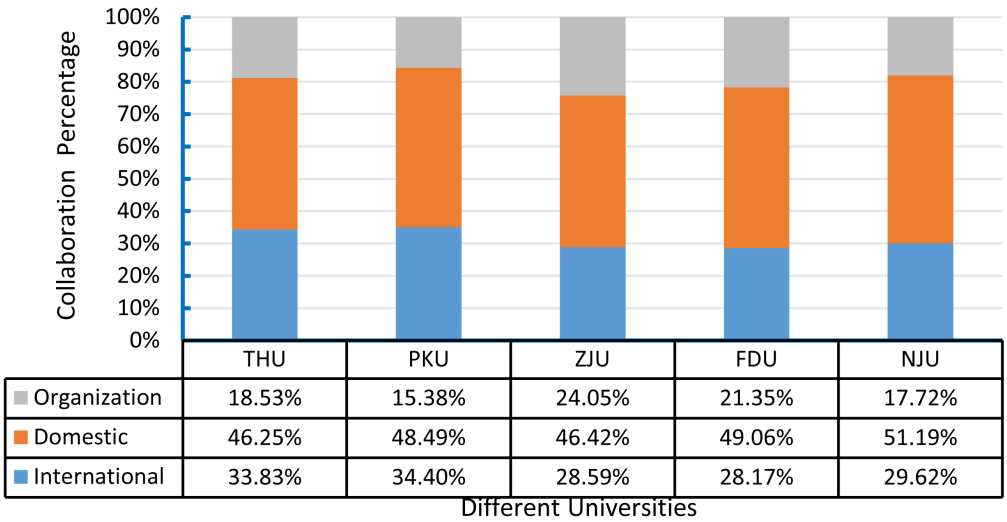
2022. The year 2002 is chosen due to insufficient article counts before that time. To enhance article quality, only documents classified as articles or review articles are included. The articles are in English. Except for data on faculty and staff (sourced from the Baidu website), all other data are from the Web of Science Core Collection. In Table 1, FDU University was the first to publish an article, while THU publishes the first article at the latest compared to the others. ZJU has the highest total number of published articles, followed by THU, with NJU publishing the fewest.

3. Results and Analysis

To address the five hypotheses mentioned earlier, we set search criteria, retrieved all relevant data from the Incites database, and analyzed the results. The results are shown below.

3.1. Distribution of Articles by Types of Geographical Collaboration

Figure 1 illustrates the distribution of articles among five universities based on three types of geographical collaboration from 2014 to 2023. THU and PKU exhibit a higher percentage of international collaboration compared to the other



	THU	PKU	ZJU	FDU	NJU
Organization	18.53%	15.38%	24.05%	21.35%	17.72%
Domestic	46.25%	48.49%	46.42%	49.06%	51.19%
International	33.83%	34.40%	28.59%	28.17%	29.62%

Figure 1. Distribution of articles according to types of collaboration by the university during 2014-2023.

three universities. Domestic collaboration is prevalent among all five universities, indicating its dominance within Chinese academia. NJU has the highest proportion of domestic collaboration. Conversely, organizational collaboration among these universities is relatively low, suggesting that significant scientific collaborations often extend beyond these institutional boundaries. Therefore, it addresses the first hypothesis that domestic collaboration is predominant.

3.2. International Collaboration Trend during 2014-2023

We analyze the articles on international collaboration trends during 2014-2023. In Figure 2, the percentage of international collaboration for the five universities slowly increased from 2014 to 2019, but began to decline from 2020, reaching its lowest point in 2023. The international collaboration trend of THU and PKU is almost the same, that of ZJU and FDU is almost the same, and that of NJU is different from the other four universities. Nanjing University's percentage of international collaboration is lower than that of Tsinghua University and Peking University, but higher than that of Zhejiang University and Fudan University. Therefore, it indicates NJU'S international collaboration is among the other four universities. However, its percentage of international collaboration has significantly decreased. Despite the decline, the percentage of international collaboration at Tsinghua University and Peking University remains higher than that of the other three universities. So, it addresses the second hypothesis that top international universities still require a high level of international collaboration.

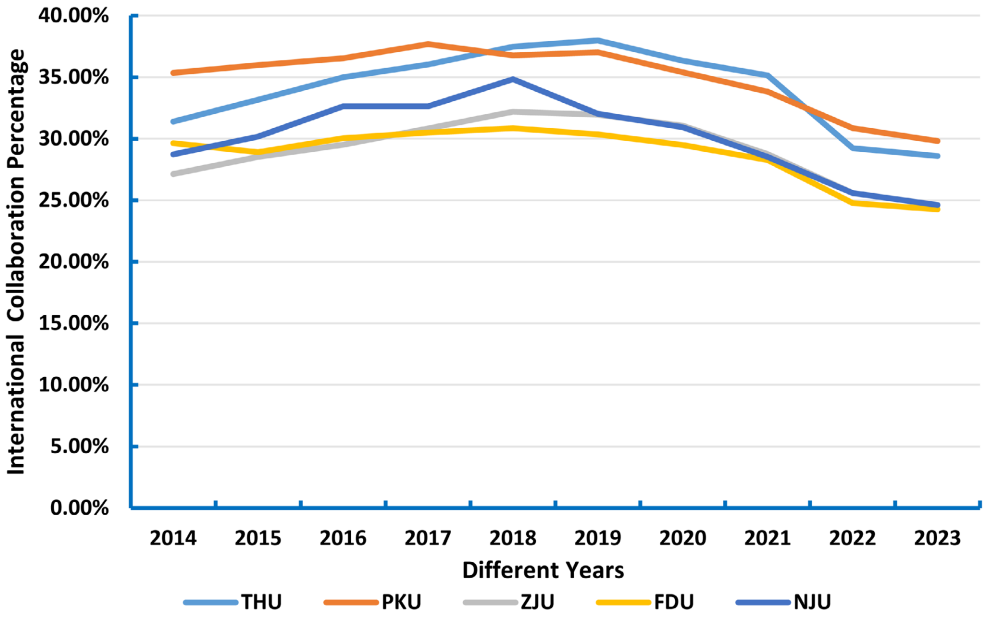


Figure 2. Trend of international collaboration percentage in the university during 2014-2023.

3.3. Articles According to JIF Quartiles, Collaboration Distribution in Q1-Q4 Journals and Scientific Impact (2014-2023)

To demonstrate the persuasiveness of the data, we used quartiles (Q) based on

journal impact factors to analyze the articles. We then examined the distribution of Q1-Q4 articles across different geographic collaborations from 2014 to 2023. The results are shown in Figure 3. To further analyze the impact of the articles, we evaluated the research influence of the five universities. The results are shown in Table 2.

In Figure 3(a), the percentage of articles in Quartile 1 (Q1) is relatively high across all universities, followed by Q2, with Q4 showing the lowest percentage. This indicates that all five universities publish a significant number of high-quality articles in Q1. Specifically, Tsinghua University, Peking University, and Nanjing University have a higher percentage in Q1. Figure 3(b) analyzes Q1 articles, showing that international and domestic collaborations constitute the majority among the five universities, whereas organizational collaboration is minimal.

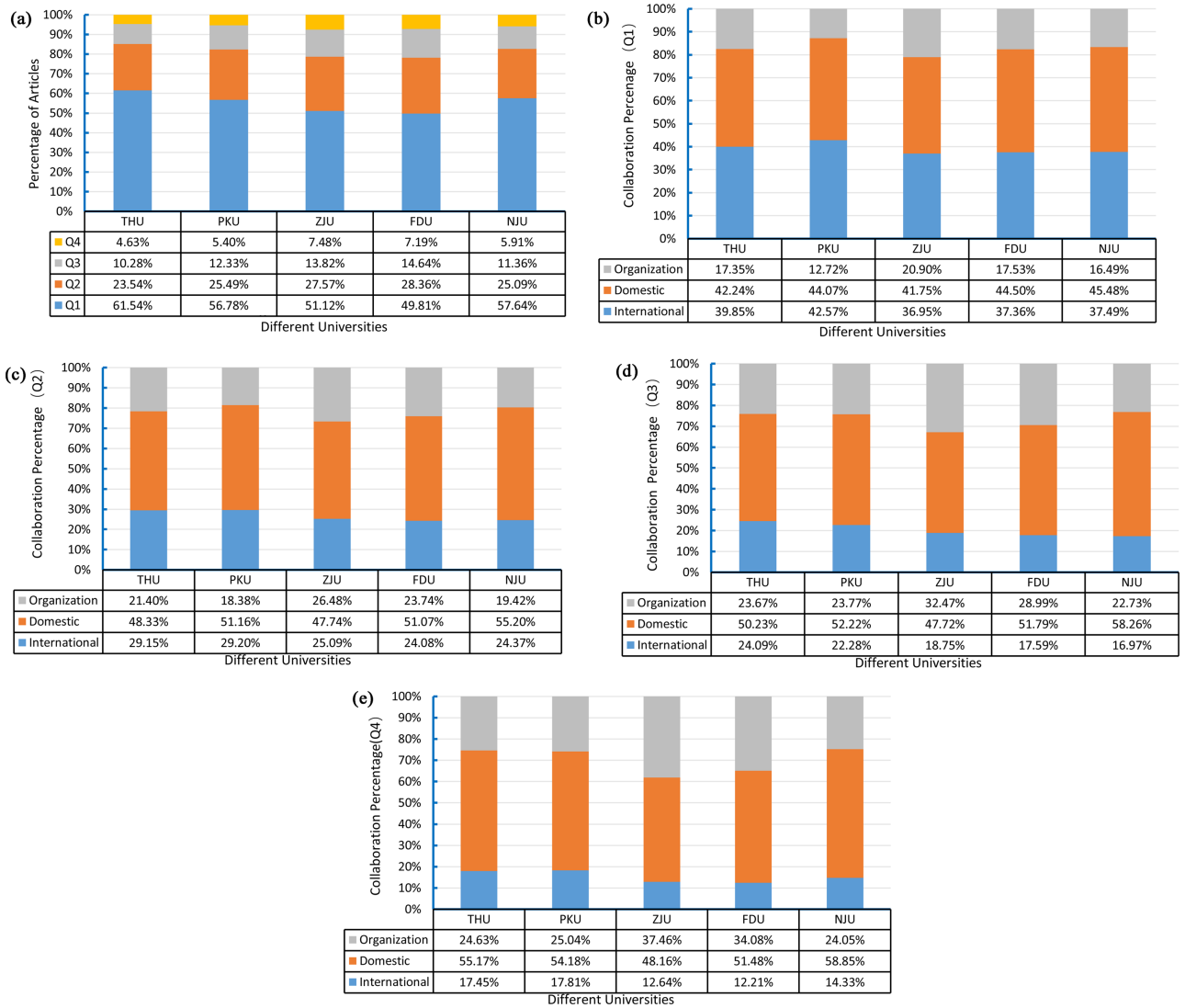


Figure 3. (a) Impact of articles according to JIF quartiles during 2014-2023; (b) Geographical collaboration of articles in Q1; (c) Geographical collaboration of articles in Q2; (d) Geographical collaboration of articles in Q3; (e) Geographical collaboration of articles in Q4.

Table 2. Scientific impact of articles in Q1-Q4 according to universities during 2014-2023

University	Quartile	Web of Science Documents	Times Cited	% Documents Cited	Category Normalized Citation Impact
THU	Q1	62,268	2,568,440	98.19%	2.10
	Q2	23,823	344,522	94.35%	0.85
	Q3	10,403	97,980	89.81%	0.55
	Q4	4689	33,476	80.06%	0.38
PKU	Q1	56,436	2,159,934	97.71%	2.02
	Q2	25,337	338,743	93.76%	0.85
	Q3	12,251	118,453	90.12%	0.60
	Q4	5367	35,666	79.36%	0.39
ZJU	Q1	59,932	1,994,015	97.79%	1.86
	Q2	32,324	425,548	93.83%	0.81
	Q3	16,204	150,202	89.78%	0.55
	Q4	8,769	49,270	78.26%	0.33
FDU	Q1	39,486	1,459,684	97.46%	2.02
	Q2	22,481	288,160	93.17%	0.83
	Q3	11,601	115,775	90.47%	0.61
	Q4	5,699	34,311	79.54%	0.37
NJU	Q1	34,196	1,293,272	98.11%	1.96
	Q2	14,883	204,804	94.06%	0.83
	Q3	6737	63,503	89.46%	0.56
	Q4	3509	22,967	81.13%	0.37

THU and PKU exhibit a higher percentage of international collaboration. Figure 3(c) examines Q2 articles, revealing that domestic collaboration is predominant among the universities, with minimal international and organizational collaboration. THU and PKU still maintain a higher international collaboration percentage compared to the other universities. NJU has the highest domestic collaboration percentage. In Figure 3(d), focusing on Q3 articles, domestic collaboration remains dominant and shows an increasing trend among the universities. International collaboration decreases compared to Q1 and Q2, while organizational collaboration increases. NJU exhibits the highest domestic collaboration percentage and the lowest percentages in international and organizational collaborations. Figure 3(e), analyzing Q4 articles, continues to show domestic collaboration as primary with an increasing trend. Compared to Q1, Q2, and Q3, international collaboration decreases across Q4, while organizational and domestic collaborations increase. Tsinghua University and Peking University demonstrate a relatively

high percentage of international collaboration. This indicates that international collaborations can lead to the publication of high-quality articles across JIF Q1, with THU and PKU consistently showing higher percentages than other universities across Q1-Q4.

In Table 2, Q1 of the five universities exhibits the highest number of Web of Science documents, citations, percentage of citations, and CNCI value, whereas Q4 shows the lowest. From the table, it can be seen that Tsinghua University's Q1 demonstrates higher indicators compared to the other universities. For example, in the Q1, Tsinghua University leads with the highest number of Web of Science articles, totaling 62,268. It also boasts the highest number of article citations, reaching 2,568,440. Additionally, it achieves the highest CNCI value at 2.10. Zhejiang University has fewer articles in Q1 than Tsinghua University, but surpasses in articles in Q2-Q4 compared to the other universities. It indicates that Zhejiang University needs to improve the quality of its published articles. Figure 3 and Table 2 address the third hypothesis that international collaboration contributes to the publication of high-quality articles, and that the impact of international articles from top universities is generally high.

3.4. Collaboration and Impact of Articles According to Main Research Areas from 2014 to 2023

We analyzed the top five research areas ranked by five universities from 2014 to 2023. This analysis of article impact includes Web of Science documents, CNCI, and metrics on both international and domestic collaborations, among other indicators. The results are shown in Table 3.

In Table 3, these five universities share three research areas, namely MATERIALS SCIENCE, MULTIDISCIPLINARY，CHEMISTRY, PHYSICAL and CHEMISTRY, MULTIDISCIPLINARY. Tsinghua University has the highest number of Web of Science articles, as well as the most international and domestic collaboration articles. The top five research areas of Tsinghua University and Zhejiang University are the same, with only differences in ranking order. However, in these five research areas, Tsinghua University has more Web of Science documents, citations, higher percentage of cited documents, higher CNCI value, and more domestic collaboration articles compared to Zhejiang University. Due to certain factors, Zhejiang University only has a higher percentage of international collaboration compared to Tsinghua University. In the area of MATERIALS SCIENCE, MULTIDISCIPLINARY, Tsinghua University has 16,951 Web of Science articles, Peking University has 10,446, Zhejiang University has 13,043, Fudan University has 7979, and Nanjing University has 8612. Among these five universities, each university has more domestic collaboration articles than international collaboration articles across their five research areas. The percentage of domestic collaboration articles is also higher than that of international collaboration articles. For example, in MATERIALS SCIENCE, MULTIDISCIPLINARY, at Tsinghua University, the number of international collaboration articles is 4727, while the

Table 3. Articles and impacts of collaborations according to research areas from 2014 to 2023.

University	Rank	Research Areas	Web of Science Documents	Times Cited	% Documents Cited	Category Normalized Citation Impact	Documents of International Collaboration	% International Collaborations	Documents of Domestic Collaborations	% Domestic Collaborations
THU	1	MATERIALS SCIENCE, MULTIDISCIPLINARY	16,951	618,730	91.20%	1.72	4727	27.89%	9034	53.29%
	2	CHEMISTRY, PHYSICAL	10,009	470,095	93.32%	1.84	2822	28.19%	5276	52.71%
	3	CHEMISTRY, MULTIDISCIPLINARY	9,033	440,965	92.58%	2.13	2399	26.56%	4856	53.76%
	4	NANOSCIENCE & NANOTECHNOLOGY	7444	346,307	92.15%	1.66	2244	30.15%	3898	52.36%
	5	PHYSICS, APPLIED	9949	340,782	90.65%	1.91	2826	28.40%	5088	51.14%
PKU	1	MATERIALS SCIENCE, MULTIDISCIPLINARY	10446	398,781	91.79%	1.72	3064	29.33%	6073	58.14%
	2	CHEMISTRY, MULTIDISCIPLINARY	7788	346,665	92.39%	1.81	2043	26.23%	4559	58.54%
	3	ENVIRONMENTAL SCIENCES	9778	299,292	91.62%	1.67	3978	40.68%	4358	44.57%
	4	CHEMISTRY, PHYSICAL	6394	294,487	92.88%	1.77	1947	30.45%	3573	55.88%
	5	NANOSCIENCE & NANOTECHNOLOGY	5986	259,027	92.08%	1.47	1670	27.90%	3482	58.17%
ZJU	1	MATERIALS SCIENCE, MULTIDISCIPLINARY	13043	394,217	89.38%	1.58	4176	32.02%	6045	46.35%
	2	CHEMISTRY, MULTIDISCIPLINARY	8956	323,021	90.40%	1.65	2609	29.13%	4045	45.17%
	3	CHEMISTRY, PHYSICAL	7469	285,092	91.54%	1.57	2193	29.36%	3417	45.75%
	4	NANOSCIENCE & NANOTECHNOLOGY	6299	228,871	89.95%	1.46	2130	33.81%	2847	45.20%
	5	PHYSICS, APPLIED	8026	212,133	87.64%	1.61	2514	31.32%	3691	45.99%
FDU	1	MATERIALS SCIENCE, MULTIDISCIPLINARY	7979	308,017	90.71%	1.91	2362	29.60%	3908	48.98%
	2	CHEMISTRY, MULTIDISCIPLINARY	6347	268,336	91.35%	1.91	1687	26.58%	3114	49.06%
	3	ONCOLOGY	10,461	224,843	90.48%	1.20	1857	17.75%	5395	51.57%
	4	CHEMISTRY, PHYSICAL	4839	216,047	92.37%	1.84	1385	28.62%	2317	47.88%
	5	NANOSCIENCE & NANOTECHNOLOGY	4922	208,068	90.13%	1.60	1362	27.67%	2562	52.05%

Continued

NJU	1	MATERIALS SCIENCE, MULTIDISCIPLINARY	8612	281,258	91.06%	1.64	2337	27.14%	4745	55.10%
	2	CHEMISTRY, MULTIDISCIPLINARY	6460	250,026	92.00%	1.75	1642	25.42%	3368	52.14%
	3	CHEMISTRY, PHYSICAL	5070	192,840	92.43%	1.61	1310	25.84%	2812	55.46%
	4	ENVIRONMENTAL SCIENCES	6377	183,194	91.67%	1.55	2495	39.12%	2955	46.34%
	5	PHYSICS, APPLIED	6817	180,121	89.61%	1.53	1839	26.98%	3670	53.84%

number of domestic collaboration articles is 9034. This corresponds to an international collaboration percentage of 27.89% and a domestic collaboration percentage of 53.29%. For the field of NANOSCIENCE & NANOTECHNOLOGY, except for Nanjing University, the other four universities have research in this area. This indicates that this field is also quite important. Overall, almost all indicators for THU rank high. It is worth mentioning that, although THU has the highest absolute number of articles, the percentage of international collaboration articles is relatively low compared to the other four universities. Therefore, domestic collaboration is very important. Of course, we also pay attention to international collaboration. According to the results in Table 3, this addresses the fourth hypothesis: Research areas in top universities are primarily focused on domestic collaboration studies. Moreover, articles published in the research areas of top universities also have a higher impact.

3.5. Collaboration and Impact of Articles According to Funding Agencies from 2014 to 2023

An analysis was conducted on the top five funding agencies as ranked by five universities from 2014 to 2023. This analysis of article impact includes Web of Science documents, CNCI, and metrics on international and domestic collaborations, along with other relevant indicators. The results are shown in Table 4.

According to data from the InCites database, there are 118 funding agencies and it publishes 3,573 articles in THU, 120 funding agencies and publishes 3742 articles in PKU, 112 funding agencies and publishes 2073 articles in ZJU, 121 funding agencies and publishes 1707 articles in FDU, and 106 funding agencies and it publishes 1872 articles in NJU. Table 4 lists the top 5 funding agencies supporting the five universities. In Table 4, NSF-Directorate for Mathematical & Physical Sciences (MPS) of the USA ranks first at THU. Web of Science documents is 1199, the cited times is 101,286, the percentage of cited documents is 99.17%, CNCI is 3.56, the percentage of international collaboration is 99.42%, and the percentage of domestic collaborations is only 0.25%. All the indicators of PKU in NSF-Directorate for Mathematical & Physical Sciences are lower than those of THU. These five universities share two common funding agencies: UK Research & Innovation (UKRI) (England) and Grants-in-Aid for Scientific Research (KAKENHI) (Japan), which means they sponsor all five universities.

Table 4. Articles and impacts of collaborations according to Funding Agencies by universities from 2014 to 2023.

University	Rank	Name	Web of Science Documents	Times Cited	% Documents Cited	Category Normalized Citation Impact	International Collaborations	% International Collaborations	Domestic Collaborations	% Domestic Collaborations
THU	1	NSF—Directorate for Mathematical & Physical Sciences (MPS)	1,199	101,286	99.17%	3.56	1192	99.42%	3	0.25%
	2	UK Research & Innovation (UKRI)	714	94,052	96.78%	5.93	701	98.18%	5	0.70%
	3	Grants-in-Aid for Scientific Research (KAKENHI)	446	45,731	98.43%	4.35	441	98.88%	1	0.22%
	4	Medical Research Council UK (MRC)	56	35,355	100.00%	24.82	55	98.21%	1	1.79%
	5	NSF—Directorate for Computer & Information Science & Engineering (CISE)Engineering (CISE) Engineering (CISE)	284	34,084	96.48%	5.54	281	98.94%	2	0.70%
PKU	1	UK Research & Innovation (UKRI)	889	81,044	97.75%	5.04	854	96.06%	24	2.70%
	2	NSF—Directorate for Mathematical & Physical Sciences (MPS)	988	71,478	98.99%	2.88	981	99.29%	1	0.10%
	3	Grants-in-Aid for Scientific Research (KAKENHI)	586	47,863	98.29%	4.08	584	99.66%	1	0.17%
	4	National Science Foundation (NSF)	275	38,433	100.00%	4.43	263	95.64%	4	1.45%
	5	Japan Society for the Promotion of Science	359	36,952	98.61%	5.07	357	99.44%	1	0.28%
ZJU	1	UK Research & Innovation (UKRI)	363	41,551	99.17%	4.95	348	95.87%	12	3.31%
	2	Grants-in-Aid for Scientific Research (KAKENHI)	362	34,735	97.51%	4.02	360	99.45%	2	0.55%
	3	Japan Society for the Promotion of Science	240	27,258	97.92%	5.10	238	99.17%	2	0.83%
	4	Medical Research Council UK (MRC)	87	25,015	97.70%	11.76	82	94.25%	3	3.45%
	5	Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), Japan (MEXT)	191	23,513	98.43%	5.04	189	98.95%	2	1.05%
FDU	1	UK Research & Innovation (UKRI)	309	84,141	98.38%	12.40	301	97.41%	7	2.27%
	2	Medical Research Council UK (MRC)	168	72,210	98.21%	19.41	164	97.62%	4	2.38%
	3	Grants-in-Aid for Scientific Research (KAKENHI)	323	49,217	95.67%	6.41	316	97.83%	2	0.62%
	4	National Institutes of Health Research (NIHR)	47	45,427	97.87%	36.96	46	97.87%	1	2.13%
	5	Japan Society for the Promotion of Science	202	45,273	95.05%	9.19	199	98.51%	1	0.50%

Continued

NJU	1	UK Research & Innovation (UKRI)	270	67,267	96.67%	11.31	259	95.93%	10	3.70%
	2	Grants-in-Aid for Scientific Research (KAKENHI)	380	55,114	97.37%	5.94	378	99.47%	2	0.53%
	3	Medical Research Council UK (MRC)	51	54,431	100.00%	46.74	51	100.00%	0	0.00%
	4	NSF—Directorate for Mathematical & Physical Sciences (MPS)	721	45,847	99.31%	2.71	720	99.86%	1	0.14%
	5	Japan Society for the Promotion of Science	184	39,026	97.28%	9.10	182	98.91%	2	1.09%

For UK Research & Innovation, the articles of all five universities have high CNCI values. The percentage of cited documents and the percentage of international collaboration articles are both high, and some even are 100%. Web of Science documents of THU is 714, CNCI is 5.93, the number of international collaboration articles is 701, and the number of domestic collaborations is only 5. Web of Science documents of PKU is 889, CNCI is 5.04, the number of international collaboration articles is 854, and the number of domestic collaborations is only 24. Compared with THU and PKU, the other three universities have fewer Web of Science documents, but their number and percentage of international collaboration articles are larger. However, the CNCI values of FDU and NJU in UK Research & Innovation are higher. Especially, the CNCI of FDU is 12.40. The articles funded by the Medical Research Council UK (MRC) (England) are fewer in number, but they have a higher CNCI value. The number of Web of Science articles funded by the Medical Research Council UK (MRC) published by Tsinghua University, Zhejiang University, and Nanjing University are 56, 87, and 51, respectively, with international publications totaling 52, 82, and 51. The CNCI values for articles funded by the Medical Research Council UK (MRC) are 24.82 for Tsinghua University, 11.76 for Zhejiang University and 46.74 for Nanjing University. In addition, Fudan University has published relatively few articles funded by the National Institutes of Health Research (NIHR) (England). The number of Web of Science articles is 47, with 46 of these being internationally published for Fudan University. These data clearly demonstrate that foreign funding significantly contributes to the publication of high-level international articles, particularly in the field of medical research. Therefore, this addresses the fifth hypothesis.

3.6. Collaboration and Impact of Articles According to Countries from 2014 to 2023

We conducted an analysis of the top six countries as ranked by five universities from 2014 to 2023. This analysis of article impact covers Web of Science documents, percentage of cited documents, CNCI, international collaboration, and other metrics. The results are presented in Table 5.

Based on the InCites database data, Tsinghua University collaborates with 168 countries, Peking University with 182 countries, Zhejiang University with 181 countries, Fudan University with 187 countries, and Nanjing University with 162

Table 5. Articles and impacts of collaborations according to countries from 2014 to 2023.

University	Rank	Country	Web of Science Documents	Times Cited	% Documents Cited	Category Normalized Citation Impact	International Collaborations	% International Collaborations
THU	1	USA	22,393	942,576	92.62%	2.29	22,293	99.55%
	2	UNITED KINGDOM	7683	347,161	91.08%	2.69	7659	99.69%
	3	ENGLAND	7051	329,015	91.16%	2.75	7030	99.70%
	4	GERMANY (FED REP GER)	5877	273,673	91.51%	2.80	5862	99.74%
	5	AUSTRALIA	4995	261,427	91.69%	3.05	4977	99.64%
	6	JAPAN	3664	208,559	91.78%	3.08	3657	99.81%
PKU	1	USA	24,234	916,542	91.70%	2.22	24,091	99.41%
	2	UNITED KINGDOM	7605	339,234	90.49%	2.90	7565	99.47%
	3	ENGLAND	6991	315,386	90.20%	2.95	6956	99.50%
	4	GERMANY (FED REP GER)	6545	274,700	91.34%	2.71	6507	99.42%
	5	AUSTRALIA	4902	226,327	90.66%	3.07	4883	99.61%
	6	FRANCE	4098	212,267	90.39%	3.23	4059	99.05%
ZJU	1	USA	18,318	595,495	91.86%	1.90	18,254	99.65%
	2	UNITED KINGDOM	5658	173,110	88.28%	2.13	5642	99.72%
	3	ENGLAND	5001	158,389	88.26%	2.18	4987	99.72%
	4	AUSTRALIA	4149	154,249	90.84%	2.45	4132	99.59%
	5	GERMANY (FED REP GER)	3373	113,653	89.59%	2.28	3362	99.67%
	6	SINGAPORE	2505	111,665	90.38%	2.73	2502	99.88%
FDU	1	USA	15,199	556,070	90.69%	2.18	15,105	99.38%
	2	UNITED KINGDOM	3966	199,455	86.94%	3.29	3922	98.89%
	3	ENGLAND	3676	188,426	86.67%	3.33	3632	98.80%
	4	GERMANY (FED REP GER)	3370	174,996	87.86%	3.32	3355	99.55%
	5	AUSTRALIA	2569	173,384	90.04%	3.96	2561	99.69%
	6	CANADA	1977	151,784	90.69%	4.48	1971	99.70%
NJU	1	USA	11,528	481,805	93.25%	2.25	11,454	99.36%
	2	UNITED KINGDOM	3401	181,048	90.24%	3.10	3382	99.44%
	3	GERMANY (FED REP GER)	3341	180,086	91.62%	3.09	3336	99.85%
	4	JAPAN	2598	177,170	92.76%	3.61	2596	99.92%
	5	ENGLAND	3166	175,177	90.15%	3.21	3147	99.40%
	6	CANADA	2543	162,975	93.31%	3.57	2536	99.72%

countries. In Table 5, we list the top six countries with the most collaborations with these five universities, along with their total number of published articles and article impact. The United States, the United Kingdom (including England), and Germany (Fed Rep Ger) have the most collaborations with the five universities in China. In addition, there are also France, Australia, Canada, Singapore, and Japan. The top six countries with which each of these five universities collaborates the most are all developed countries. The United States is the largest partner. Tsinghua University and Peking University have collaborated more with foreign universities than the other three universities. The number of Web of Science articles co-authored by Tsinghua University and the United States is 22,393, with 22,293 of these being international collaborations, accounting for 99.55% of the total. Similarly, the number of Web of Science articles co-authored by Peking University and the United States is 24,234, with 24,091 of these being international collaborations, accounting for 99.41% of the total. Although there are fewer articles on collaboration between Fudan University and the UK, Germany, Australia, and Canada, its CNCI values are higher. Nanjing University, like Fudan University, with fewer collaboration articles from the United Kingdom (including England), Germany, Japan, and Canada, but with higher CNCI values. The percentage of international collaborative articles from five universities has reached over 98%. These data indicate that collaboration with developed countries can enhance a nation's international research publication output. Hence, according to the results in Table 5, this addresses the sixth hypothesis.

4. Discussion

The development of China's economy can not be separated from scientific research. China now surpasses the European Union in research and development. To catch up with the West in research, the Chinese government has invested in new projects and introduced talents from trained at North American and European universities. International collaboration can keep up with domestic research. International collaboration can also compensate for relatively weak domestic research, and it even intensified their strong activities in the preferred science fields. In mathematics and the natural sciences, internationally co-authored papers were published on average in journals with distinctly lower impact than their domestic papers. So, international scientific collaboration proved to be complex [20].

The earlier an article is published abroad, the more international articles can be published in the future. PKU is a good example. Because PKU and ZJU are merged universities with relatively large campuses and a large number of teachers, they publish more English articles. In fact, Peking University has not published many articles, while Zhejiang University and Tsinghua University have published much more articles. There are also many teachers at Fudan University, but there are not many published articles.

Through the analysis of geographical collaboration, Tsinghua University and Peking University are truly first-class international universities. There are lots of

international collaboration articles from these two universities. However, the percentage of domestic collaboration articles is also high, all of which are above 40%, especially at Nanjing University. For the geographical distribution of international and domestic articles, scholars have in-depth insights. Research collaboration is more localized since 2000, relative to international collaboration [12].

In most countries, domestic collaborations increased faster than international collaborations [21]. Except for Nanjing University, the trend of international collaboration continues to increase among the other four universities. Therefore, Nanjing University needs to strengthen its international collaborations. Based on the data, Tsinghua University and Peking University show higher levels of international collaboration compared to Zhejiang University and Fudan University. Hence, international collaboration among top-tier universities is notably high. The trend shows increasing international collaborations [22]. As the network extends globally, the average number of authors per internationally co-authored publication has grown, with this trend accelerating [23].

According to the JIF quartile, all five universities mainly publish high-quality Q1 articles during 2014-2023. International collaboration is important, but domestic collaboration is more important. Because domestic collaboration has always accounted for the majority percentage in Q1-Q4. Internationalists also collaborate extensively at the domestic level [24]. Collaboration at the domestic level increases, and it is for scientists who remain or become top. At the same time, international collaboration is greater for scientists who become or remain top than compared with their peers [25]. In addition, Q1 has the greatest scientific impact. Therefore, for five universities, the number of Web of Science documents, number of citations, percentage of citations, and CNCI value are all the highest. Based on these situations, Tsinghua University is the most outstanding, and Nanjing University shows a slightly lower level.

Five universities share two common research areas, though there is a slight difference in the ranking of research areas. No matter how it changes, MATERIALS SCIENCE, MULTIDISCIPLINARY ranks first among the five universities. Through the analysis of the top five research areas of five universities, it is found that the percentage of domestic collaboration is greater than that of international collaboration. All the CNCI values of research areas are greater than one. The phenomenon of research areas indicates that universities are aimed at solving local or national problems. International research collaboration is to resolve domestic problems. Foreign financing can promote the development of domestic research. NSF-Directorate for Mathematical & Physical Sciences makes Mathematical & Physical Sciences of China catch up with international research, and Medical Research Council UK (MRC) can make China be at the forefront of the world, *et al.* Articles with international funding show greater collaboration, and internationally funded research also has the highest citation rates. High-level international collaboration improves the possibility of accessing new funding support [26]. On average, international papers are more highly cited. However, more citations do not necessarily

result from more government funds spent. That is, international collaboration is more important than government funding [27].

The countries in less-developed regions are more affected by international collaborations than those in developed regions. Many results also show that the United States is the most important scientific collaborator with China. 40 percent of Chinese publications are based on collaboration with the United States. More international collaboration will positively affect the performance of Chinese institutions if more Chinese institutions collaborate with U.S. institutions [28]. When the number of collaborating authors, institutions, and countries is respectively below 20, 14, and 9, an increase in team size is directly and steadily correlated to an increase in Average Relative Citation (ARC) counts. The fact that China collaborates mostly with USA-affiliate scholars. Indeed, research has shown that USA's citation advantage affects other countries' citation impact [29]. Data on international collaboration between five universities and foreign countries in this article also proves this point. In science and technology, China and the United States have already formed the world's largest partnership [30].

In reality, the role of international collaboration in scientific research is controversial. On the one hand, international collaboration can promote research quality. Brazil's collaboration with foreign partners benefits both sides, providing Brazilian research access to international funding and increasing impact for both [31]. On the other hand, international collaboration does not always positively affect research performance. Collaborations with some nations seems to decrease impact [32]. Harvard-authored publications did not benefit from international collaboration. Approximately 69% of the publications were produced through collaboration among American researchers, while about 31% were co-authored internationally [33]. There are many factors to consider the problem. First, it is important to collaborate with successful researchers. Because they are excellent or they are more highly funded. Second, international collaboration is only an advantage with specific nations, for example, developing countries. It is worth mentioning that international collaboration may be advantageous compared to not collaborating. However, compared to domestic collaboration, international collaboration is not always advantageous [32]. The relevant data in the previous section also illustrates this viewpoint.

In short, international collaboration research is an important and efficient way to raise the impact and visibility of a country's scientific research. Most countries encourage collaboration with other countries in scientific research. Although China produces a large number of publications, its centralities are low on its positions in publication output. China has the largest centrality increase, which demonstrates the rapid growth of China's role and importance in the international collaboration network. And China is also an important collaborator with researchers in other countries in the world. Despite the USA already has a dominant position, it has continued to focus on increasing collaboration with other large countries. China should study from the USA. To drive further economic deve-

lopment, China needs substantial investment and purposeful focus on increasing its international influence and impact in science and innovation [34]. In addition, to prevent international opportunities from being restricted by governmental politics and a lack of research funding, China should have an open policy and invest in research funding [35].

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Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Sharma, S. and Thomas, V.J. (2008) Inter-Country R&D Efficiency Analysis: An Application of Data Envelopment Analysis. *Scientometrics*, **76**, 483-501. https://doi.org/10.1007/s11192-007-1896-4

[2] Sarwar, R. and Hassan, S. (2015) A Bibliometric Assessment of Scientific Productivity and International Collaboration of the Islamic World in Science and Technology (S&T) Areas. *Scientometrics*, **105**, 1059-1077. https://doi.org/10.1007/s11192-015-1718-z

[3] Kato, M. and Ando, A. (2013) The Relationship between Research Performance and International Collaboration in Chemistry. *Scientometrics*, **97**, 535-553. https://doi.org/10.1007/s11192-013-1011-y

[4] Abramo, G., D'Angelo, C.A. and Solazzi, M. (2010) The Relationship between Scientists' Research Performance and the Degree of Internationalization of Their Research. *Scientometrics*, **86**, 629-643. https://doi.org/10.1007/s11192-010-0284-7

[5] Xie, Q., Zhang, X., Kim, G. and Song, M. (2022) Exploring the Influence of Coauthorship with Top Scientists on Researchers' Affiliation, Research Topic, Productivity, and Impact. *Journal of Informetrics*, **16**, Article 101314. https://doi.org/10.1016/j.joi.2022.101314

[6] Li, W., Aste, T., Caccioli, F. and Livan, G. (2019) Early Coauthorship with Top Scientists Predicts Success in Academic Careers. *Nature Communications*, **10**, Article No. 5170. https://doi.org/10.1038/s41467-019-13130-4

[7] Lee, S. and Bozeman, B. (2005) The Impact of Research Collaboration on Scientific Productivity. *Social Studies of Science*, **35**, 673-702. https://doi.org/10.1177/0306312705052359

[8] Mêgnigbêto, E. (2014) Information Flow within the West African Innovation Systems. *Triple Helix*, **1**, Article No. 5. https://doi.org/10.1186/s40604-014-0005-y

[9] Coccia, M. and Bozeman, B. (2016) Allometric Models to Measure and Analyze the Evolution of International Research Collaboration. *Scientometrics*, **108**, 1065-1084. https://doi.org/10.1007/s11192-016-2027-x

[10] Larivière, V., Gingras, Y., Sugimoto, C.R. and Tsou, A. (2014) Team Size Matters: Collaboration and Scientific Impact since 1900. *Journal of the Association for Information Science and Technology*, **66**, 1323-1332. https://doi.org/10.1002/asi.23266

[11] Frenken, K., Hölzl, W. and Vor, F.d. (2005) The Citation Impact of Research Collaborations: The Case of European Biotechnology and Applied Microbiology (1988-

2002). *Journal of Engineering and Technology Management*, **22**, 9-30. https://doi.org/10.1016/j.jengtecman.2004.11.002

[12] Fitzgerald, J., Ojanperä, S. and O'Clery, N. (2021) Is Academia Becoming More Localised? The Growth of Regional Knowledge Networks within International Research Collaboration. *Applied Network Science*, **6**, Article No. 38. https://doi.org/10.1007/s41109-021-00371-w

[13] Sá, C. and Grieco, J. (2015) International Collaboration in Brazilian Higher Education. *Frontiers of Education in China*, **10**, 7-22. https://doi.org/10.1007/bf03397050

[14] Limaymanta, C.H., Quiroz-de-García, R., Rivas-Villena, J.A., Rojas-Arroyo, A. and Gregorio-Chaviano, O. (2022) Relationship between Collaboration and Normalized Scientific Impact in South American Public Universities. *Scientometrics*, **127**, 6391-6411. https://doi.org/10.1007/s11192-022-04523-2

[15] Fernández, A., Ferrándiz, E. and León, M.D. (2020) Are Organizational and Economic Proximity Driving Factors of Scientific Collaboration? Evidence from Spanish Universities, 2001-2010. *Scientometrics*, **126**, 579-602. https://doi.org/10.1007/s11192-020-03748-3

[16] Darmadji, A., Prasojo, L.D., Kusumaningrum, F.A. and Andriansyah, Y. (2018) Research Productivity and International Collaboration of Top Indonesian Universities. *Current Science*, **115**, 653-658. https://doi.org/10.18520/cs/v115/i4/653-658

[17] Payumo, J., Sutton, T., Brown, D., Nordquist, D., Evans, M., Moore, D., *et al.* (2017) Input-Output Analysis of International Research Collaborations: A Case Study of Five U.S. Universities. *Scientometrics*, **111**, 1657-1671. https://doi.org/10.1007/s11192-017-2313-2

[18] Jones, B.F., Wuchty, S. and Uzzi, B. (2008) Multi-University Research Teams: Shifting Impact, Geography, and Stratification in Science. *Science*, **322**, 1259-1262. https://doi.org/10.1126/science.1158357

[19] Ray, W. and Solem, M. (2009) Gauging Disciplinary Engagement with Internationalization: A Survey of Geographers in the United States. *Journal of Geography in Higher Education*, **33**, 103-121. https://doi.org/10.1080/03098260802276425

[20] Glanzel, W. (2001) National Characteristics in International Scientific Co-Authorship Relations. *Scientometrics*, **51**, 69-115. https://doi.org/10.1023/a:1010512628145

[21] Maisonobe, M., Eckert, D., Grossetti, M., Jégou, L. and Milard, B. (2016) The World Network of Scientific Collaborations between Cities: Domestic or International Dynamics? *Journal of Informetrics*, **10**, 1025-1036. https://doi.org/10.1016/j.joi.2016.06.002

[22] Persson, O., Glänzel, W. and Danell, R. (2004) Inflationary Bibliometric Values: The Role of Scientific Collaboration and the Need for Relative Indicators in Evaluative Studies. *Scientometrics*, **60**, 421-432. https://doi.org/10.1023/b:scie.0000034384.35498.7d

[23] Leydesdorff, L. and Wagner, C.S. (2008) International Collaboration in Science and the Formation of a Core Group. *Journal of Informetrics*, **2**, 317-325. https://doi.org/10.1016/j.joi.2008.07.003

[24] Sooryamoorthy, R. (2013) Publication Productivity and Collaboration of Researchers in South Africa: New Empirical Evidence. *Scientometrics*, **98**, 531-545. https://doi.org/10.1007/s11192-013-0990-z

[25] Abramo, G., D'Angelo, C.A. and Di Costa, F. (2018) The Collaboration Behavior of Top Scientists. *Scientometrics*, **118**, 215-232. https://doi.org/10.1007/s11192-018-2970-9

[26] Morillo, F. (2019) Collaboration and Impact of Research in Different Disciplines with

International Funding (from the EU and Other Foreign Sources). *Scientometrics*, **120**, 807-823. https://doi.org/10.1007/s11192-019-03150-8

[27] Wagner, C.S. and Jonkers, K. (2017) Open Countries Have Strong Science. *Nature*, **550**, 32-33. https://doi.org/10.1038/550032a

[28] Geng, H., Wu, Y. and Shi, X. (2022) International Collaboration and Research Organization Performance: Evidence from China. *Asian Economic Papers*, **21**, 60-77. https://doi.org/10.1162/asep_a_00856

[29] Gingras, Y. and Khelfaoui, M. (2017) Assessing the Effect of the United States "Citation Advantage" on Other Countries' Scientific Impact as Measured in the Web of Science (WoS) Database. *Scientometrics*, **114**, 517-532. https://doi.org/10.1007/s11192-017-2593-6

[30] Wagner, C.S., Bornmann, L. and Leydesdorff, L. (2015) Recent Developments in China-U.S. Cooperation in Science. *Minerva*, **53**, 199-214. https://doi.org/10.1007/s11024-015-9273-6

[31] McManus, C., Baeta Neves, A.A., Maranhão, A.Q., Souza Filho, A.G. and Santana, J.M. (2020) International Collaboration in Brazilian Science: Financing and Impact. *Scientometrics*, **125**, 2745-2772. https://doi.org/10.1007/s11192-020-03728-7

[32] Sud, P. and Thelwall, M. (2015) Not All International Collaboration Is Beneficial: The mendeley Readership and Citation Impact of Biochemical Research Collaboration. *Journal of the Association for Information Science and Technology*, **67**, 1849-1857. https://doi.org/10.1002/asi.23515

[33] Gazni, A. and Didegah, F. (2011) Investigating Different Types of Research Collaboration and Citation Impact: A Case Study of Harvard University's Publications. *Scientometrics*, **87**, 251-265. https://doi.org/10.1007/s11192-011-0343-8

[34] Zhang, Z., Rollins, J.E. and Lipitakis, E. (2018) China's Emerging Centrality in the Contemporary International Scientific Collaboration Network. *Scientometrics*, **116**, 1075-1091. https://doi.org/10.1007/s11192-018-2788-5

[35] Kwiek, M. (2020) Internationalists and Locals: International Research Collaboration in a Resource-Poor System. *Scientometrics*, **124**, 57-105. https://doi.org/10.1007/s11192-020-03460-2