

STI 2018 Leiden

*23rd International Conference on Science and Technology Indicators
"Science, Technology and Innovation Indicators in Transition"*

STI 2018 Conference Proceedings

Proceedings of the 23rd International Conference on Science and Technology Indicators

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ISBN: 978-90-9031204-0

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China’s increasing leadership in scientific collaboration¹

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Introduction

China has become increasingly active in research over the last 3 decades, as the growing Chinese economy was accompanied by a gradual increase of scientific R&D investments (Ma, Lee, and Chen 2009). China’s R&D funding actually increased from 1.42 to 2.1% of the GDP between 2006 and 2016, which likely explains the growth of China’s research output. International collaboration also played an important role in China’s publication growth (Arunachalam, Srinivasan, and Raman 1994). In 2016, the 25,8% of Chinese publications were coauthored with other countries (Statistical Data of Chinese S&T Papers 2016, 2017). This changing role of China in the global scientific community has stirred the interest of scholars both in China and abroad who have investigated those trends at the level of countries, institutions and disciplines (Wang et al. 2013c).

Arunachalam’s study showed that China increasingly collaborated with other Asian countries and the advanced countries from 1990s (Arunachalam, Srinivasan, and Raman 1994), most of those collaborations involving the US. They also compared China and India and found that both countries collaborations with US were mostly in the field of physics and much less frequent in other disciplines. They also found that India collaborated with the US more than China in chemistry. They also found that, while China collaborates with more than 150 countries and regions, the growth of its international collaboration remains lower than that of its total publications; a finding that was confirmed by Zhou and Glänzel (2010). He (2009) investigated the international scientific collaboration of China with the G7 countries, US is the most important collaboration country and the international collaboration between China and the G7 countries display differences at each research field (He, 2009). The level of international collaboration in China varies by collaborating country, US scholars contributing to the larger share of Chinese collaborative papers. One factor explaining this is that collaboration with US scholars may be useful for Chinese scholars to have success in the beginning of their careers (Amjad et al. 2017). The level of international collaboration also varies by field, the highest levels of international collaboration occurring in the natural sciences (especially physics and engineering).

¹ This work was supported by Wuhan University Scholarship Fund and Yu Gang-Song Xiao scholarship from Wuhan University, China, and MERIT SCHOLARSHIP PROGRAM FOR FOREIGN STUDENTS(PBEEE)-Québec-China¹⁶ Short-term research or professional development scholarships (3C), and China Scholarship Council (CSC).

At the institutional level, it has been shown that the growth of Chinese research output (Quan, Chen, and Shu 2017) and international collaboration has been mainly driven by universities, with Zhejiang University, Peking University and Tsinghua University displaying the highest levels of international collaboration (Wang et al. 2013a). A report entitled *China's International Scientific Collaboration Status: A Bibliometrics Study* (Wang et al, 2017) showed that half of the most important institutions with which Chinese researchers collaborate are in the US. The same report also showed that Chinese papers written in collaboration with those 20 main collaborators yielded a significantly greater share of highly cited papers than the world average.

At the level of disciplines, China has been found to be a major player in fields like nanotechnology (Tang and Shapira 2011, Zhou and Leydesdorff 2006). A surge in China–US co-authored nanotechnology papers was also observed (Tang and Shapira 2011). Along these lines, Jin et al (2007) analyzed the collaboration trend between China and the United States in 44 research areas of nanotechnology, chemistry, genetics, and cell biology, while other focused on other fields such as fisheries (Jing et al., 2012) as well as humanities and social sciences (Liu et al., 2010). The fields in which China produces the most papers also tend to be those with higher level of collaboration.

While many of the previous studies investigated China's level of international collaboration, none has compared the papers that are led by Chinese authors and those that are led by their international collaborators. They also often analyzed publication data over a short period of time. Finally, most studies remained at the disciplinary level, without digging deeper into more precise research areas in which the international collaboration takes place. This paper aims contribute to filling these gaps by providing answers to the following research questions:

- What is the evolution of China's international collaboration from 1980 to 2016?
- What are China's main countries of collaboration?
- In what research areas do Chinese scholars collaborate internationally?
- How does China's international leadership is evolving?
- What is the relation between international collaboration and the scientific impact of Chinese papers?

Data and Methods

We use the Web of Science Core Collection (SCI, SSCI, A&HCI) to identify the China's international collaboration patterns. All articles, notes and reviews published between 1980 and 2016 and with at least one author affiliated to a Chinese institution are retrieved from the WoS relational database hosted by the *Observatoire des sciences et des technologies*. Each article in our dataset is assigned to one of 14 disciplines and one of 144 specialties following the NSF journal classification. The discipline and specialty are thus based on the journal in which the paper is published. We analyses the data at the specialty level in order to provide an answer to our third research question. The first author typically plays a significant role in the research (Rennie, Yank, and Emanuel 1997, Larivière et al., 2016), and the corresponding author is usually dealing with the submission process and all communications with the journal and the readers (Mattsson, Sundberg, and Laget 2011).

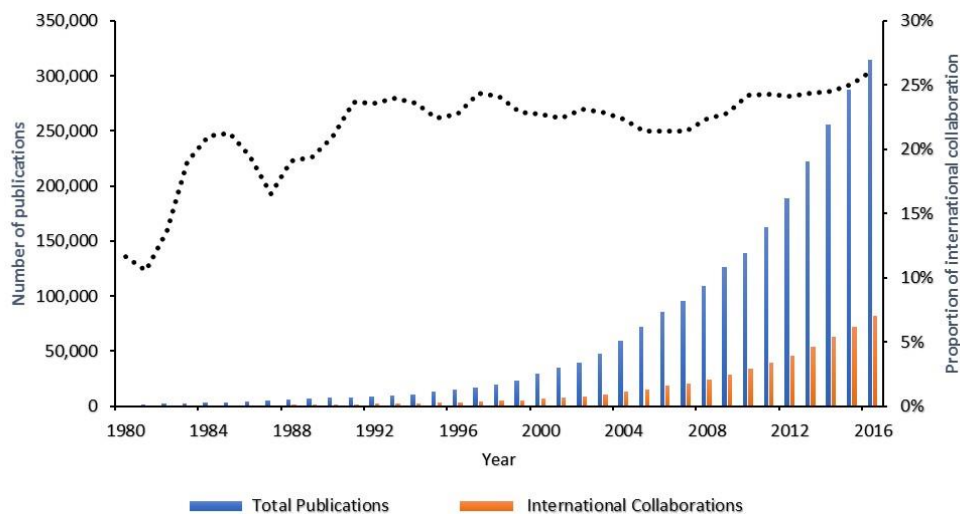
In this paper, *China as leader* thus refers to co-authored papers in which the first or corresponding author is affiliated to a Chinese institution. The term *China as participant* refers to co-authored papers in which the author(s) affiliated to a Chinese institution are neither first nor corresponding author. On the whole, the dataset includes 2,436,247 of which 581,919 are international collaborations and 399,688 of which China plays a leadership role.

Results

Growth of international collaboration

Figure 1 shows the evolution of the Chinese scientific output as well as the raw and relative number of papers in international collaboration. While the 1980s were characterized by a growth of international collaboration in China, the results show that the proportion of papers in international collaboration remained decreased after the early 1990s, then started to increase again in 2005, from about 21% to 26% in 2016. This suggests that most of the growth of China's scientific production is due to an increased research capacity (endogenous growth) and not driven by increased collaboration (exogenous growth), although international collaborations are increasingly important since 2005.

Figure 1: Proportion and number of China's international publications and international collaborative publications (1980-2016).



What countries collaborate with China?

Although China now ranks second in terms of scientific output according to WoS (it ranks first in Scopus), the country had very low international scientific visibility until not so long ago. Figure 1, we find that in China had very few scientific publications indexed in western databases in the 1980s. For example, the US had 175,778 publications in 1980, while China only had 413. Similarly, Figure 1 suggests that an increase in international collaboration in the 1980s preceded the important growth of China's scientific output in the following decades.

Ninety-five percent (95%) of China's collaborations are with the countries in Figure 2. The X axis is the number specialties in which China has at least one paper in collaboration with the country and the Y axis is the number of papers in collaboration. The bubbles' size is also determined by the number of collaborations. We see that the US is by far the most important collaborator of China, followed by other countries with an important research output (e.g., the United Kingdom, Germany, Canada) as well as those who are geographically closer to China (e.g., Japan, South Korea, Australia).

Figure 2: China’s top international collaborators from 1980 to 2016.

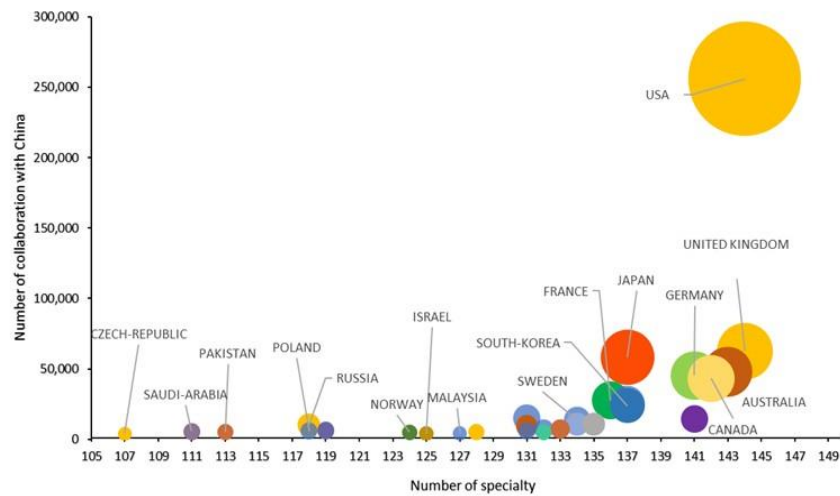
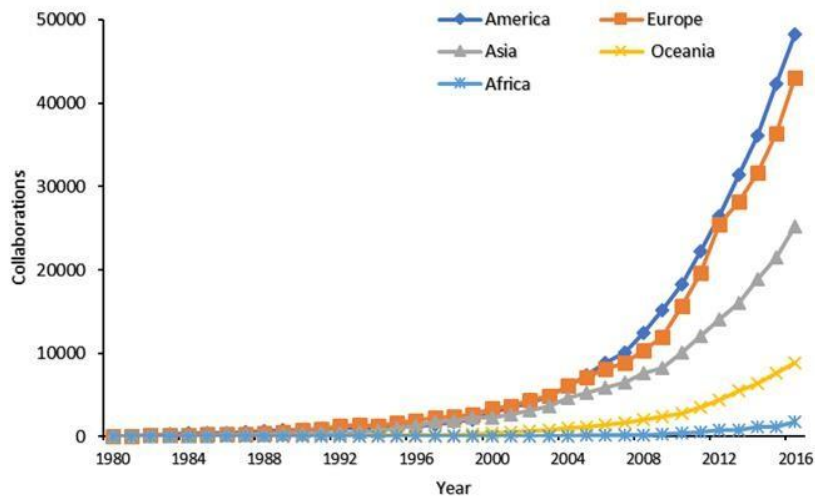


Figure 3 presents the evolution of China’s international collaboration by region over the 1980 to 2016 period. It shows that China mainly collaborated with America and Europe in the 1980s. Its collaboration network expanded to Asia and Oceania in the 1990s, then to Africa in the 2010s. The growth of China’s scientific output was thus not only accompanied with a growth of international collaboration, but also with a diversification of collaboration partners from around the globe.

Figure 3: Number of China’s scientific collaborations by region.



In what research areas are Chinese scholars leading international collaborations?

Table 1 displays the number and share of articles in international collaboration by specialty as well as the share of those collaborations in which a Chinese author plays a leading role (first or corresponding author). The twenty specialties in which China as the highest number of papers in international collaboration are displayed on the left side of the table. We see that China is mainly active and collaborating in natural sciences and engineering, but that these collaborations constitute a minority of the overall Chinese output in these fields. The Chinese authors also play more often than not a leading role in these collaborations, except in some fields such as General Physics, Biochemistry & Molecular Biology, Neurology & Neurosurgery and Cancer.

Table 1. China's top 20 collaborative specialties ranked by collaboration number (left) and rate (right) from 1980 to 2016.

Specialty	International collaborations	Collaboration rate	China as leader	Specialty	International collaborations	Collaboration rate	China as leader
Materials Science	34859	21.35%	63.78%	Demography	194	70.04%	33.20%
Electrical Engineering & Electronics	27198	28.37%	62.91%	Psychoanalysis	2	66.67%	0.00%
General Biomedical Research	25041	28.57%	54.85%	Experimental Psychology	754	66.43%	42.91%
Physical Chemistry	22050	15.69%	57.95%	Social Sciences, Biomedical	220	66.07%	41.11%
General Physics	21222	16.42%	35.36%	Developmental & Child Psychology	593	63.90%	29.55%
Computers	19940	31.39%	68.13%	Addictive Diseases	346	58.45%	38.35%
Applied Physics	17951	25.39%	52.29%	Anthropology and Archaeology	385	54.92%	38.98%
General Chemistry	17130	13.84%	63.92%	Economics	5039	54.24%	50.79%
Environmental Science	16431	29.31%	64.23%	Management	8287	53.51%	50.73%
Biochemistry & Molecular Biology	16147	27.83%	48.25%	Allergy	232	53.33%	15.95%
Botany	13567	31.73%	55.63%	Miscellaneous Psychology	774	53.01%	49.49%
Neurology & Neurosurgery	12132	31.10%	47.21%	Miscellaneous Professional Field	1209	52.91%	63.10%
Agriculture & Food Science	12088	31.26%	62.86%	Public Health	1651	52.55%	41.95%
Cancer	11650	24.73%	39.17%	Physiology	1794	52.30%	30.80%
Optics	11647	18.18%	60.34%	Geography	892	51.18%	48.04%
Earth & planetary Science	11593	38.57%	56.29%	Environmental & Occupational Health	2427	50.87%	37.20%
Applied Mathematics	11379	23.50%	62.51%	Psychiatry	1835	50.68%	34.75%
General Mathematics	11229	20.94%	58.83%	Human Factors	524	50.53%	61.32%
Mechanical Engineering	10487	20.91%	66.10%	Health Policy & Services	670	50.49%	42.18%
Pharmacology	10391	21.00%	52.90%	Astronomy & Astrophysics	6773	49.36%	28.84%

The twenty specialties in which the biggest share of China's publications involve international collaboration are listed on the right side of table 2. These are specialties where China publishes a small number of papers which are in most cases international collaborations led by scholars from other countries. Overall, the results presented in Table 1 suggest China has become a leader in certain fields (mainly Natural Sciences) and is able to produce a lot of publications without having to collaborate. Inversely, the specialties where the collaboration rates are the highest are typically fields in which China is not very active and mostly plays a participant role in the collaborations.

Who leads international collaborations?

Figures 4 and 5 show the evolution of the proportion of international collaboration in which China played a leading role by discipline. In the Natural Sciences (Figure 4), we see that China's leading role

was slightly declining in the 80s, but has continuously increased since the beginning of the 1990s, except in physics, which might be due to China's increasing participation in international big science projects. Figure 5 shows the same trend but for the Social Science, starting in 1990 instead of 1980 since the number of publications was too small in these disciplines at the time. Also, because China only has few publications in Arts and Humanities, those two disciplines are been excluded from figure 5.

Figure 4: China's leadership of international collaborations by discipline from 1980-2016.

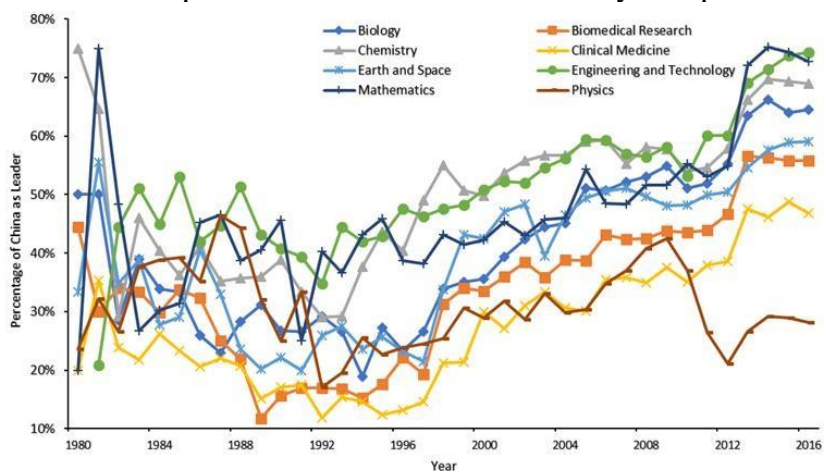
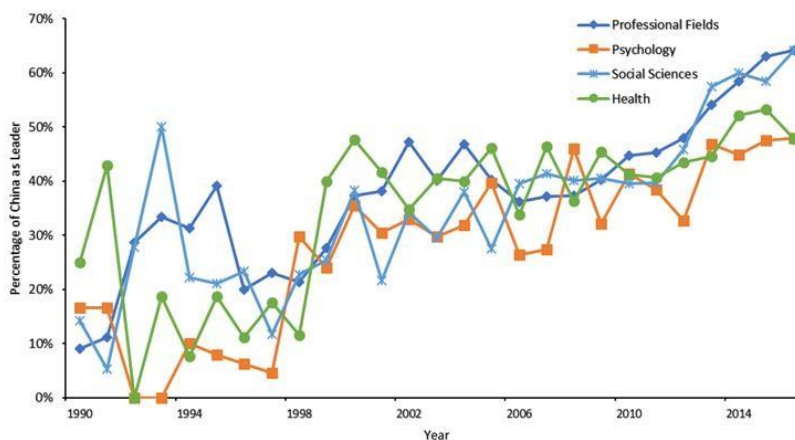


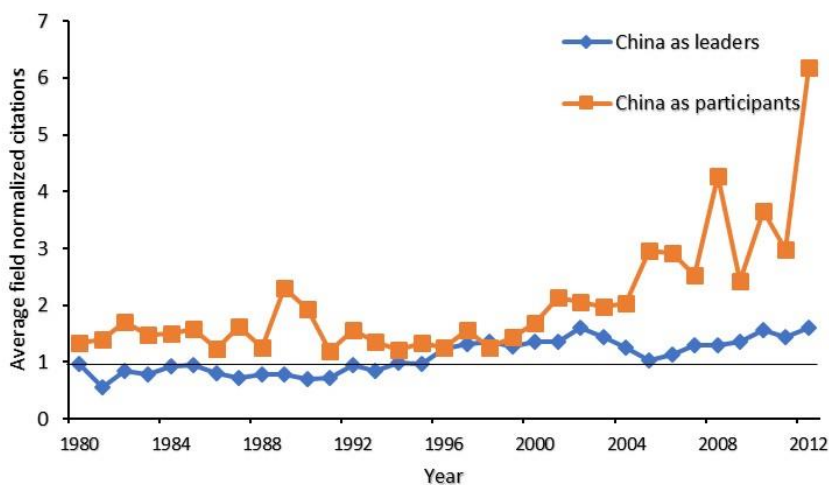
Figure 5: China's leadership of international collaborations by discipline from 1980-2016.



How do citations relate to leadership?

To determine whether leadership of international collaborations is related to higher or lower citation rates, analyzed the average of relative citations of collaborative articles led by china or led by a collaborator (Figure 6). A value of 1 is the baseline: a value above 1 indicates that a paper has received citations than the average for all papers in the same field. The results show that papers in which China has a leading role are less cited then those where China is a participant.

Figure 6: China's average 5-year field normalized citations from 1980 to 2012.



Conclusion

This paper analyzed WoS publications to provide a portrait of international collaboration in China over the 1980-2016 period. The tremendous growth of Chinese scientific output was first accompanied by a steep increase of the level of international collaborations in the 1980s. The level of collaboration then stabilized in the 1990s, and then increased over the last 10 years studied, as China quickly became one of the most productive country in terms of scientific output. We also found that the share of international collaboration in which the Chinese researchers play a leading role varies between disciplines: China plays a leading mostly in the disciplines in which the country publishes the most. This may indicate that China's scientific development had not fully reached maturity yet in some disciplines. Our results also show that international collaborations in which China plays a leading role tend to have lower citation impact than those collaborations led by researchers in other countries. One limitation of our study is that we do not consider mobility patterns influenced China's international collaboration. China is one of the countries to which the largest number of mobile researchers are associated (Robinson-Garcia et al. 2018), but the difficult disambiguation of Chinese names limits the in-depth study of Chinese scholars' mobility. Further analyses will aim at including mobility to better understand international collaboration patterns.

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