CHAPTER

1 Scholarly output and academic impact of nanoscience

Key findings

4.2%
of global scholarly output were nano-publications (2000–19).

2,211,585
authors published nano-publications (2000–19).

1.6
was the field-weighted citation impact for nano-publications, which was 1.6 times the world average (2000–19).

28.8
citations per paper were received by nano publications, which is 48% more than the world average (2000–19).

11%
of output in the top 1% citations was nano-related (2000–19).

25%
of output in the top 1% citations in China was nano-related (2000–19).

The growth rate of nanoscience was several times the average for many key indicators, which reflects the full flourishing of nanoscience (Table 1.1).

Big Data Analysis of Nanoscience Bibliometrics, Patent, and Funding Data (2000–2019)
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Table 1.1 Global totals for nano-related authors, scholarly output, and output in top 1% highly cited publications (2000–19).

Nano-related	2000–19 overall number (share)	Number in 2000 (share)	Number in 2019 (share)	Growth rate of 2019 compared with 2000	CAGR of nano-related items (2000–19)	CAGR of nano-related items/CAGR of all fields' items
Author counts	2,211,585 (5.2%)	32,591 (2.5%)	498,948 (10.9%)	1,431%	15.4%	2.3
Scholarly output	1,418,496 (4.2%)	11,555 (1.1%)	153,455 (6.2%)	1,228%	14.6%	3.2
Top 1% highly cited publications	54,052 (11%)	585 (4.2%)	5393 (13.6%)	374%	8.5%	1.5

CAGR, *compound annual growth rate.*
From Scopus.

1.1 Overview of scholarly output and academic impact of nanoscience

This section provides an evaluation of global nano-related research output and its academic impact between 2000 and 2019. Assessment indicators include scholarly output, citation count, author count, field-weighted citation impact (FWCI), and publication output in the top 1% citations. Details about the definitions of these indicators and values can be found in Appendix A. Further information about the data is presented in Fig. 1.1.

Based on these data on nanoscience academic output and impact, further findings are presented subsequently.

(1) Nanoscience contributed significantly to global scientific research. The global share of nanoscience research output was relatively high: 4.2% of global research output was related to nanoscience. Approximately 1.4 million publications in nanoscience (nano-publications) had a total citation count about 40.9 million, contributing to 6.4% of all citations worldwide.

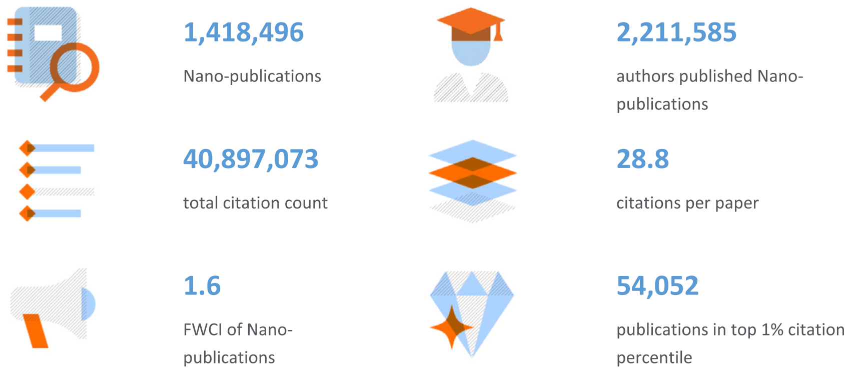

FIGURE 1.1

Overall nanoscience scholarly output and impact in the world (2000–19). *FWCI*, field-weighted citation impact.

From Scopus.

(2) The FWCI of nano-publications was higher than that of the world average. A citation refers to the source of information, such as academic literature, used in other research work. The citation count is one of the most widely recognized indicators for evaluating academic impact. However, assessing a publication's influence is challenging because of differences in citation practices across fields, publication years, and document types. To address the issue, Elsevier developed a standardized impact indicator, the FWCI, to appraise research academic impact of publications. This book includes relative indicators, such as citations per publication and highly cited publications, to present full academic impact of nanoscience.

Some overall statistics from 2000 to 2019 are:

- Whereas the global average FWCI was 1, the FWCI of nano-publications worldwide was 1.6, indicating that nano-publications' academic impact was 1.6 times the global average.
- Citations per paper for nano-publications totaled 28.8, 48% higher than the world average, which was 19.4.
- Of the top 1% highly cited publications, 11% were nano-related, for a total of 54,052 publications.

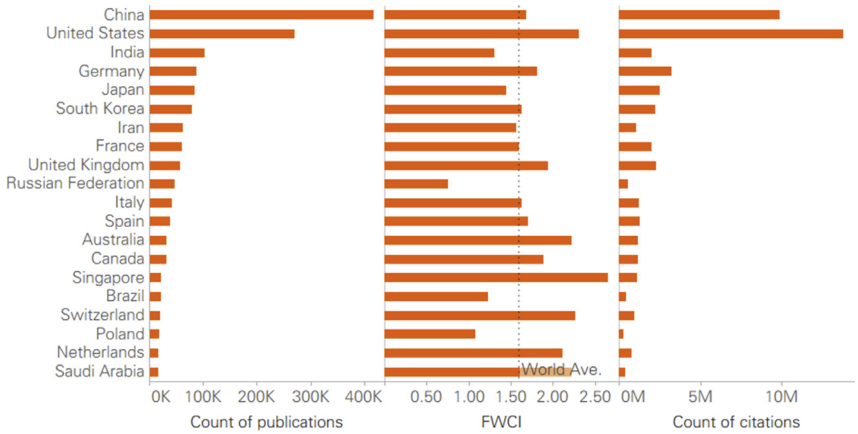

FIGURE 1.2

Top 20 countries by nano-publication output (2000—19). *Ave.*, Average; *FWCI*, field-weighted citation impact.

From Scopus.

(3) China ranked first for nano-publication output worldwide. Among the 20 countries with the highest scholarly outputs in nanoscience between 2000 and 2019, the top five were China, the United States, India, Germany, and Japan (Fig. 1.2). The five countries' nano-publications accounted for 29.4% (416,554 publications), 19% (269,747 publications), 7.3% (102,904 publications), 6.1% (87,164 publications), and 5.9% (54,079 publications) of global nano-publications, respectively.
Between 2000 and 2019, the top five among the 20 countries with the highest FWCI scores for nano-publications were Singapore (2.65), the United States (2.31), Switzerland (2.26), Australia (2.22), and the Netherlands (2.12). In the same period, the average world FWCI of nano-publications was 1.6. However, the output volumes of nano-publications in Switzerland, the Netherlands, and Singapore were lower than for other leading countries.
The top five countries by total citation count were the United States (13,762,200), China (9,854,878), Germany (3,222,746), Japan (2,498,856), and the United Kingdom (2,270,916). To provide a comprehensive comparison based on the volume and impact of academic output in nanoscience across countries between 2000 and 2019, the book selected these five countries as the key comparators for further analysis.

1.2 Trends in scholarly output in nanoscience

The number of nano researchers worldwide is rising

Research talent is a crucial element for science advancement. This section assesses current developments in nanoscience by analyzing publication authors. Refer to Appendix A for descriptions of the statistical methods used.

The number of authors who published nano-publications continued growing between 2000 and 2019 (Fig. 1.3), indicating a rise in scientists engaged in nanoscience-related work or integrating nanotechnology into their field. The total number of authors publishing nano-related research grew from 32,591 in 2000 to 498,948 in 2019, accounting for 2.5% and 10.9%, respectively, of the researcher population worldwide. Over the past 2 decades, the compound annual growth rate (CAGR) of authors in nanoscience was 15.4%, which was 2.3 times the global CAGR.

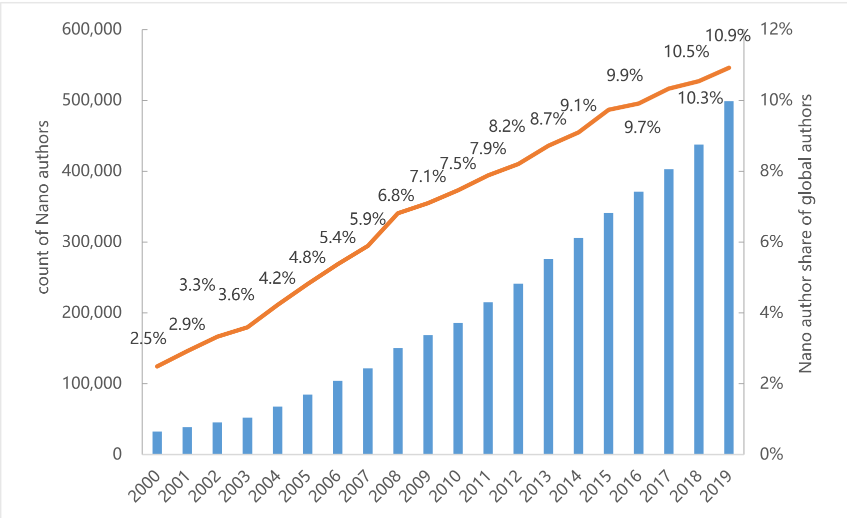

FIGURE 1.3

Number and global share of authors with nano-publications (2000–19).

From Scopus.

Nano-related academic output is rising

In this book, academic output is measured by the number of nano-publications. The volume of global nano-related output proliferated between 2000 and 2019, its share of worldwide research output rose as well. The number of nano-publications increased from 11,555 in 2000 to 153,455 in 2019, accounting for 1.1% and 6.2%, respectively, of global publications in each year (Fig. 1.4). Whereas the CAGR for global publications was 4.5%, the CAGR of nano-publications in the past 2 decades was 3.2 times higher, at 14.6%.

The nano-related academic output and impact of key countries (China, Germany, Japan, the United States, and the United Kingdom) are analyzed in this book. In general, the number of nano-publications in each key country grew steadily. The CAGR of nano-publications in these countries exceeded each country's average CAGR for all academic output (Fig. 1.5). The analysis shows the rapid development of nanoscience in these countries.

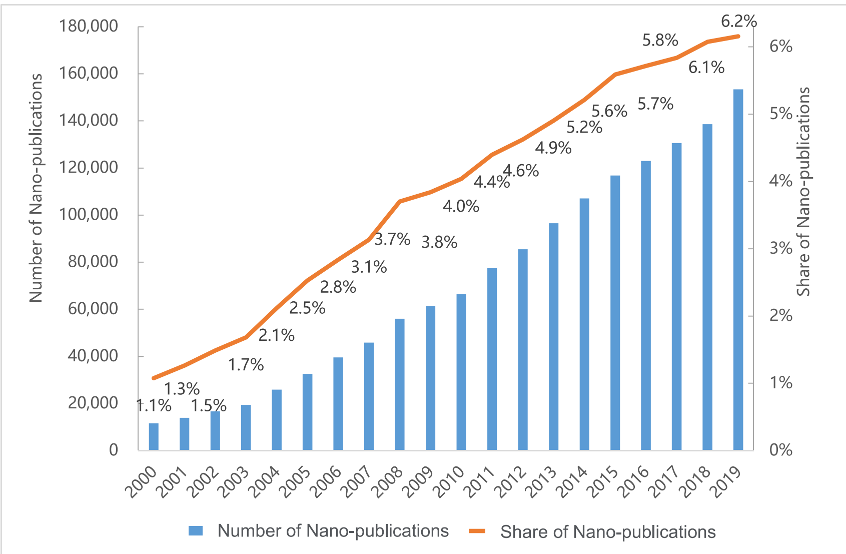

FIGURE 1.4

Number and global share of nano-publications (2000–19).

From Scopus.

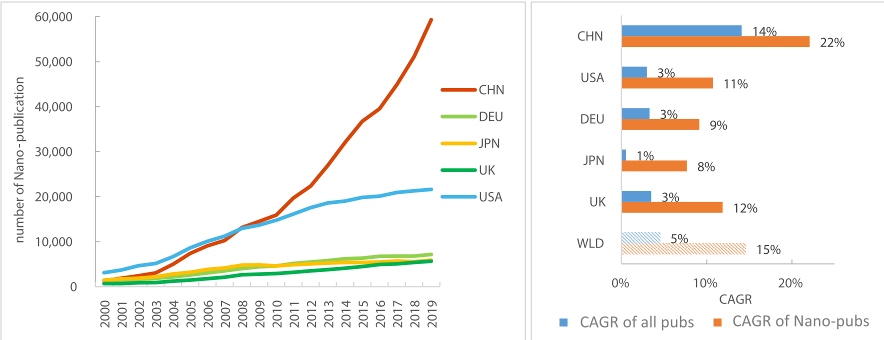

FIGURE 1.5

Scholarly output (left) and compound annual growth rate (CAGR) (right) of nano-publications in key countries (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

China had the highest growth rate for the number of nano-publications among the comparators (Fig. 1.5), and its output accounted for the highest percentage of global nano-publications. China's nanoscience publications grew from 1,341 in 2000 to 59,349 in 2019, which accounted for 11.6% and 38.7% of nano-publications worldwide for each year. The CAGR of China-published nanoscience research was 22%, which was 1.6 times the nation's total academic output growth rate (CAGR = 14%). Over the same period, the amount of US-published nanoscience output increased from 3,115 in 2000 to 21,608 in 2019, accounting for 27% and 14.1% of nano-publications worldwide, with a CAGR of 12%. The growth rate in the field was four times the average of the growth rate for all publications in the United States (CAGR = 3%) in the same period.

The analysis showed that the percentage of nano-publications from China had been continuously growing (Fig. 1.6). The share of nano-publications also varied in each country (Fig. 1.7), the result of different focuses of high-yield research in each country. Statistics from the Scopus database for 2000–19 indicate that the biggest four research fields in China were engineering, materials science, physics and astronomy, and chemistry, which are subjects closely related to

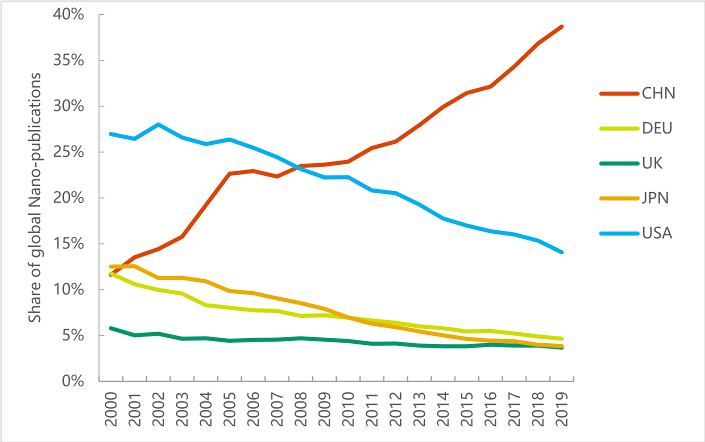

FIGURE 1.6

Share of global nano-publications per country (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

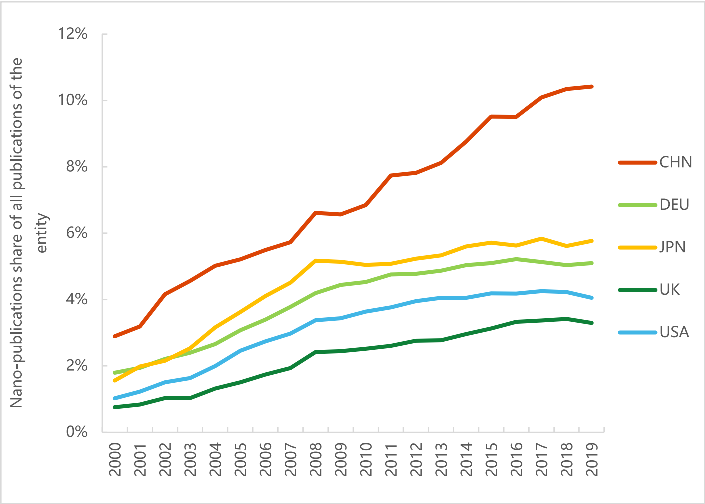

FIGURE 1.7

Nano-publications' share of all publications per country (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

nanoscience. In the United States, fields with the highest academic output were medicine and biochemistry, genetics, and molecular biology. To date, nano-related research in these fields is less than in engineering, materials science, physics and astronomy, and chemistry. Similar disciplinary differences were also existed in Germany, the United Kingdom, and Japan.

1.3 Trends in the academic impact of nanoscience

Nano-publications scored a higher field-weighted citation impact than the global average, and China's field-weighted citation impact of nano-publications had steadily increased

FWCI is an indicator of the citation impact of a publication. It is calculated by comparing the number of citations received by a publication with the number of citations expected to be received by a publication of the same document type, publication year, and subject. An FWCI of more than 1.00 indicates that the entity's publications have been cited more than would be expected based on the global average for similar publications. For example, an FWCI of 2.11 means the publications of the entity in question were cited 111% more than the world average. For further details about this indicator, please refer to Appendix A.

Between 2000 and 2019, the overall FWCI of nanoscience publications declined slightly. However, the FWCI scores increased slightly between 2015 and 2019. In addition, the figures were higher than the worldwide average for all publications (Fig. 1.8). The decline in the FWCI of global nano-publications resulted from the rapid growth in new nano-research, in which accumulated nano-publications outnumbered accumulated citations (Fig. 1.9). This drop in impact is a common occurrence when there is high growth of publication output. In the early development stages of nanoscience, in 2000–05, many high-profile publications that were considered to be classics were cited intensively, spiking the FWCI of nano-publications in the early days.

At the national level for China, the nano-publication FWCI increased from 1.3 in 2000 to 2.9 in 2019, achieving a 43% growth

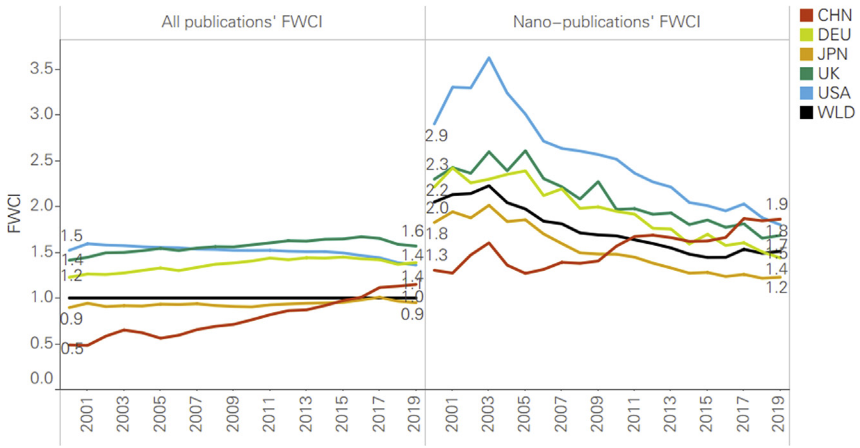

FIGURE 1.8

Trends in nano-publication field-weighted citation impact (FWCI) for the world and leading countries (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

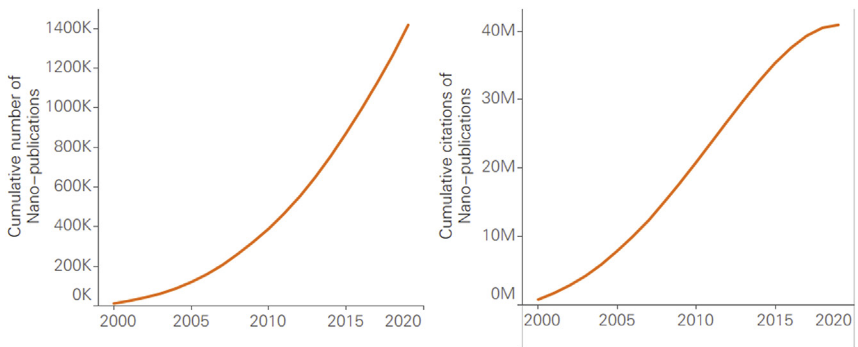

FIGURE 1.9

Trends in accumulated scholarly output and citation count of global nano-publications (2000–19).

From Scopus.

over the two decades. Nano-related research has driven the increase in the overall FWCI in China, contributing significantly to China's academic research impact. The FWCI of US nano-publications remained relatively high between 2000 and 2005 and has declined since then. However, the United States still has the highest impact for nano-publications among the key countries. In 2019, China surpassed the United States in the nano-publication FWCI score, but the United States still holds a higher average FWCI than Germany, Japan, the United Kingdom, and the other countries.

The share of citations contributed by nano-publications is increasing

The citation count is a widely adopted direct indicator for measuring the academic impact of scientific research output. It reflects the degree of a scientific publication's impact on other publications. However, the publication's volume can influence the citation count, and the number of citations also increases over time. To reduce this bias, the citation rate (the citation count of the country's nano-publication/overall citation count in the country) was applied to measure nano-publications' citation performance for the world and key countries. Nano-publication citation trends were as follows (Fig. 1.10):

- In key countries and worldwide, the citation rate continued to increase, indicating a growing significance in nano-publications' contribution to the citation system.

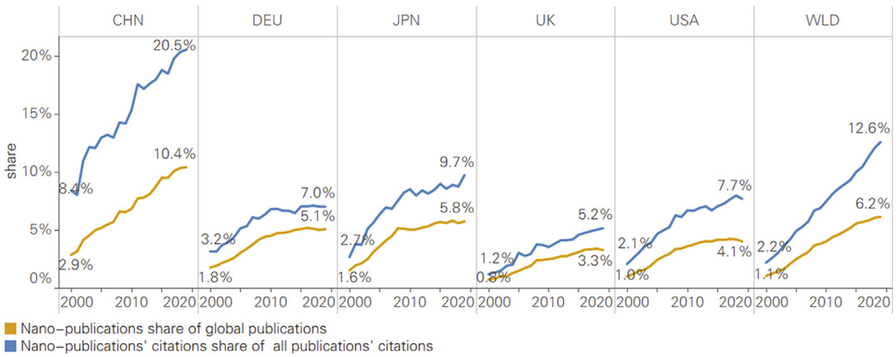

FIGURE 1.10

Percentage of scholarly output and citation count for the world and leading countries (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

- Nano-publications contributed more to the citation count than to the publication count. For example, whereas 6.2% of publications worldwide were related to nanoscience in 2019, these publications accounted for 12.6% of the global citation count.

About 13.6% of nano-publications were in the top 1% highly cited publications worldwide, a much higher percentage than all other fields combined

The top 1% highly cited publications refers to publications with citation counts reaching the top 1% of all publications worldwide on the subject, demonstrating the publishing entity's significant academic impact. In this section, the number and share of nano-publications with citation counts in the top 1% were evaluated to reflect nanoscience's importance in academic research.

Between 2000 and 2019, 11% of the world's top 1% highly cited publications were nano-publications, and the percentage gradually increased every year (Fig. 1.11). In 2000, 4.2% of the top 1% highly cited publications were related to nanoscience.

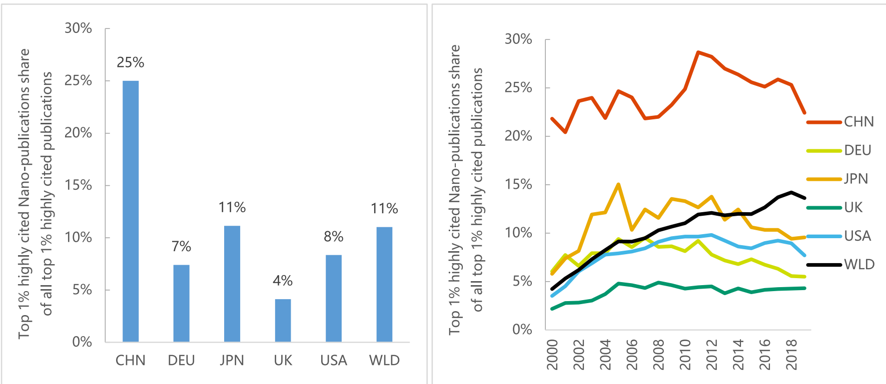

FIGURE 1.11

Nano-publications' share and trend in top 1% highly cited publications worldwide (2000—19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

From Scopus.

For the key comparator countries, nanoscience research has been crucial for the output of high-impact research. In China, 25% of the top 1% most cited publications were related to nanoscience research over the study period, demonstrating the vital contribution of nanoscience to China's academic excellence in research output.

1.4 Analysis of institutional academic research output and impact on nanoscience

Institutions are essential components of nano-research. In this section, we provide an overview and analysis from the perspective of leading institutions with high publication yields.

Top 20 institutions by number of nano-publications

The top 20 institutions[1] with the highest nano-publication output in 2010–2019 were selected for a comparative analysis of their research output and academic impact on nanoscience. Of these top 20 institutions, 11 were from China (Fig. 1.12). Among them, the Chinese Academy of Sciences (CAS) ranked first globally, with 49,441 nano-publications, followed by the French National Center for Scientific Research, with 25,266 nano-publications. The University of California system, including 11 branches, ranked third. The University of the Chinese Academy of Sciences ranked fourth, and the Russian Academy of Sciences fifth.

Academic impact as measured by the FWCI showed that 17 institutions among the top 20 had higher FWCI scores than the global average for nano-publications. The University of Science and Technology of China and Fudan University ranked fourth and fifth, whereas CAS ranked ninth. The positive correlation between the share

[1] Eleven University of California campuses and 98 Max Planck Society institutes were combined to participate in the rankings.

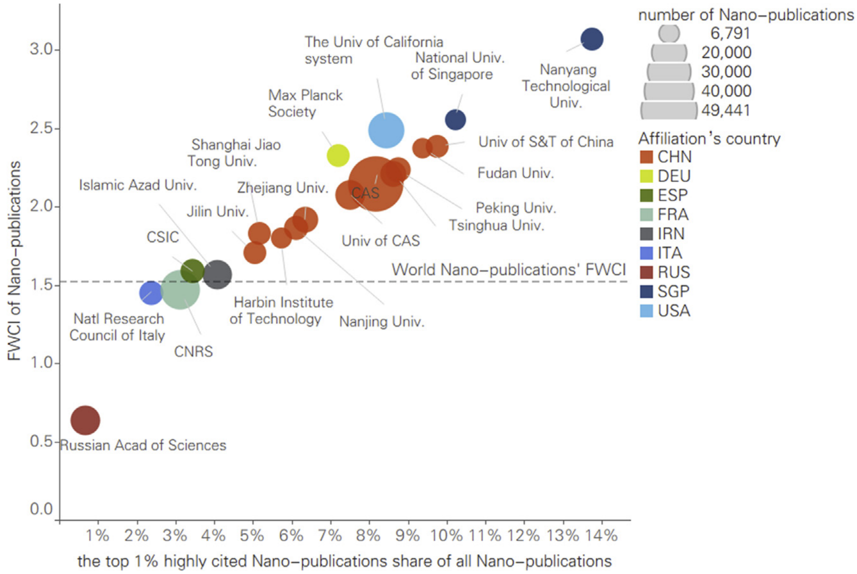

FIGURE 1.12

Scholarly output and academic impact of nano-publications of top 20 institutions (2010–19). *AUS*, Austria; *BRA*, Brazil; *CAN*, Canada; *CHE*, Switzerland; *CHN*, China; *DEU*, Germany; *ESP*, Spain; *FRA*, France; *IND*, India; *IRN*, Iran; *ITA*, Italy; *JPN*, Japan; *KOR*, Korea; *NLD*, The Netherlands; *POL*, Poland; *RUS*, Russia; *SGP*, Singapore; *TWN*, Taiwan; *UK*, United Kingdom; *USA*, United States.

From Scopus.

of the top 1% highly cited publications and the FWCI illustrates the significant role of highly cited publications in enhancing institutions' academic influence.

In addition, research in nanoscience had a crucial role in these institutions' academic impact and research output. Take Chinese institutions as an example (Fig. 1.13), 8% to 17% of their academic research yield was related to nanotechnology, and 13% to 27% of their citations were from nano-publications.

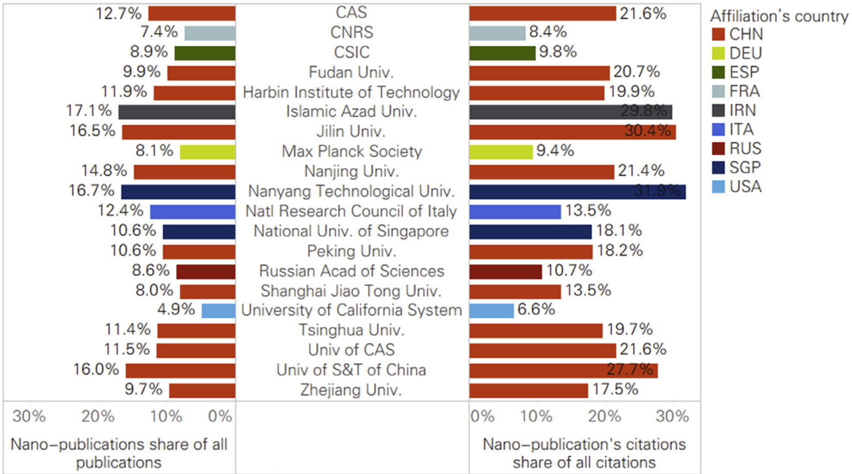

FIGURE 1.13

Nano-publications' share of total scholarly output and citation count at institution level (2010–19), by number of nano-publications. *CAS*, Chinese Academy of Sciences; *CHN*, China; *CNRS*, French National Center for Scientific Research; *CSIC*, Spanish National Research Council; *DEU*, Germany; *ESP*, Spain; *FRA*, France; *IRN*, Iran; *ITA*, Italy; *RUS*, Russia; *SGP*, Singapore; *Univ of S&T*, University of Science and Technology; *USA*, United States.

From Scopus.

Comparison of National Center for Nanoscience and Technology, China and global leading institutions

As well as the top publishing institutions, several of the world's leading nano-research centers were selected for a comparative analysis with the National Center for Nanoscience and Technology (NCNST). Comparison of the academic research output and nano-publication impact between the NCNST and other world-class institutions showed that nano-publications from the NCNST are at the forefront of global academic impact.

In terms of research output, the number of nano-publications from the NCNST ranked in the middle of the group of comparator institutions between 2010 and 2019 (Fig. 1.14), mainly owing to differences in the numbers of authors. Further analysis of research output

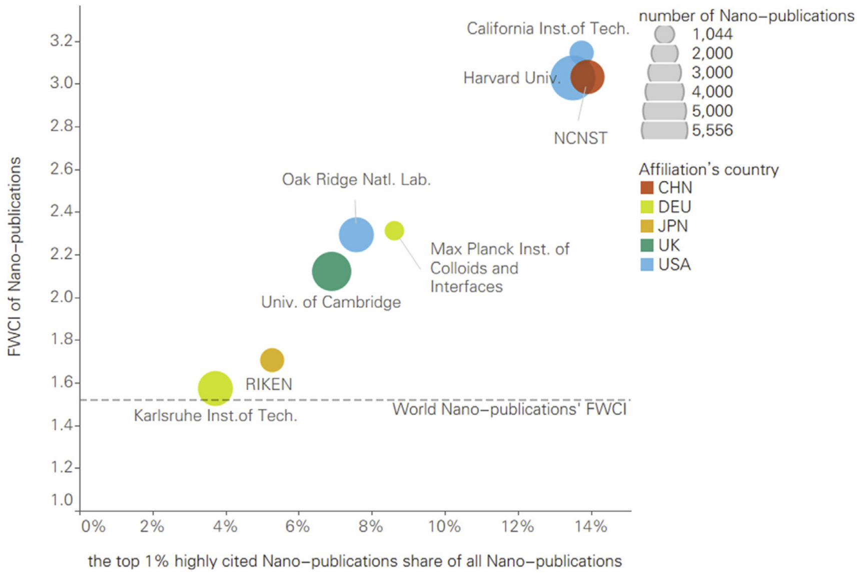

FIGURE 1.14

Comparison of nano-publication research output and academic impacts of the National Center for Nanoscience and Technology and world-class institutions (2010–19). *CHN*, China; *DEU*, Germany; *FWCI*, field-weighted citation impact; *Inst.*, Institute; *JPN*, Japan; *Natl.*, National; *NCNST*, National Center for Nanoscience and Technology; *RIKEN*, Japan Institute of Physical and Chemical Research; UK, United Kingdom; *Univ.*, University; *USA*, United States.

From Scopus.

per capita[2] showed that Oak Ridge National Laboratory, the Max Planck Institute of Colloids and Interfaces, and the NCNST was ranked the top three.

In terms of academic impact, the California Institute of Technology, Harvard University, and the NCNST ranked top three for nano-publication FWCI (Fig. 1.14, *y*-axis) between 2010 and 2019. The NCNST held the highest percentage in the top 1% highly cited nano-publications (Fig. 1.14, *x*-axis) among the comparator institutions. The analysis showed that nano-related academic outputs from the NCNST, the California Institute of Technology, and Harvard University had a relatively higher academic impact.

[2] Per capita = total output from the institution/count of authors from the institution.