Conclusions

Nanoscience and nanotechnology progressed rapidly between 2000 and 2019, with growth rates in nano-related academic output and patent output significantly higher than the overall world average. China was an important driver of this growth of global nanoscience output. In this book, we use the field-weighted citation impact (FWCI), which is the normalized citations, as a proxy for academic impact. China's academic impact in nanoscience was also increasing: its FWCI increased from 1.3 in 2000 to 1.9 in 2019, with the same trend shown for its share of the 1% most highly cited papers in nanoscience. In 2000−19, for every four Chinese 1% most highly cited publications, one was relevant to nanoscience. As shown in Fig. 1, China ranked highly for many key indicators in nanoscience.

As a universal science, nanoscience and nanotechnology stood at the intersection between various basic sciences and were integrated with multiple research areas, enhancing academic output and the impact of scientific research. Nanoscience had the closest relationship with physical sciences, which includes subjects such as materials, chemistry, chemical engineering, physics and astronomy, and engineering. However, emerging trends also showed a strengthened integration of nanoscience with life sciences and health sciences. In recent years, the percentage of research outputs involving nanoscience has increased in biochemistry, genetics and molecular biology, and pharmacology, toxicology, and pharmaceutics. Furthermore, nanotechnology has been significant to each fundamental science for its contribution to overall academic output and also indispensable to some of the most prominent research topics.

Besides being imperative to basic science, nanoscience and nanotechnology have contributed immensely to industry via advanced technology application. In recent years, many countries have introduced policies to promote the transfer of scientific research results to

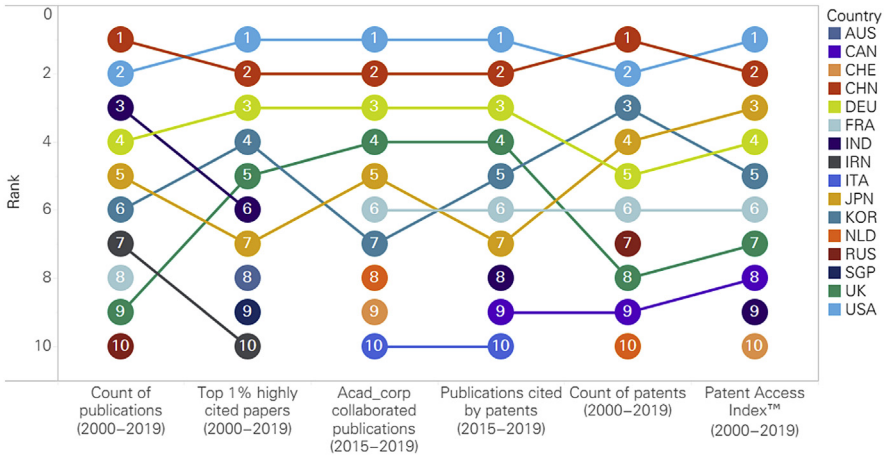

FIGURE 1

Top 10 countries by main evaluation indicators in nanoscience. *AUS*, Austria; *CAN*, Canada; *CHE*, Switzerland; *CHN*, China; *DEU*, Germany; *FRA*, France; *IND*, India; *IRN*, Ireland; *ITA*, Italy; *JPN*, Japan; *KOR*, Korea; *NLD*, the Netherlands; *RUS*, Russia; *SGP*, Singapore; *UK*, United Kingdom; *USA*, United States.

From Scopus, PatentSight.

industrial applications, and the collaboration between industry and academia has opened doors to this opportunity. Although China's academic–corporate collaboration in nanoscience still lagged behind other developed countries, its academic–corporate collaborated nanopublications have proliferated, showing the highest growth rate among comparator countries during the study period. The United States, Germany, the United Kingdom, and Japan had relatively higher academic–corporate collaboration rates in nanoscience, all of which were higher than their national averages. Lessons can be learned from accumulated experience in academic–corporate collaborations in these countries. The United States, France, South Korea, and China had the best global academic–corporate collaboration network in nanoscience. The collaborating corporate entities in China were mainly from the petrochemical industry, and the academic impact of these partnerships still has room for improvement. Corporate entities involved in academic–corporate collaboration from the United States

were mostly high-tech and research and development—intensive companies such as IBM, whose academic output had a more noteworthy impact.

The citation of academic publications by patents reflects the uptake of basic research results by industrial applications and indicates the economic benefits of academic research. Compared with other key countries, China was behind in patent citations received per 1000 publications in nanoscience for three main reasons. First, part of the lag resulted from varying disciplinary focus from different countries, in which those with publications in life sciences and medicine can have higher patent citations. Second, the study included only patent citation data from the World Intellectual Property Organization, US Patent and Trademark Office, European Patent Office UK Patent Office, and Japan Patent Office, resulting in a limited data set that can contribute to lower patent citations. Third, the analysis showed that corporate entities active in nano-related fields actively cited nano-publications, indicating academic—corporate collaboration closely related to the number of patent-cited nano-publications. From this perspective, China also needs to improve its academic—corporate collaboration in nanoscience.

Over the past 2 decades, the application of nanotechnology has boomed in the industrial sector, with a total of more than 690,000 nano-related patents worldwide, 58% of which came from China. China's nano-related patents had an absolute advantage in number but had a relatively low impact owing to the patents' low market coverage and technology relevance. Historically, most Chinese patents applied for protection only in China, whereas those in Europe and America applied for protection across different countries and regions.

More funding was available for nano-related research projects between 2009 and 2018, and the total of nano-related awards was increasing in both number and percentage, pushing development in nanoscience. Comparison between top funders by the amount of nano-awards and top funders by the scholarly output of nano-research showed a positive correlation between funding strength and academic output: a good return on investment.

Financial support and the development of technology have promoted frequent academic exchange. Cross-regional collaboration can also inspire ideas and facilitate the communication and spread of knowledge, which is conducive to advancing science. As found by this book, nano-research is undergoing globalization. The international collaboration rate of nano-publications was higher than the global average, and global cooperation has positively affected academic impact in many countries. China has had a remarkable academic impact resulting from its international collaboration in nanoscience and has become a competitive candidate as a global partner.