CHAPTER

The impact of nanoscience on industry

3

Key findings

2.6%
of worldwide nano-publications involved academic and corporate collaborations in 2015–19. The number was 0.2% lower than the global average of 2.8% for all publications.

1.5%
of Chinese nano-publications involved academic and corporate collaborations in 2015–19, which was lower than the overall average in China. In the United Kingdom, the United States, Japan, and Germany, academic–corporate collaboration rates in nanoscience were higher than the overall average in each country.

CNRS, Samsung, Chinese Academy of Sciences (CAS), IBM, and Sinopec
were the top five institutions with the highest number of academic–corporate collaborated nano-publications between 2015 and 2019.

1.04%
of nano-publications were cited at least once by patents in the top five international patent libraries in the world, which was 89% ahead of the all-fields average (2015–19).

Big Data Analysis of Nanoscience Bibliometrics, Patent, and Funding Data (2000–2019)
https://doi.org/10.1016/B978-0-323-91311-9.00003-7

693,000
patents[1] were related to nanoscience in 2000–19, accounting for 2% of patents worldwide. Among them, 58% came from China.

CAS, Tsinghua U, and MIT
were the top three academic institutions with the highest nano-related Patent Asset Index (2000–19).

Samsung, LG Chem, and Foxconn
were the top three corporate entities with the highest nano-related Patent Asset Index (2000–19).

Based on Scopus data, 17,326 nano-publications were published worldwide via academic–corporate collaborations between 2015 and 2019, accounting for 2.6% of all nano-publications. The rapid growth of China's overall nano-publications drove the development of academic–corporate collaborative nano-research in the nation. However, in contrast to other key countries, China's share of academic–corporate collaborative nano-publications among all of its nano-publications was still relatively low.

The 100 global corporate entities with the most nano-publications produced in collaboration with academic research institutions were located in the countries and regions with the most advanced nanoscience research. These corporations belonged to a range of industries that varied among countries, indicating diversified nanoscience application across industries. The corporate entities involved in nanoscience research in China were mainly petrochemical companies, whereas those in the United States were mostly high-tech companies such as IBM, Intel, and Thermo Fisher.

Research in basic science was the driving force for science and technology innovations and also the source for applied science and

[1] Nano-related patents: obtained by searching "Nano*" in the title, abstract or claim of patents. Data source: PatentSight. Search time: Mar. 30, 2020. Filing year: 2000–19.

breakthroughs. The growing share of nanoscience research output has shifted from basic research to industrial application, in which the percentage of patent-cited publications was higher than in other fields.

Patents can foretell the application prospects of a certain technology in the industry. Between 2000 and 2019, a total of 693,789 nano-related patents were granted worldwide, 58% of which were from China and 12% from the United States. The rapid growth of China's nano-related patents has driven the surge of nano-related patents globally. However, compared with the United States and European countries, the competitiveness of nano-related patents from China still has space for improvement.

3.1 Analysis of academic—corporate collaborations in nanoscience

Academic—corporate collaborative research output in nanoscience

Collaborations between academic institutions, mainly universities and research centers, and corporate research and development (R&D) centers often contributes to the basic research knowledge flow between academia and industry. The flow increases the opportunity for technology transfer and helps to secure funding for academia. In this section, academic—corporate collaborative research outputs between 2015 and 2019 are analyzed to evaluate cross-sectoral nano-research between academic institutions and corporate entities.

Number of academic—corporate collaborative nano-publications

Based on Scopus data, a total of 17,326 nano-publications were published with academic—corporate collaborative between 2015 and 2019, accounting for 2.6% of all nano-publications in that period. During that time, the academic—corporate collaboration rate across all research fields was 2.8%. With 6,124 publications, the United States contributed 35% of academic—corporate nano-publications, the most of all countries. The number of Chinese academic—corporate nano-publications increased rapidly. Between 2015 and 2019, the compound annual growth rate (CAGR) of Chinese academic—corporate nano-publications was 14.2%, the highest rate of all comparator countries (Fig. 3.1).

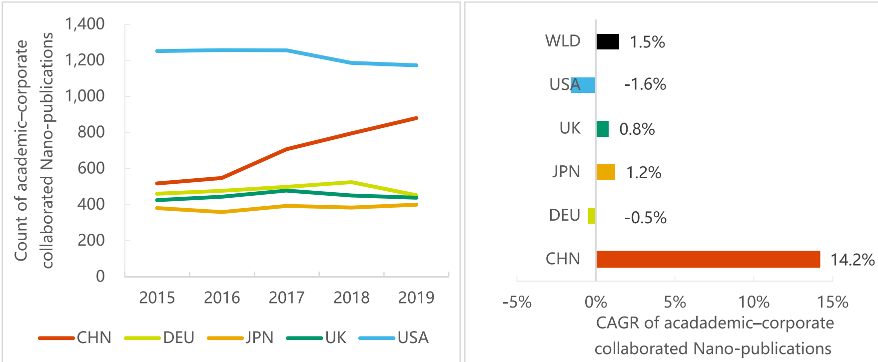

FIGURE 3.1

Trends in research output and compound annual growth rate (CAGR) of academic—corporate collaborated nano-publications (2015—19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

Academic—corporate collaboration rate

The increasing number of academic—corporate collaborative nano-publications was tightly connected to overall development in nanoscience. The academic—corporate collaboration rate, which is the share of academic—corporate collaborative publications in all publications, can be used to evaluate the progress of cooperation efforts in nanoscience.

The global academic—corporate collaboration rate in nanoscience was lower than the overall average rate for the world (Fig. 3.2). However, in the United States, Japan, Germany, and the United Kingdom, each country's academic—corporate collaboration rate was higher than its overall average, indicating the close relationship between academia and industry in the nanoscience research. China's academic—corporate collaboration rate in nano-research was lower than its national rate as well as the rates of comparator countries and the global average. The academic—corporate collaboration rate for Chinese nano-publications also barely increased between 2015 and 2019.

In terms of research fields, generally, academic—corporate collaboration rates in the areas of medicine and life sciences, such as pharmacology, toxicology and pharmaceutics; immunology and microbiology;

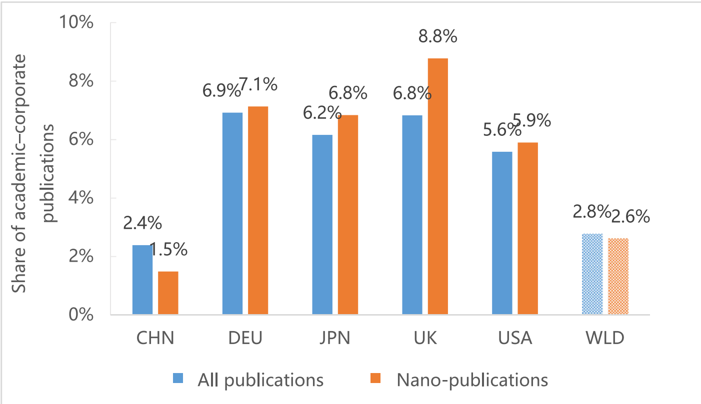

FIGURE 3.2

Comparison of nano-publications' academic—corporate collaboration rate and overall average for each country and the world (2015—19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

and biochemistry, genetics, and molecular biology, were higher than those in other subject areas (Fig. 3.3). For example, the United Kingdom had a 13.7% share in academic—corporate nano-publications in pharmacology, toxicology, and pharmaceutics.

The degree of academic—corporate collaborations varied across fields. To avoid disparities caused by disciplinary differences, the book evaluated the degree of nano-research collaboration efforts in each country and the world by the relative academic—corporate collaboration rate[2]. The assessment revealed that Japan had a significantly higher nano-publication academic—corporate collaboration rate in biochemistry, genetics, and molecular biology; immunology and microbiology; and medicine than the average academic—corporate collaboration rate in these subjects (Fig. 3.4).

[2] Relative academic—corporate collaboration rate = academic—corporate collaboration rate of nano-publications in the subject/academic—corporate collaboration rate of the subject. If the value is equal to 1, it means the degree of academic—corporate collaboration in nanoscience is same as the average degree of all research fields.

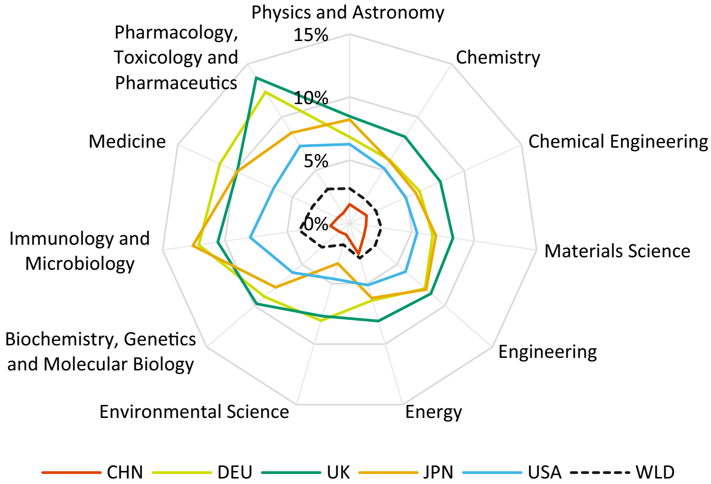

FIGURE 3.3

Academic–corporate collaboration rates of nano-publications in key subjects for comparator countries and the world (2015–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

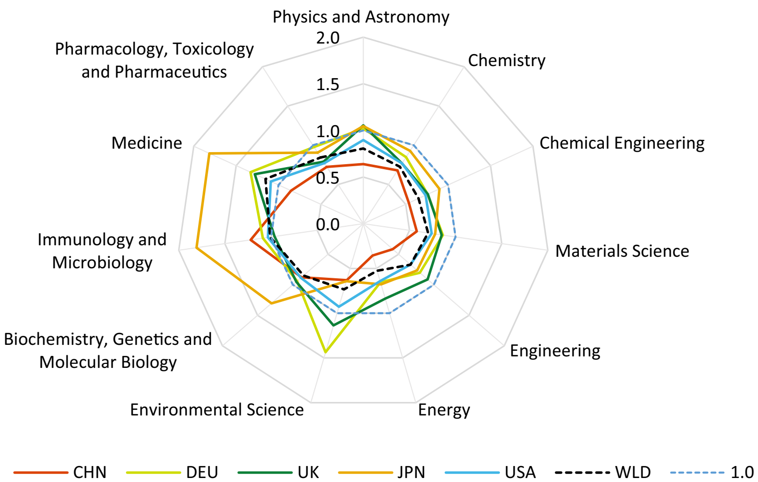

FIGURE 3.4

Relative academic–corporate collaboration rates of nano-publications in key subjects for the comparator countries and the world (2015–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

Academic–corporate collaboration network based on coauthorship

Fig. 3.5 illustrates the world's top 100 corporate entities with the most nano-publications produced in collaboration with academic institutions. The statistics show that these corporations were concentrated in countries and regions with relatively advanced nanoscience research. Among them, corporate entities in the United States were the largest contingent (27 entities in the top 100 corporate list), followed by China (15), Germany (9), Japan (7), Switzerland (5), the Netherlands (5), France (5), and South Korea (4).

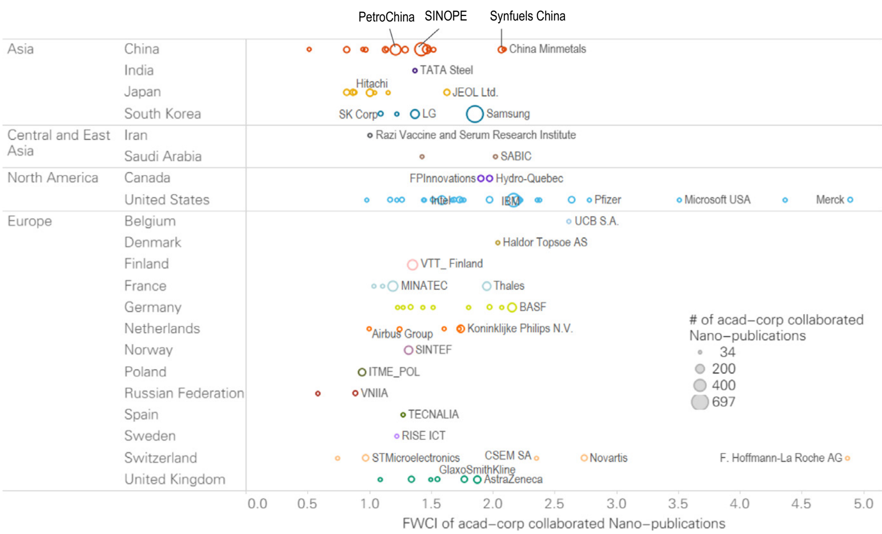

FIGURE 3.5

Top 100 corporate entities by academic–corporate (acad-corp) collaborated nano-publications (2015–19). (Only the some entities' names are marked; the full list is presented in Appendix A). *FWCI*, field-weighted citation impact.

Source: Scopus.

Samsung, IBM, and Sinopec were the top three corporate entities with the most nano-publications copublished with academic institutions (Fig. 3.6). Furthermore, corporations that partnered with academic institutions for nanoscience research came from diverse industries in different countries. For example, most of these top corporate entities were pharmaceutical companies in the United Kingdom such as GSK AstraZeneca; petrochemical companies in China such as Sinopec, CNPC, and RIPED; high-tech companies in the United States such as IBM, Intel, and Thermo Fisher; pharmaceutical and chemical engineering enterprises in Germany such as BASF; electronics enterprises in South Korea such as Samsung and LG; manufacturing companies in Japan such as Hitachi, Toyota Motor Corporation, and JEOL; and semiconductor and pharmaceutical companies in Switzerland such as Novartis and Roche Pharma.

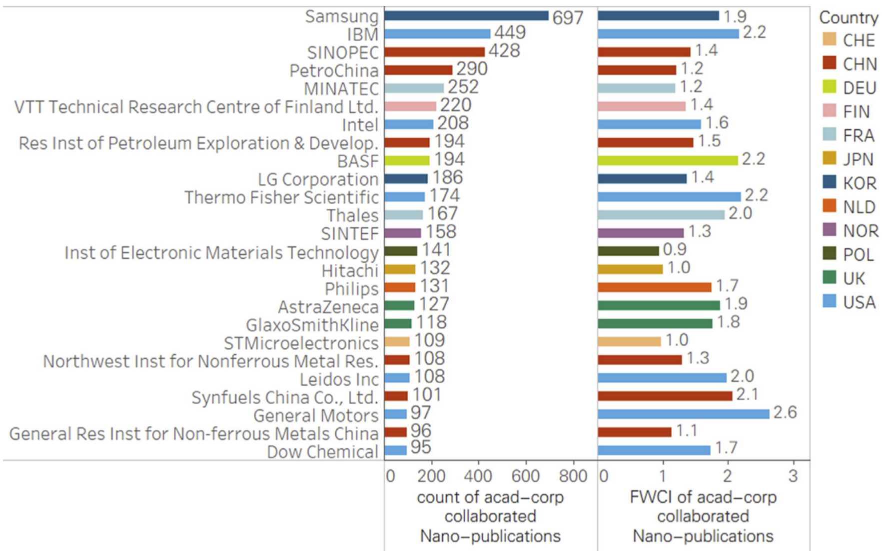

FIGURE 3.6

Top 25 corporate entities[3] with the most academic—*corporate* (acad-corp) collaborated nano-publications (2015—19). *CHE*, Switzerland; *CHN*, China; *DEU*, Germany; *FIN*, Finland; *FRA*, France; *FWCI*, field-weighted citation impact; *JPN*, Japan; *KOR*, Korea; *NLD*, The Netherlands; *NOR*, Norway; *POL*, Poland; *UK*, United Kingdom; *USA*, United States.

Source: Scopus.

In terms of academic impact, as measured by the field-weighted citation impact (FWCI) of nano-publications coauthored by industry and academia, corporate entities from the United States were ahead of those from other countries. China's corporate entities had a relatively weaker

[3] Thermo Fisher Scientific Inc. is a US-based biotechnology and medical instruments company. It was formed by the merger of two US biotechnology companies on May 14, 2006 and is headquartered in Waltham, Massachusetts. It mainly produces laboratory equipment, reagents, analytical instruments, consumables, and software. Thales Group is a French electronics group focusing on aerospace, defense, ground transportation, security, and manufacturing electrical systems. The company is headquartered in France; its R&D arms are located in Silicon Valley, France, Paris, and Russia. Since the acquisition of Racal in the United Kingdom in 2000, Thales Group has continuously expanded its business, and its civilian business has continued to grow. Now it has developed into a professional electronic high-tech company known for its design, development, and production of aviation, defense, and information technology service products.The Norwegian Institute of Science, Technology and Industry (SINTEF) is headquartered in Trondheim, Norway. It is an independent research organization established in 1950, engaged in contract R&D projects. Based on its R&D in technology, natural sciences, pharmacy, and social sciences, SINTEF provides paid research-based knowledge and related technical services. SINTEF also actively transforms its scientific research results to establish new companies and helps these companies develop. After success, they will sell the shares they own, and the liquidity obtained will then be reinvested in the creation of new knowledge. To ensure a high level of research, SINTEF works closely with the Norwegian University of Science and Technology and the University of Oslo. Many researchers are engaged in formal work in both institutions.The Polish Institute of Electronic Materials Technology (ITME) is a leading multidisciplinary research institution in Poland dedicated to the development of new materials and materials based on innovative tools and components for applications in electronics, microsystems, optoelectronics, micromechanics, and metrology. The high-tech materials, instruments, and components developed by the research institute have been published in many Polish and international journals, which can promote scientific cooperation between it and universities and research institutions and help prospective clients to implement their projects and implement them in industry or use them in the research institutes for short-term continuous production.Leidos, formerly known as Science Applications International Corporation, is a US defense, aerospace, information technology, and biomedical research company headquartered in Reston, Virginia, providing science, engineering, system integration, and technical services. STMicroelectronics is an international semiconductor manufacturer headquartered in Geneva, Switzerland.

impact score than those from the United States and European comparator countries.

Based on the number of academic–corporate nano-publications, the top three academic institutions were all research centers, including the French CNRS, Chinese Academy of Sciences, and the French Alternative Energies and Atomic Energy Commission (CEA) (Fig. 3.7).

Fig. 3.8 illustrates the major worldwide network of academic–corporate collaboration in nanoscience. As a first observation, several large institutions from respective regions in the countries led most of the collaboration efforts. These leading institutions with high academic impact boosted the academic influence of academic–corporate collaborations in these countries. For example, Samsung had the most academic–corporate collaborative nano-publications globally and was also the key entity that led South Korea's cross-sector cooperation

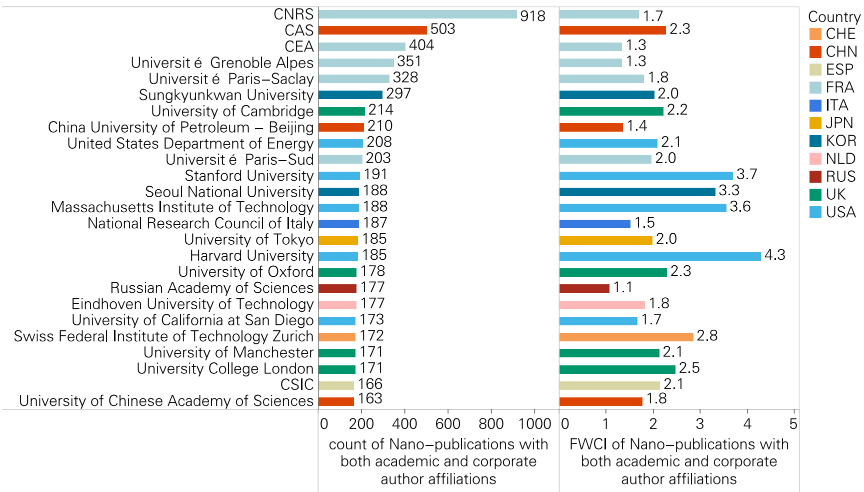

FIGURE 3.7

Top 25 academic affiliations with the most academic–corporate collaborated nano-publications (2015–19). *CHE*, Switzerland; *CHN*, China; *ESP*, Spain; *FRA*, France; *ITA*, Italy; *FWCI*, field-weighted citation impact; *JPN*, Japan; *KOR*, Korea; *NLD*, The Netherlands; *RUS*, Russia; *UK*, United Kingdom; *USA*, United States.

Source: Scopus.

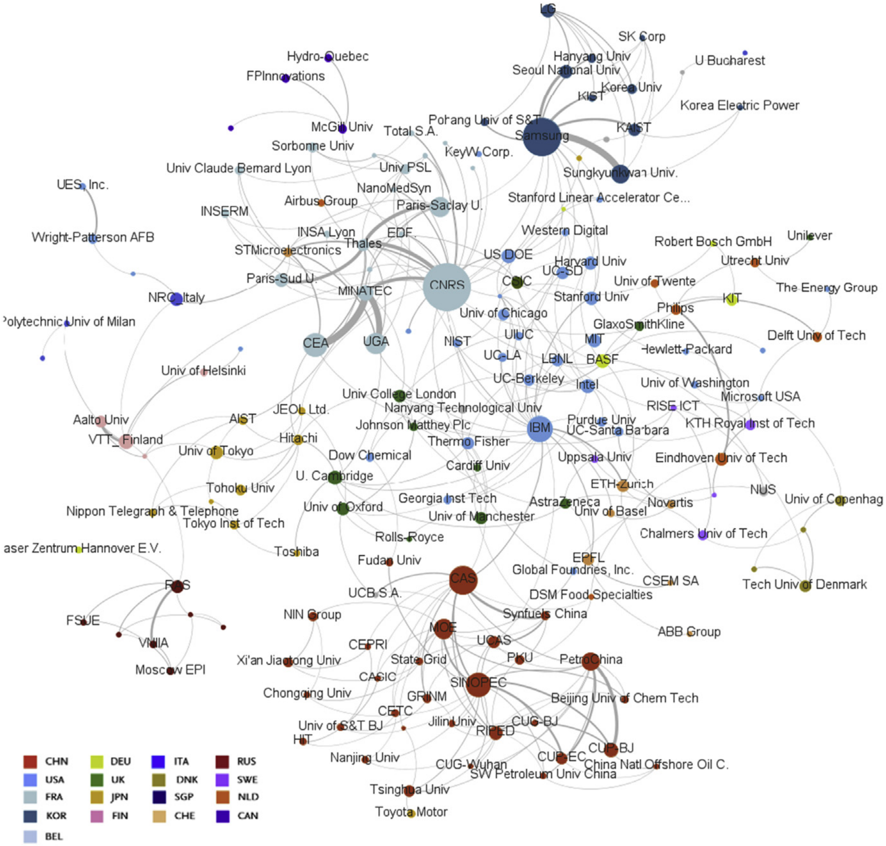

FIGURE 3.8

Collaboration network of the most active institutions with academic–corporate collaborations in the world (2015–19). The bubble size represents the number of publications from academic–corporate collaborations of the given institution. The larger the bubble, the larger the number of publications it represents. Countries are distinguished by bubble colors. The size of the edges represents the number of nano-publications collaborated between the two institutions. The thicker an edge is, the more collaborated nano-publications there are. *BEL*, Belgium; *CAN*, Canada; *CHN*, China; *DEU*, Germany; *DNK*, Denmark; *FIN*, Finland; *FRA*, France; *ITA*, Italy; *JPN*, Japan; *KOR*, Korea; *NLD*, the Netherlands; *RUS*, Russia; *SGP*, Singapore; *SWE*, Sweden; *UK*, United Kingdom; *USA*, United States.

Source: Scopus.

efforts in nanoscience. The United States had many corporate entities participating in academic–corporate collaborations; these cooperation efforts were relatively decentralized and frequent compared to other countries. Besides Samsung, other institutions that had an active role in global nanoscience academic–corporate collaborations including IBM (United States), CNRS (France), MINATEC (France), Sinopec (China), and Chinese Academy of Sciences (CAS) (China).

Second, most collaborating institutions were from the same country as the collaborating corporate entity, indicating a geographic relationship in academic–corporate collaboration. The largest group of academic–corporate collaborators was distributed across the United States, China, France, and South Korea; smaller groups were located in the United Kingdom, Japan, Russia, the Netherlands, Finland, Germany, and Switzerland. A possible explanation for this kind of regional collaboration is that corporate entities might have placed their R&D departments around universities and academic institutes to benefit from academic research, strengthening partnerships with local research centers through geographical proximity. For example, many corporate entities with active academic–corporate collaborations in the United States were located in the northeastern coastal areas, where universities are densely located. Most of China's corporate institutions actively collaborating with academia were in Beijing, where there are substantial academic resources (Fig. 3.5).

In China's nanoscience academic–corporate collaboration network, the CAS collaboration network has produced publications with a relatively high academic impact and extended its partnership to Europe and the United States: for example, with IBM in the United States and UCB Pharma S.A. in Belgium. The collaboration between CAS and IBM was primarily carried out via IBM's Thomas J. Watson Research Center, Albany NanoTech, and other R&D departments at IBM. The CAS Key Laboratory for Biomedical Effects of Nanomaterials and Nanosafety of NCNST and the Institute of High Energy Physics had the most partnerships with IBM's Thomas J. Watson Research Center. Soochow University also participated in many of those studies. In addition, the Institute of Process Engineering of the State Key Lab of Biochemical Engineering, the Beijing Institute of Nanoenergy and Nanosystems, the Wuhan Institute of Physics and Mathematics, the

Institute of Metal Research, the Institute of Applied Chemistry, the Dalian Institute of Chemical Physics, and the Institute of Microelectronics also published nano-publications in collaboration with IBM (Fig. 3.9).

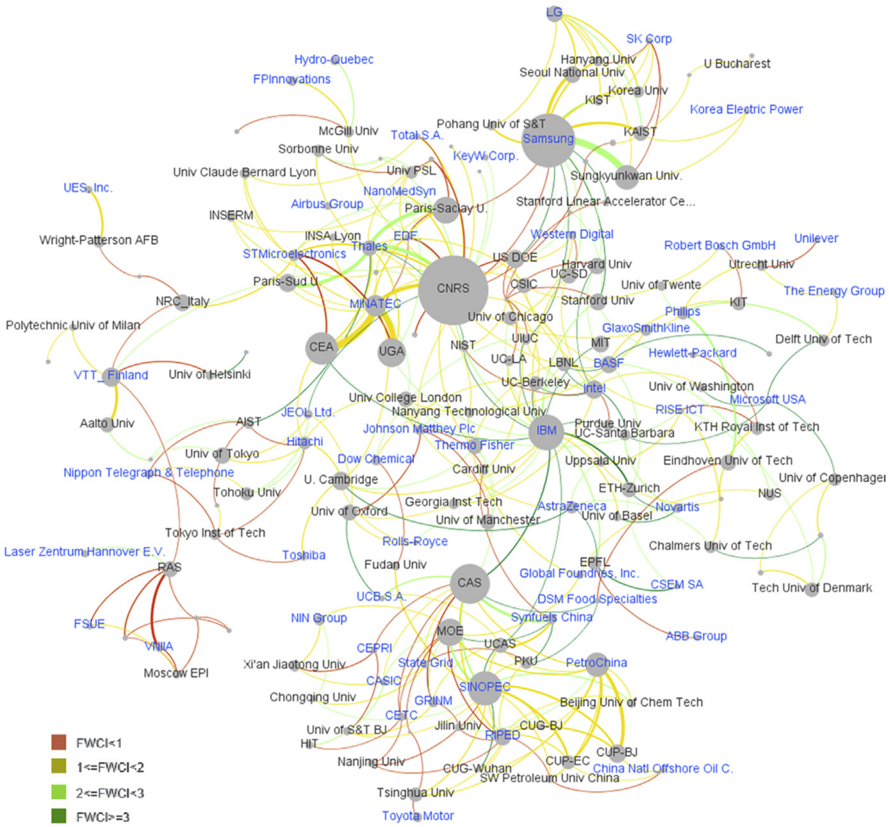

FIGURE 3.9

Network diagram of academic impact of collaborations between the most active institutions in nanoscience in the world (2015–19). The bubble size represents the number of publications from academic–corporate collaborations of this institution. The larger the bubble, the more publications it represents. The tag color represents the sector of the institution, with blue being corporate. The size of edges represents the number of nano-publications collaborated between the two institutions. The thicker an edge is, the more collaborated nano-publications there are. The colors of edges represent the field-weighted citation impact (FWCI) of the collaborated publications; red, yellow, light green, and dark green represent the FWCI from low to high.

Source: Scopus.

3.2 Knowledge transfer: patent citations to academic publications

Basic science is the foundation of research applications, scientific breakthroughs, and technology innovations. Shifting basic research to industrial applications enables scientific developments to serve a wider community, improving the quality of people's daily life. Academic publications that are cited by patents reflect the potential applications for basic research in industry. These patent-cited publications can serve as indicators to help evaluate the transfer of knowledge from basic research to industry, a crucial step for nanoscience.

This section analyzes 66,300 nano-publications cited by patents filed under the five largest intellectual property offices[4], based on Scopus data between 2015 and 2019. The results were used to track the impact of basic nanoscience research on industry.

Share of scholarly output cited by patents

The patent citation rate is the proportion of publications cited by patents in a collection of academic outputs. The rate serves as an indicator to assess an academic research output's possibility of being cited by patents. From 2015 to 2019, 1.04% of nano-publications in the world were cited by at least one patent filed under the five international intellectual property offices (Fig. 3.10). The number was 89% higher than the average global patent citation rate, which was 0.55%. Similar results were found in all key countries (China, Germany, Japan, the United Kingdom, and the United States), indicating that a higher proportion of knowledge from nano-publications was taken up by industry than the global average.

Of all key countries, the United States had the highest nanoscience patent citation rate at 2.4%, which was 2.4 times the rate for all publications combined (1%). The United States, the United Kingdom, Germany, and Japan all had higher patent citation rates for

[4] Patent article citation data is from the EPO, Intellectual Property Office (UK), Japan Patent Office, USPTO, and WIPO.

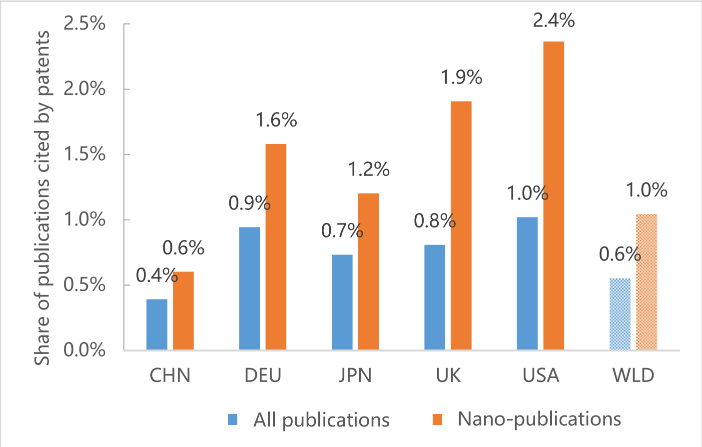

FIGURE 3.10

Share of all publications cited by patents versus share of nano-publications cited by patents (2015—19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

nano-publications than the global average. In contrast, China scored lower than the worldwide average for this indicator and was relatively behind the other countries.

Patent citations per 1000 scholarly outputs

The number of patent citations per scholarly output[5] from the five major global international intellectual property offices can serve as an indicator to measure the magnitude of publications cited by patents. The patent citation counts per 1000 nano-publications in the United States and the United Kingdom reached 23.7 and 19.1 between 2015 and 2019 (Fig. 3.11), both higher than their national averages of research in all fields. The results indicated that nano-publications in these two countries had a higher magnitude of patent citations. Meanwhile, the average citation count by patents per 1000 nano-publications in China was 6.0.

[5] Patent citations per scholarly output = Patent Citations Count/Scholarly Output × 1000.

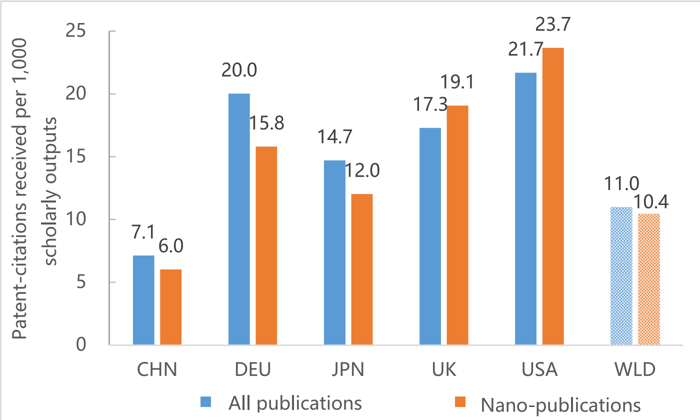

FIGURE 3.11

Patent citations per 1000 scholarly outputs for nano-publications (2015–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

Possible reasons for the relatively low patent citations of nano-publications in China include:

- China's academic–corporate collaborations in nanoscience were far less common than those of other developed countries, negatively influencing the chance of its basic nanoscience research being cited by industry. By analyzing the publications cited by patents, we found that most institutions with high citation counts were those with strong academic–corporate collaborations in nanoscience.
- The citing-patents data came from the five major intellectual property offices: European Patent Office (EPO), the UK's Intellectual Property Office, Japan Patent Office, US Patent and Trademark Office (USPTO), and World Intellectual Property Organization (WIPO). Citations from the Chinese Patent Office were not included, thus reducing the number of patent citations from Chinese literature in the evaluation.

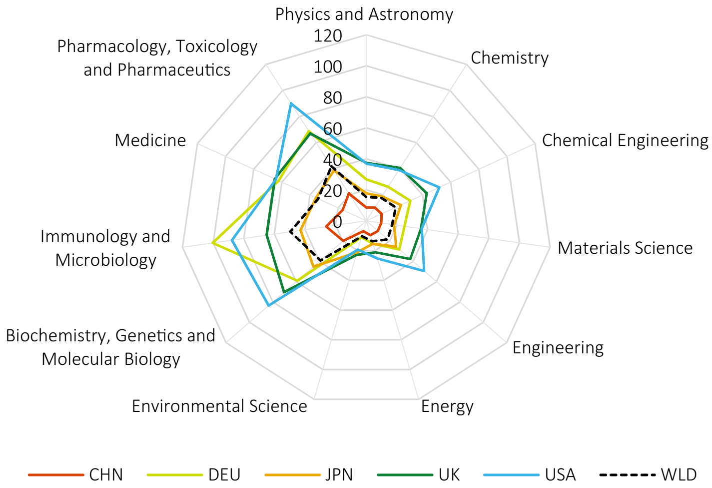

FIGURE 3.12

Patent citations per 1000 scholarly outputs for nano-publications (2015–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, = United States; *WLD*, world.

Source: Scopus.

- Patent citation counts differ across fields. The analysis showed that patent citation counts of nano-publications were higher in the fields of pharmacology, immunology and microbiology, biochemistry, genetics, and molecular biology and the like (Fig. 3.12). However, China's research impact in these fields still lagged behind the United States and the United Kingdom.

Fig. 3.13 lists the top 20 patent owners citing the most nano-publications. More than half of institutions were from Europe or North America. Fig. 3.14 presents the top 20 institutions with the most nano-publications cited by patents.

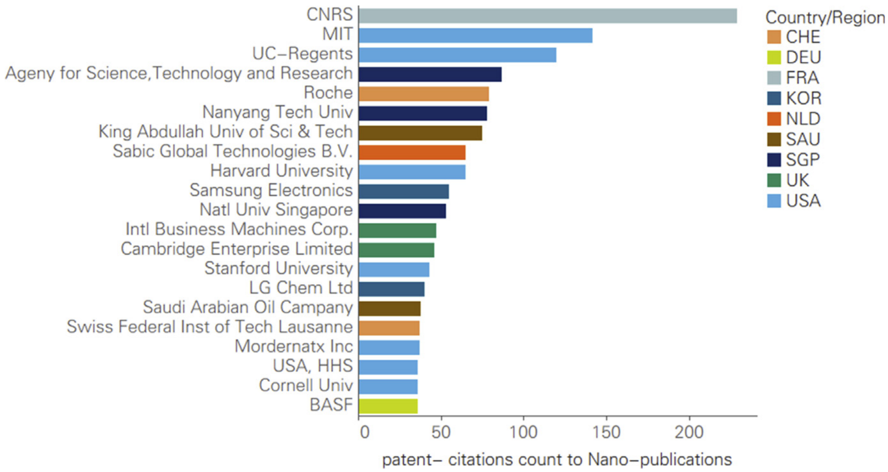

FIGURE 3.13

Top 20 patent owners by patent citation count to nano-publications (2015–19). *CHE*, Switzerland; *DEU*, Germany; *FRA*, France; *KOR*, Korea; *NLD*, the Netherlands; *SAU*, Saudi Arabia; *SGP*, Singapore; *UK*, United Kingdom; *USA*, United States.

Source: Scopus.

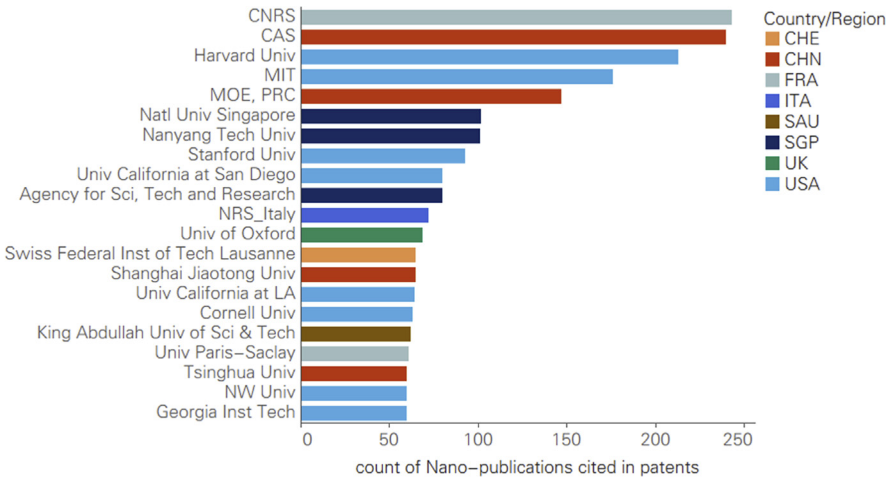

FIGURE 3.14

Top 20 institutions by number of nano-publications cited by patents (2015–19). *CHE*, Switzerland; *CHN*, China; *FRA*, France; *ITA*, Italy; *SAU*, Saudi Arabia; *SGP*, Singapore; *UK*, United Kingdom; *USA*, United States.

Source: Scopus.

3.3 Overview of nano-related patents

Patents are another form of output, reflecting the application prospects of technology in the industry. In this section, nano-related patents are analyzed via patent documents issued by patent licensing agencies in about 115 countries and regions around the world and indexed by PatentSight.[6]

Top inventing countries by nano-related patents

Between 2000 and 2019, there were 693,789 nano-related patents,[7] accounting for 2% of patents worldwide and 72% of all active patents, based on PatentSight data. Of these nano-related patents, 58% were from China, 12% from the United States, and 10% from South Korea. The top five countries with the most nano-related patents accounted for 91% of global nanoscience patents (Fig. 3.15).

The rapidly growing number of nano-related patents in China drove a worldwide surge of patents related to nanoscience. Between 2000 and 2018, the CAGR[8] of global nano-related patents was 14.4%, close to the CAGR of nano-publications in that period. Because the patent data were delayed in 2019, the CAGR was calculated only for 2000–18 (Fig. 3.16).

The indicator used in this book to measure the quality of patents is the Patent Asset Index (PAT), which is derived from a set of three newly developed patent indicators: technology relevance, market coverage, and competitive impact. Technology relevance mainly measures the citations of patents, and market coverage evaluates the degree of protection for a patent or the patent family in the world. Competitive impact is the product of technology relevance and market coverage. The PAT is the aggregation of all patents' competitive impact in a patent collection.

[6] https://go.patentsight.com/.

[7] Nano-related patents: search "Nano*" in the title/abstract/claim of patents. Search time: Mar. 30, 2020. Filing year: 2000–19. For China's patents, we included the utility model patents and deactivated patents; data from Hong Kong, Macau, and Taiwan were omitted.

[8] Affected by the delays in the publication of patent applications, the number of patents in 2019 was excluded when calculating CAGR, because it does not represent the true patent data for 2019.

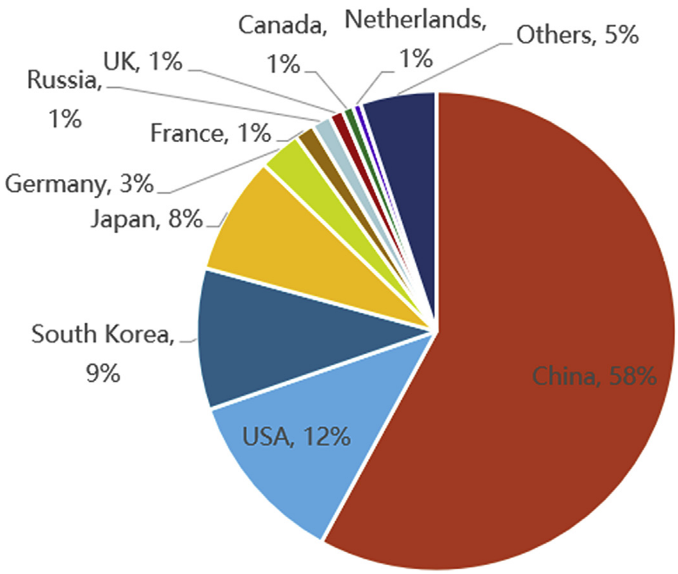

FIGURE 3.15

Share of nano-related patents by top 10 origin countries (2000–19).

Source: PatentSight.

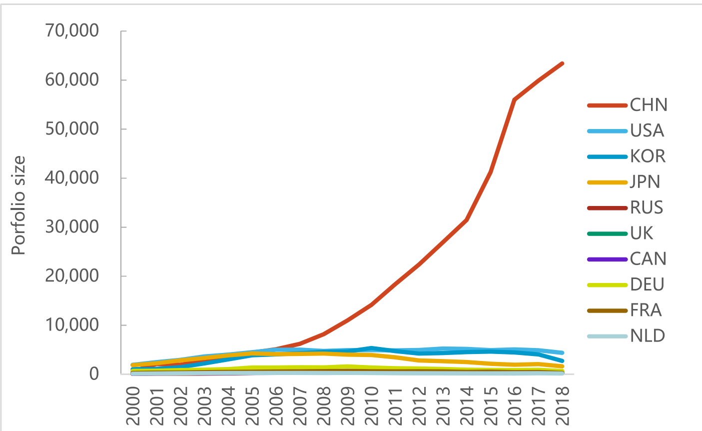

FIGURE 3.16

Trends for nano-related patent counts in top 10 countries of origin (2000–18).[9] *CAN*, Canada; *CHN*, *DEU*, Germany; China; *FRA*, France; *JPN*, Japan; *KOR*, Korea; *NLD*, the Netherlands; *RUS*, Russia; *UK*, United Kingdom; *USA*, United States.

Source: PatentSight.

In general, the more influential a patent is, the higher its quality is considered to be. See Appendix B for detailed descriptions of each indicator.

Although China had a dominant advantage in the total number of nano-related patents, which improved its PAT, its competitive impact ranked low among the top 10 most innovative countries and regions by nanoscience patent count (Fig. 3.17). The lagging gap in its competitive impact comes from its relatively low market coverage and technology relevance. Most of China's nano-related patents were only protected within the nation, resulting in smaller market coverage. Of all China's active nano-related patents between 2000 and 2019, 98% were filed under the National Intellectual Property Administration in China. Compared with China, European countries held a higher

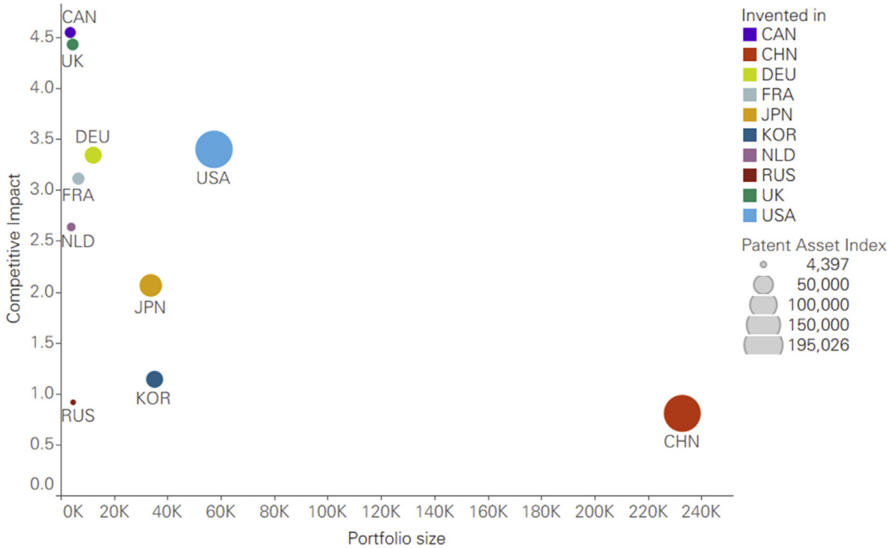

FIGURE 3.17

Top 10 countries of origin by nano-related patents count (2000–19). *CAN*, Canada; *CHN*, China; *DEU*, German; *FRA*, France; *JPN*, Japan; *KOR*, Korea; *NLD*, the Netherlands; *RUS*, Russia; *UK*, United Kingdom; *USA*, United States.

Source: PatentSight.

[9] Because it is affected by the delays in the publication of patent applications, the number of patents in 2019 will be excluded.

Table 3.1 Top 10 countries of origin by nano-related patents count (2000–19).

Invented in	Portfolio size[11]	Patent asset Index	Competitive impact	Technology relevance	Market coverage
China	233,010	188,619	0.8	1.2	0.6
United States	57,364	195,026	3.4	2.1	1.4
Korea	35,079	39,940	1.1	1.2	0.6
Japan	33,912	69,973	2.1	1.6	1.0
Germany	12,314	41,176	3.3	1.9	1.4
France	6,715	20,912	3.1	1.7	1.5
Russia	4,821	4,397	0.9	1.0	0.3
United Kingdom	4,416	19,538	4.4	2.4	1.7
The Netherlands	4,070	10,741	2.6	1.9	1.1
Canada	3,682	16,739	4.5	2.4	1.6

Source: PatentSight.

percentage of patents in their own patent offices, and more patents from these countries were also filed under the USPTO. France, Germany, and the United Kingdom had 61%, 57%, and 70% of nano-related patents filed for protection under the USPTO. The United Kingdom's and Canada's nano-related patents had relatively more protection from the EPO and the WIPO. For example, 11% and 10% of nano-related patents in the United Kingdom and Canada, respectively, were WIPO patents (Table 3.1).[10]

Top 10 patent owners per Patent Asset Index of nano-related patents

The patent owner is the entity that owns the patent rights. Table 3.2 and Fig. 3.17 list the top 10 patent owners in industry and academia by their PAT of nano-related patents.

[10] Data source: PatentSight.
[11] To ensure the accuracy of the PAT, this table counts only the number of valid patents and does not include Chinese utility model patents.

Table 3.2 Patent metrics of top 10 patent-owning corporates by Patent Asset Index of nano-related patents (2000–19).

Owner (corporate)	Patent asset Index	Portfolio size	Competitive impact	Technology relevance	Market coverage
Samsung	10,738	4,153	2.6	1.9	1.2
LGChem	4,681	1,744	2.7	1.6	1.2
Foxconn	4,532	3,070	1.5	1.2	1.0
Intel	3,427	1,189	2.9	1.9	1.4
BASF	3,253	708	4.6	2.4	1.7
Dow Inc	2,885	704	4.1	2.2	1.7
Fujifilm	2,808	1,124	2.5	2.0	1.1
Merck KGaA	2,764	526	5.3	3.1	1.7
Johnson & Johnson	2,666	339	7.9	3.5	2.0
BOE	2,645	1,278	2.1	1.7	1.2

From PatentSight.

Many patent-owning companies have departments actively involved in nano-related academic–corporate collaborations. For example, Samsung and LG participated the most in academic–corporate collaborations in South Korea, and the two enterprises produced a higher patent output. Sinopec from China ranked third for patent counts, but its competitive impact was relatively low, and its PAT did not make it into the top 10. The United States had four companies among the top 10 patent owners, the most country. Intel had the highest nano-related PAT, followed by Dow Chemistry, Johnson & Johnson, and Boeing. Despite being actively involved in academic–corporate collaboration in the United States, IBM's PAT for nano-related patents did not make its way to the top 10. This was because 60% of IBM's nano-related patents were filed in the last 5 years, and the patents' technology relevance had yet to reach its full potential. Between 2000 and 2019, 45% of Foxconn's nano-related patents shared co-ownership with Tsinghua University, demonstrating close cooperation between the two entities. BASF and Merck, two German companies, had nano-related patents with a relatively higher competitive impact, ranking in the top three among all 10 companies (Table 3.2, Fig. 3.18).

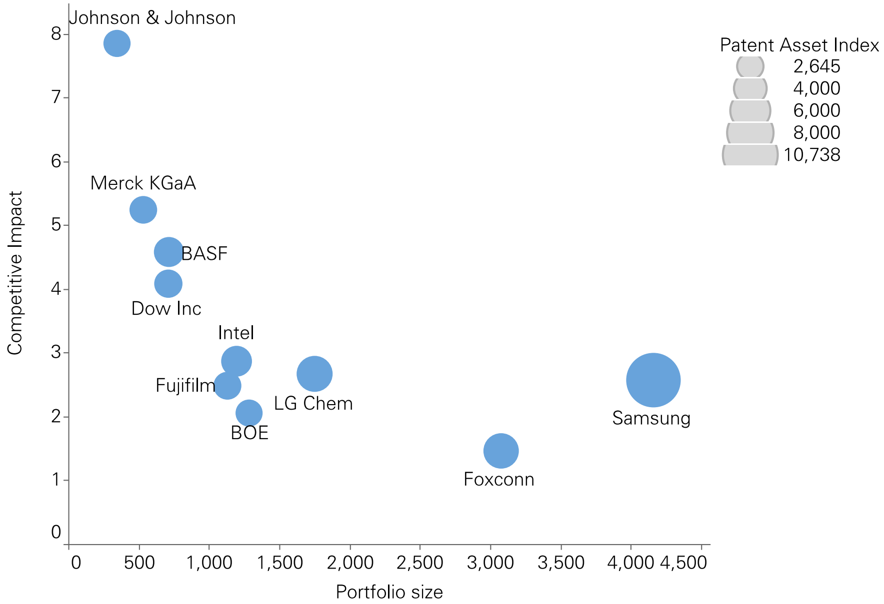

FIGURE 3.18

Top 10 patent-owning corporates by Patent Asset Index of nano-related patents (2000–19). *DEU*, Germany; *JPN*, Japan; *KOR*, Korea; *TWN*, Taiwan; *USA*, United States.

Source: PatentSight.

From 2000–19, four of the top 10 patent-owning academic institutions ranked by the PAT of nano-related patents were from China. Although China had an edge in the number of patents, its competitive impact was relatively low. CAS had the most nano-related patents, but its market coverage was small because most patents were protected only in China. Academic institutions from the United States, such as MIT, Harvard University, the University of California, and Broad Institute,[12] had higher competitive impacts. Among these US institutions, Broad Institute only had 43 nano-related patents between 2000 and 2019, but its competitive impact was immense, especially for technology relevance, indicating that the patents were cited by other patents more often (Table 3.3, Fig. 3.19).

[12] Broad Institute is a research collaboration center owned by both MIT and Harvard University.

Table 3.3 Patent metrics of top 10 academic institutions with patent ownership by Patent Asset Index of nano-related patents (2000–19).

Owner (academic)	Patent asset Index	Portfolio size	Competitive impact	Technology relevance	Market coverage
Chinese Academy of Sciences	10,795	11,747	0.9	1.4	0.6
Tsinghua University	4,847	3,220	1.5	1.5	1.0
MIT	4,717	711	6.6	3.5	1.5
Harvard University	3,333	364	9.2	4.6	1.7
University of California	3,331	1,265	2.6	1.8	1.4
Semiconductor Energy Lab	2,185	449	4.9	3.0	1.4
Broad Institute	1,980	43	46.0	18.7	2.3
Zhejiang University	1,851	2,061	0.9	1.4	0.6
Southern University of Science and Technology	1,796	1,859	1.0	1.6	0.6
CNRS	1,689	902	1.9	1.1	1.6

Source: PatentSight.

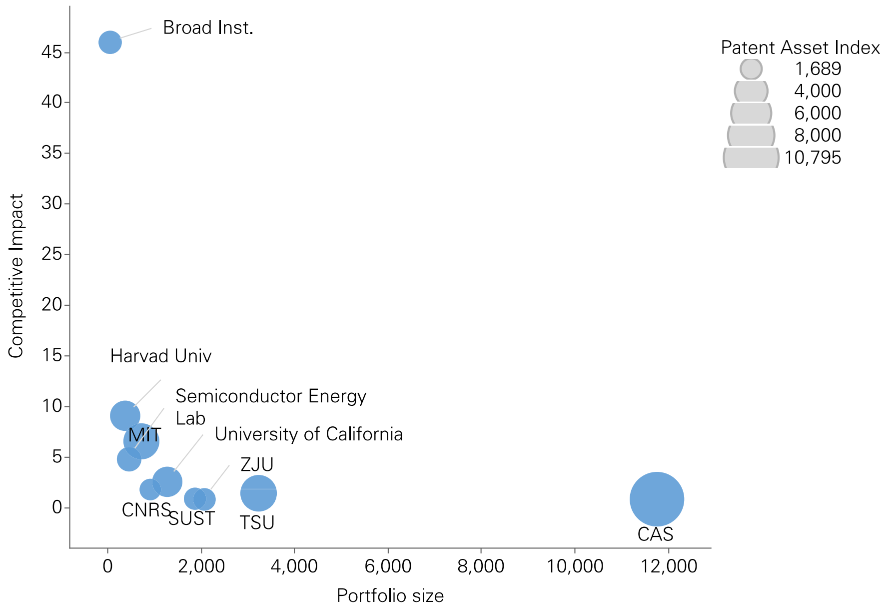

FIGURE 3.19

Top 10 academic institutions with patent ownership by Patent Asset Index of nano-related patents (2000–19). *CHN*, China; *FRA*, France; *JPN*, Japan; *USA*, United States.

Source: PatentSight.

Patent transfer

Patent ownership transfer

In this section, we analyze the nano-related patents filed in China, the United States, Germany, the United Kingdom, and Japan that went through a change in patent ownership. The reassignors and reassignees[13] are analyzed to understand the process of patent assignment from academic institutions to industries.

Between 2015 and 2019, a total of 976 nano-related patents were transferred from research institutes and universities to corporate entities. Of these assigned patents, 415 were from the United States, 306 were from China, and 166 were from Japan, accounting for 43%, 31%, and 17%, respectively, of transfers. In addition, 60 transferred patents were from Germany and 51 were from the United Kingdom.

Tsinghua University was the biggest patent reassignor, with the largest number of patent assignments. Between 2015 and 2019, the university assigned 217 nano-related patents to Hon Hai Technology Group (Foxconn). These patents were mainly related to nanotubes, capacitive touch screens, semiconductors, storage, and graphene sheets. Twelve nano-related patents were assigned from the California Institute of Technology to Samsung (Tables 3.4 and 3.5).

Joint ownership

Besides patent assignment, academia and industry can jointly own patent rights. Table 3.6 lists academic and corporate partners worldwide that co-owned[14] the most nano-related patents between 2015 and 2019. Wuhan University and Wuhan Fanglue Digital Technology jointly owned 433 nano-related patents. Among the patents, those

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[13] Here, reassignor represents an academic entity and reassignee represents a corporate entity. Data include deactivated patents and exclude utility model patents. Filing Date: Jan. 1, 2015 to Dec. 31, 2019, Title/Abstract/claim=(Nano*), Invented In=(CN, DE, GB, JP, US).

[14] Both entities own the patent. Data include deactivated patents and exclude utility model patents.

Table 3.4 Top 10 patent reassignors with nano-related patents transferring from the academic to the corporate sector (2015–19).

Top 10 academic reassignor	Count of reassigned patents (2015–19)
Tsinghua University	217
University of California	31
Georgia Institute of Technology	24
University of Tokyo	16
Japan Institute of Industrial Technology (AIST)	16
California Institute of Technology	15
Massachusetts Institute of Technology	15
Osaka University	14
Kyoto University	11
Harvard University	10
Tohoku University	10

Source: PatentSight.

Table 3.5 Top 10 patent reassignees with nano-related patents transferring from academic to corporate sector (2015–19).

Top 10 reassignees (company)	Count of reassigned patents (2015–19)
Hon Hai Precision Industry Co., Ltd., Taiwan	215
Samsung Electronics Co.	29
Toyota Jidosha Kabushiki Kaisha, Japan	13
UT-Battelle, LLC, Tennessee	12
Proctor & Gamble Company, Ohio	11
International Business Machines Corporation, New York	10
Zeon Corporation, Japan	9
Alliance for Sustainable Energy, LLC, Colorado	8
BASF	7
Rohm & Haas Elect Materials LLC	7

Source: PatentSight.

Table 3.6 Institution pairs with the most nano-related patents jointly owned by academic and corporate sectors (2015–19).

Co-owner of academic entity	Co-owner of corporate entity	Count of co-owned patents (2015–19)
Wuhan University	Wuhan Wuda Fang Lue Digital Technology Co. Ltd.	433
Tsinghua University	Foxconn	254
Hebrew University	Yissum R&D (in: Hebrew University)	67
University of Oxford	Oxford Innovation (in University of Oxford)	57
Soochow University	Jiangsu Industrial Technology Research Institute	49
Soochow University	SVG group	47
CNRS	INSERM	43
University of Tennessee	Battelle	39
Wuyi University	Jinjiang Ruibi Tech	34
South China Normal University, Shenzhen Guohua Photoelectric Tech Co. Ltd.	Shenzhen Guohua Photoelectric Research Institute	30

Source: PatentSight.

with the highest PATs were in the technology fields of physics > optics > resonator; physics > chemical treatment > photocatalyst; physics > optics > antireflection film; electronics > electricity > electrode materials; chemistry > nanotechnology > semiconductor; and information > analytical materials > electrochemical sensor.