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SET Index 2024

Assessing Science and Technology, Education, and Talent for Global Innovation Cities

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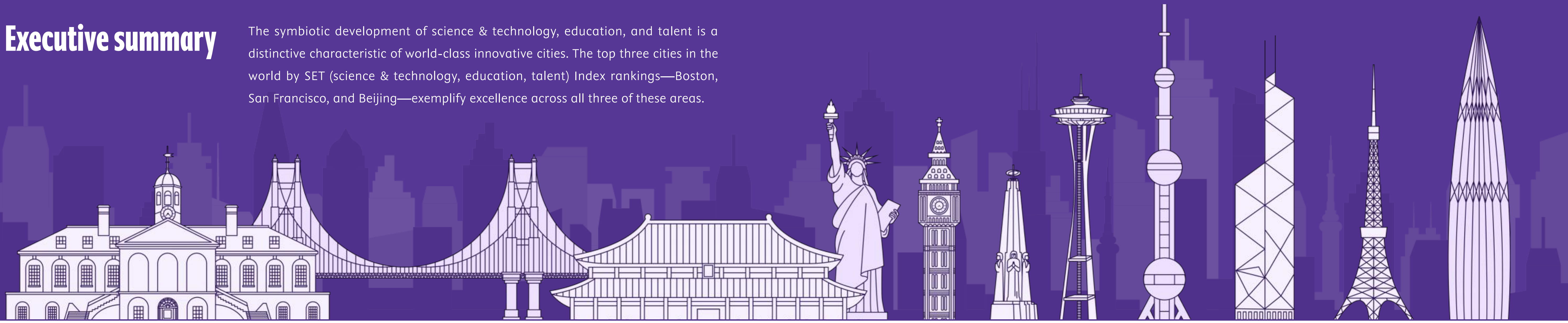
Executive summary

The symbiotic development of science & technology, education, and talent is a distinctive characteristic of world-class innovative cities. The top three cities in the world by SET (science & technology, education, talent) Index rankings—Boston, San Francisco, and Beijing—exemplify excellence across all three of these areas.



In today's interconnected world, science and technology innovation is a key driver of the competitiveness and development of cities and regions. Major cities worldwide are focusing on innovation to drive growth, actively implementing education reforms, attracting talent, and developing technology, thereby contributing to industrial progress and social prosperity. Tracking the development of science and technology (S&T), education, and talent in global cities offers valuable insights into these cities' global competitiveness and provides policy guidance to further stimulate innovation.

To comprehensively measure and compare the innovation capabilities and development potential of major global cities, the Shenzhen International Science and Technology Information Center, Tsinghua University's Center for Industrial Development and Environmental Governance, and Elsevier have collaborated to create the Science & Technology, Education, Talent Index (SET Index). This index emphasizes the coordinated development of these three factors. Using the SET Index framework, the three organizations have leveraged their strengths and jointly compiled this report, assessing 30 major global cities in terms of their education level, talent development, and S&T innovation capabilities. The report aims to identify different urban innovation models, as well as highlight the strengths and weaknesses of each city, providing guidance for further development.

Key Findings

The report shows that Chinese and American cities demonstrate strengths in innovation. The top 10 cities in the world by SET Index are, in order, Boston, San Francisco, Beijing, London, New York, Los Angeles, Seattle, Shanghai, Hong Kong, and Tokyo. The majority are Chinese or American cities. For the 30 cities evaluated in the report, major tech hubs or global metropolises in the United States (US) maintain high rankings; Chinese cities rank mostly in the upper-middle tier; while among European cities, only London is ranked among the top cities.

The top-ranked cities, particularly Boston, San Francisco, and Beijing, are leaders in all three dimensions—education, talent, and S&T—demonstrating coordinated development of these three pillars of innovation. However, different cities may follow their own development paths towards innovation. While the coordinated development of education, talent and S&T is highly beneficial, cities with distinctive strengths in a particular area may leverage these strengths to forge a unique development path, thereby playing a key role in contributing to national innovation.

Below shows the summary of city performance in each of the three dimensions.

01 Education level

- Boston, London, and Hong Kong lead in overall education level, showing their excellence in both basic (primary and secondary) and higher education.

- Asian cities, such as Singapore, Tokyo, Seoul, and Beijing, mainly excel in basic education; while Western cities, such as Boston, London, Paris, and San Francisco, lead in higher education.

- Some emerging cities, especially Chinese cities, are actively expanding educational resources to improve their education level. For instance, Shenzhen shows an 18% compound annual growth rate in research institutions in the past 5 years (2018–2023), leading among the 30 global cities. Many of its newly established research institutions are jointly founded with local industry or first-class universities in other Chinese cities, showing Shenzhen's exploration of its unique path towards development in education.

02 Talent Development

- Asian cities have advantages of scale for retaining and developing talent, while Western cities are home to much elite talent. For instance, Beijing and Tokyo, given their large urban population size and high population density, lead by a large margin in total researchers and number of industrial talents; Boston and London, home to some of the most prestigious universities in the world, lead in the number of top-tier researchers, with more than 5,000 top 2% highly cited scientists.

- Despite their distinctive characteristics in talent development, all cities are actively exploring how to tap into their talent potential, focusing on building a pool of young innovative talent, and strengthening talent inflow. Chinese cities perform particularly well in the retention and growth of young talent, while US cities have advantages in attracting new talent. For example, Shenzhen and Guangzhou lead in the growth of the number of active young researchers. Shenzhen also ranks highest among the 30 cities in the share of incoming researchers (inflow), with the proportion of inflow science and engineering (S&E) researchers reaching 24%. Other leading cities for researcher inflow are emerging US tech hubs such as Austin and San Diego.

03 S&T innovation

- Given the distinctive strengths of different cities in scientific research, technological progress and industrial development, distinct models of S&T innovation emerge. Cities such as Boston, San Francisco, and Beijing excel in all three factors—scientific research, technological progress and industrial development—and are leaders in S&T innovation, demonstrating their status as all-around innovation cities; New York, Seattle, and Shanghai are examples of research-driven industrial cities, with their strong research base fueling their industrial development; while technology-driven industrial cities, such as San Diego and Shenzhen, are characterized by a high technology density, driving industrial growth; finally, cities like London, Stockholm, and Amsterdam are representative of research and technology-driven cities, with advantages in both technological progress and scientific research.

- In scientific research, Western cities, such as Boston, San Francisco and London, show strengths. Chinese cities are improving rapidly, with prominent growth in high-impact research output, which is in line with China's strategic shift to focus on research quality.

- In terms of technological progress, artificial intelligence (AI) and advanced computing technologies are shown to be focus areas for many cities; nearly half of the 30 cities have this technology area as their most active area in terms of patent output. This suggests that developing AI technologies to promote next-generation industrial advancement has become a common strategic choice for innovation cities worldwide.

- In industrial development, US and Chinese cities are global engines, having fostered impactful innovative companies. Specifically, San Francisco, Beijing and Boston are the top ranked cities for industrial development. Two other Chinese cities, Shenzhen and Shanghai, are highly competitive in global top innovative companies, ranking among the top eight.

- Many cities are working to create supportive innovation ecosystems by developing international collaboration and academic-corporate collaboration. Tokyo, Paris, and London lead the way as innovation ecosystem, thanks to their relative strengths in constructing large scientific facilities, fostering research collaboration, and having strong economic foundations.

04 In focus findings

This study's detailed examination of talent development and academic-corporate collaboration reveals the following findings:

- Western cities have relatively more researchers in the fields of medicine or biochemistry; while for Asian cities, researchers are more concentrated in the fields of computer science, engineering and material science, suggesting different research focuses for these respective cities. Also, big global metropolises strong in education, such as Boston, London, Beijing and Singapore, tend to be hubs for talent flow, serving as both major destinations and sources of talent.

- Academic-corporate collaboration helps drive industrial vigor for cities. Boston is an example that demonstrates the importance of this type of collaboration in the success of innovative companies. Government support and input also play a role here, helping to promote the commercialization of research outcome of universities. Boston's successful model of government-academic-corporate collaboration can be a reference point for other cities seeking to develop S&T innovation.

Introduction

The SET Index evaluates the science and technology, education and talent development of major cities worldwide, offering a new perspective on measuring urban innovation capabilities. This serves as a valuable reference for cities aiming to enhance their innovation development.

In the context of global economic integration and the new technological revolution, innovation has become the primary driver of economic growth and societal progress. As urbanization and population concentration continue, cities have become critical centers for advancing innovation, playing a key role in boosting national competitiveness. Building global innovation hubs that generate technological innovation, incubate high-tech industries, and attract top talent is crucial for enhancing the global competitiveness of cities, their countries and beyond.

As major global cities pursue innovation-driven growth, measuring their innovation capabilities and accurately depicting their innovation profiles helps shed light on their position within the global innovation landscape. This provides valuable insights for urban innovation development. To this end, the Shenzhen International Science and Technology Information Center, Tsinghua University's Center for Industrial Development and Environmental Governance, and Elsevier, have combined their expertise and leveraged their respective strengths in urban governance, theoretical research, and data analysis to evaluate and track the innovation development of major global cities, culminating in the index in this report.

For cities and modern society to achieve innovative development, education, talent, and science and technology (S&T), are the three core elements. These elements are interdependent and mutually reinforcing, collectively driving the continuous progress of cities and society. Education cultivates innovative talent, talent fuels the progress of S&T and education, and S&T propels innovation, thus facilitating further education and talent development. Based on this concept emphasizing the "trinity" of these three elements, this report establishes the Science & Technology, Education, Talent Index (SET Index) framework. This index tracks the performance of major global cities in the dimensions of education level, talent development, and S&T innovation, assessing the cities' innovation capabilities and development potential.

Of course, there are many ways to measure the innovation capabilities of cities, and the SET Index introduced in this report just offers one way. With a focus on science and engineering research capabilities, the SET Index tracks outcomes, but also attempts to assess the growth potential of cities and depict their development trends. For a pilot of the Index, 30 major innovation cities around the world were selected for comparison in the report. It is expected that through comparison, strengths and weaknesses of these cities can be identified, offering references for mutual learning and continued development in innovation.

Constructing an index framework to assess the innovation capabilities of cities on a global scale is a highly challenging undertaking. Due to limitations such as data availability, time constraints, and other factors, this report has areas for improvement in its framework design, ranking methods, indicator selection, and city coverage. In the future, the SET Index will continue to refine and enhance the accuracy of its measurements. It is expected that through annual updates, the index will track the development trends of major innovative cities worldwide, providing insights into their development contexts. This will better support innovation and development, in cities and beyond.

PART 01

CHAPTER 1

The SET Index for Assessing Science & Technology, Education, and Talent

1.1 Conceptual model

The SET Index is built on a model that emphasizes the interplay of education, talent, and S&T, and their integrated development.

The innovation development of a city is inseparable from the three basic elements of S&T, education, and talent. Emphasizing the integrated development of the three is in line with the patterns of today's societal development and is integral to sustainable development. This report introduces and presents the SET Index, assessing innovation capabilities and development potential of major innovative cities in the world across the three interdependent dimensions of education level, talent development, and S&T innovation.

Education, as the cornerstone of innovation development, lays the foundation for both knowledge accumulation and talent cultivation. Specifically, high-quality basic education cultivates students' scientific literacy and innovative thinking, while also serving as the foundation for developing higher education, which plays a key role in expanding the frontiers of human knowledge and providing professional talent for S&T development.

Talent, as the source of innovation development, directly supports and drives education and S&T development by producing human resources. Its development primarily relies on the reserve and development of both research and industrial talent. Meanwhile, a city's talent development potential is reflected in its reserve of young talent and its ability to attract researchers.

Science and technology (S&T) drive innovation, giving rise to a multitude of new products, processes, and industries, creating economic growth, which in turn fuels the advancement of education and the development of talent. A city's S&T productivity is reflected in three aspects: scientific research strength, technology progress and industrial development. Of these, basic research makes technological progress possible, and technological progress in turn helps to foster industrial strength. The development of these three is also inseparable from a favorable ecosystem for S&T innovation, which can not only promote knowledge sharing, but also help integrate resources from all parties, promote knowledge transformation and technology incubation.

In summary, the three pillars of innovation—education, talent and S&T—interact with each other, forming a self-reinforcing cycle that jointly drives innovation development (see Figure 1.1.1 for the SET Index conceptual model). Based on this conceptual model, the SET Index evaluates innovation capabilities and development potential of major innovative cities worldwide, with a focus on science and engineering capabilities.

It should be noted that the integrated development of education, talent, and S&T is also at play at the regional and national level. Cities can leverage their own distinct strengths and position in the regional or national innovation landscape to forge their own distinctive innovation development paths, thereby promoting national innovation development and the prosperity of the entire society.

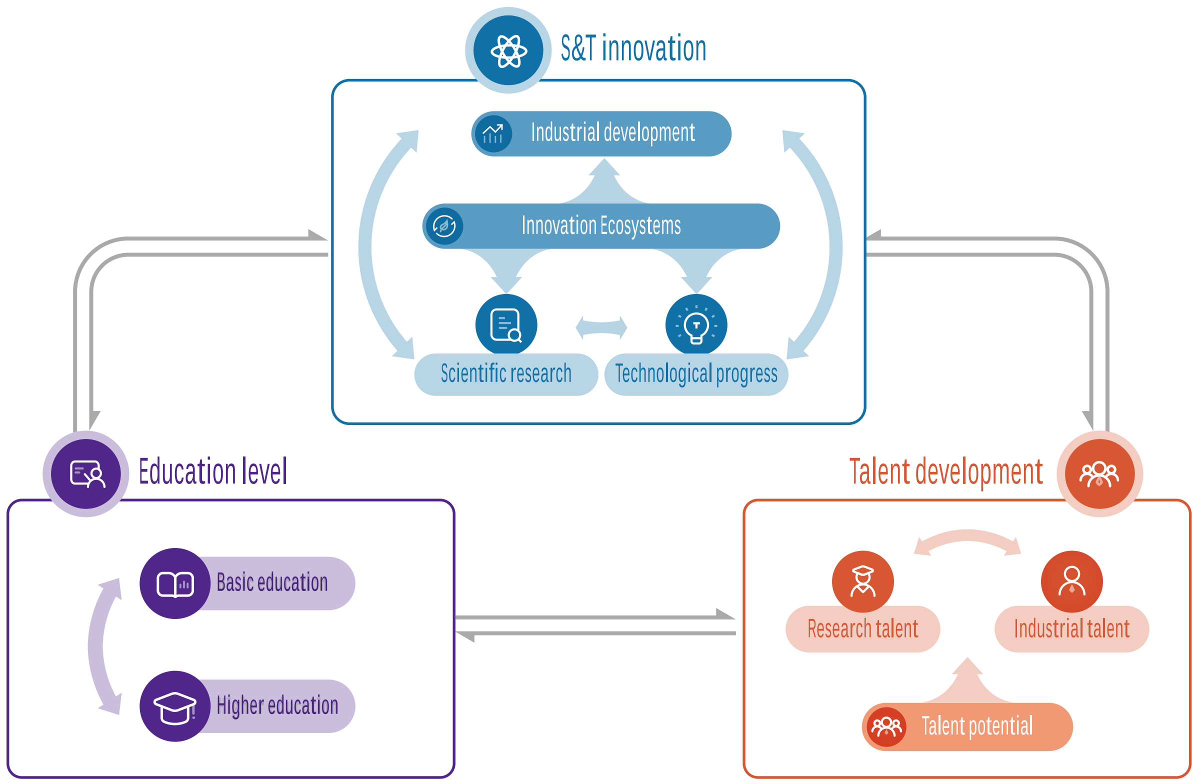


Figure 1.1.1 Logic model of the SET Index framework

1.2 SET Index framework

With three levels of diverse indicators, the SET Index framework aims to capture the current state of innovation development and output for global cities, supplemented by indicators to measure growth potential.

Based on the logic model on the interplay of education, talent, and S&T, this report proposes the SET Index framework, adhering to principles of objectivity and fairness, while also considering data accessibility and comparability. This indicator framework has included indicators on overall scale and average levels, as well as on cities' performance on indicators of top-tier talent, high-quality research, and leading technology enterprises; there are volume-based indicators to reflect current status, supplemented by indicators on growth to measure development potential. Also, the SET Index focuses on measuring performance in science and engineering (S&E) fields to reflect the hard technology innovation capabilities of cities.

The SET Index framework includes 3 primary indicators, 9 secondary indicators, and 31 tertiary indicators (see Table 1.2.1). Each tertiary indicator is weighted, starting with equal weights initially and then adjusted based on correlation with other indicators and importance suggested by the expert committee.The weights of secondary and primary indicators are determined accordingly, based on the summing of weights of respective tertiary indicators. Considering the different units of measurement across indicators, all tertiary indicator data are standardized using the minimum-max method for a scoring of 60 to 100 to ensure comparability and consistency. For detailed scoring methods, please refer to Appendix 2.

Table 1.2.1 SET Index indicators and weight of each indicator

Primary indicator	Primary indicator weight	Secondary indicators	Secondary indicator weight	Tertiary indicators
Education level	20%	Basic education	40%	Average education level of residents
				Quality of STEM education in primary and secondary schools
				International science competition awards for secondary schools
		Higher education	60%	Performance of world-class disciplines
				Number of world-class universities
				Growth rate of the number of research institutions
Talent development	30%	Research talent	40%	Competitiveness of S&E researchers
				Number of top-tier S&E researchers
		Industrial talent	40%	Total number of employees in top 1,000 innovative companies
				Proportion of employees in high-tech industries among the top 1,000 innovative companies
				Number of top-tier talents in the engineering field
		Talent potential	20%	Proportion of active young S&E researchers
				Growth rate of young S&E researcher activity
				Proportion of inflow S&E researchers
S&T innovation	50%	Scientific research	30%	High-quality S&E research output
				Growth in high-quality S&E research output
				Academic impact of S&E research output
				Proportion of S&E research output cited by patents
				Multidisciplinary score of S&E research output
		Technological progress	30%	Number of granted PCT patent families
				Number of granted PCT patent families per capita
				Patent technology impact
				Growth rate of high tech-impact patents
		Industrial development	30%	Number of top 1,000 innovative companies
				R&D investment intensity of the top 1,000 innovative companies
				Performance of unicorn companies
				Average valuation of start-ups
		Innovation ecosystem	10%	Number of large scientific facilities
				Extent of academic-corporate research collaboration
				Diversity of cross-regional collaboration
				GDP performance

1.3 Global innovation cities

The report focuses on 30 global innovation cities, which make major contributions to global research output and patent output and are home to the most innovative companies.

In the selection of cities for evaluation, this report draws from existing reports and rankings on innovation of cities or regions,[1] while also considering the development level of each city in education, talent, S&T, as well as data availability and comparability. It is important to note that although this report refers to "cities", this analysis employs the concept of metropolitan areas to capture the urban and suburban agglomeration surrounding the city core. This provides greater comparability among cities and captures a more accurate picture of the total innovation in a specific area. The delineation of specific metropolitan areas is primarily derived from the definitions provided by the respective national statistics bureaus (see Appendix 3 for a list of the geographic areas encompassed in the city definitions). Even so, it should be noted that there is still significant variation in population size across the cities evaluated here, and the size effect needs to be considered when interpreting results.

The 30 metropolitan areas, hereafter referred to as "cities", that were ultimately selected for evaluation are distributed across the world, with 11 in North America, 9 in Europe, 8 in Asia, and 2 in Oceania (see Figure 1.3.1). These cities are important gateways to major global economies and play an important role in the global innovation landscape. Over the past five years, these 30 cities have collectively published approximately 5.3 million academic papers, accounting for 27% of the global research output (data source: Scopus). Additionally, over the past ten years, these cities have had a total of nearly 6.0 million valid patent applications, accounting for 15% of the global total (data source: LexisNexis). Furthermore, over half (around 54%) of the world's top 1,000 companies have their headquarters located in these 30 cities (data source: European Commission scoreboard).

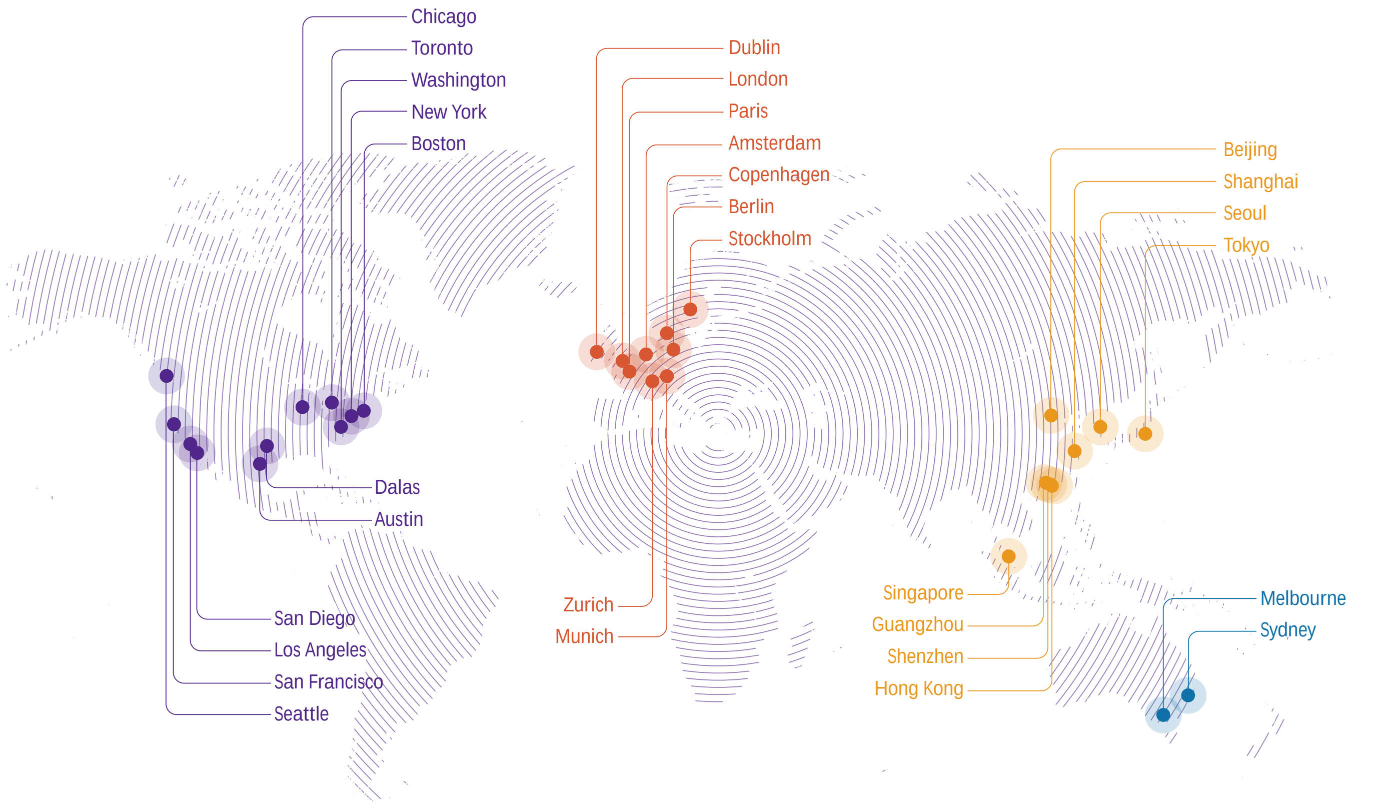


Figure 1.3.1 Geographical distribution of the 30 global innovation cities covered in this report

1 Referenced reports and rankings include: 2thinknow Innovative Cities 2022-2023, JLL Innovation Geographies 2024 (Top performing cities for innovation and talent), Elsevier's Data and insights on international science, technology and innovation - a comparative study of 20 cities around the world, WIPO Science and Technology Cluster Ranking 2024, GIHI 2023 International Science and Technology Innovation Center Index, Top 20 VC ecosystems in the world by pitchbook, KEARNEY The 2023 Global Cities Report, and Oxford Economics Global Cities Index.

CHAPTER 2

SET Index Rankings for Global Innovation Cities

PART 02

2.1
SET Index rankings

2.2
Comprehensive analysis

2.1 SET Index rankings

Based on the SET Index framework established in this report, the top 10 cities by SET Index scores are: Boston, San Francisco, Beijing, London, New York, Los Angeles, Seattle, Shanghai, Hong Kong, and Tokyo (see Figure 2.1.1). Among the top 10 cities, about half are US cities. The performance of Asian cities, particularly Chinese cities, is also noteworthy, with three Chinese cities ranking in the top 10. Among the other Chinese cities, Shenzhen ranks 11th, while Guangzhou ranks 24th.

SET Index Ranking	City	Total Score	Education Level	Talent Development	S&T innovation
1	Boston	85.83	90.45	82.37	86.05
2	San Francisco	85.22	84.50	81.18	87.93
3	Beijing	84.89	87.24	85.26	83.72
4	London	82.48	90.37	77.24	82.46
5	New York	82.43	83.90	81.69	82.30
6	Los Angeles	81.04	84.25	79.14	80.90
7	Seattle	80.58	81.29	77.51	82.13
8	Shanghai	79.68	85.68	77.74	78.44
9	Hong Kong	79.35	87.96	78.47	76.43
10	Tokyo	79.15	85.96	77.66	77.33
11	Shenzhen	78.47	67.92	80.91	81.22
12	Paris	78.38	84.47	75.37	77.75
13	Washington D.C	77.63	75.85	80.51	76.61
14	Singapore	77.33	87.48	74.95	74.69
15	Munich	77.26	82.21	75.29	76.45
16	Chicago	77.15	81.70	77.33	75.23
17	San Diego	77.14	78.80	73.58	78.60
18	Seoul	76.69	83.85	73.94	75.47
19	Amsterdam	75.78	77.95	72.90	76.65
20	Stockholm	75.64	80.62	70.30	76.85
21	Toronto	74.60	83.94	73.30	71.64
22	Zurich	74.14	80.92	70.07	73.87
23	Austin	73.67	76.93	73.22	72.63
24	Guangzhou	73.67	68.48	78.28	72.98
25	Berlin	73.23	82.77	69.52	71.65
26	Sydney	73.09	82.04	69.66	71.57
27	Copenhagen	73.01	74.15	71.05	73.74
28	Melbourne	72.54	79.10	71.80	70.37
29	Dallas	72.50	70.97	73.88	72.29
30	Dublin	70.66	67.73	69.83	72.34

Figure 2.1.1 Overall ranking and scores of SET Index of 30 global innovation cities

2.1 SET Index rankings

Looking at the global distribution (Figure 2.1.2), North American cities perform better in coordinated development of education, talents and S&T, and are ranked relatively high. Chinese cities are mainly in the upper-middle rank, with a total of 3 Chinese cities in the top 10. The SET Index score of other cities in Asia-Pacific is relatively scattered, among which Tokyo ranks 10th, the highest, and other cities are in the middle or lower rank. European cities are mostly in the middle or lower-middle rank, with only London among the top 10, ranking 4th.

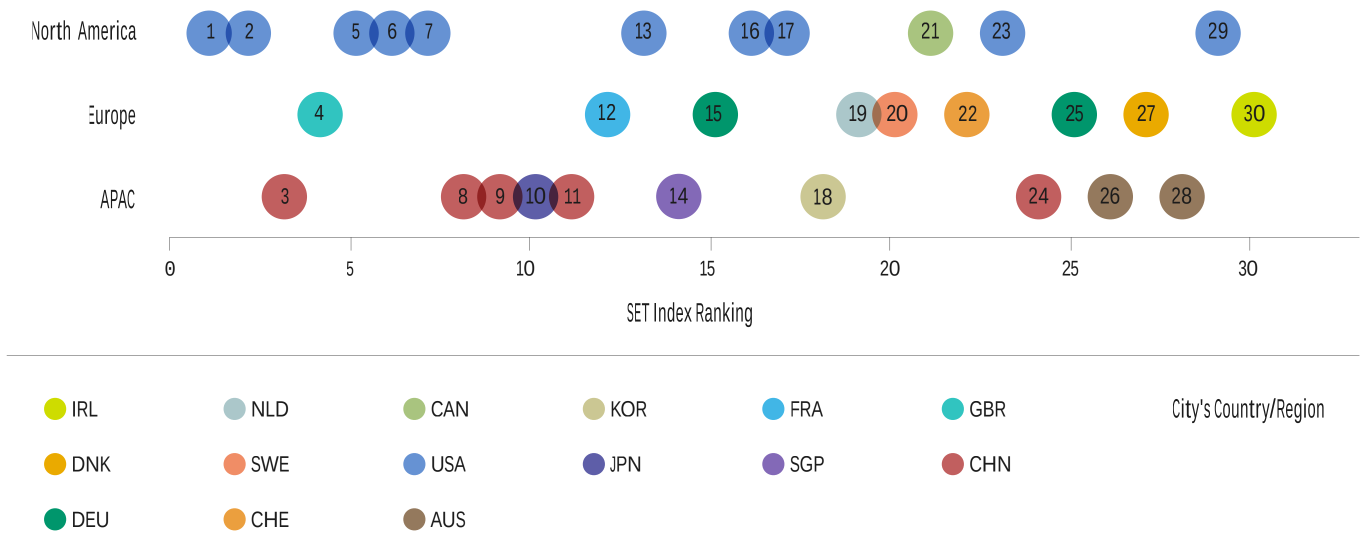


Figure 2.1.2 Distribution across North America, Europe and Asia-Pacific of cities by SET Index rankings

2.2 Comprehensive analysis

The top three cities according to the SET Index are Boston, San Francisco and Beijing, which serve as leading examples of innovation development worldwide. Benefiting from top educational resources, thriving high-tech industries, and prominent research institutions, these three cities attract significant talent and have become hubs for the accumulation of knowledge, technology and information, which in turn drives their innovation capabilities.

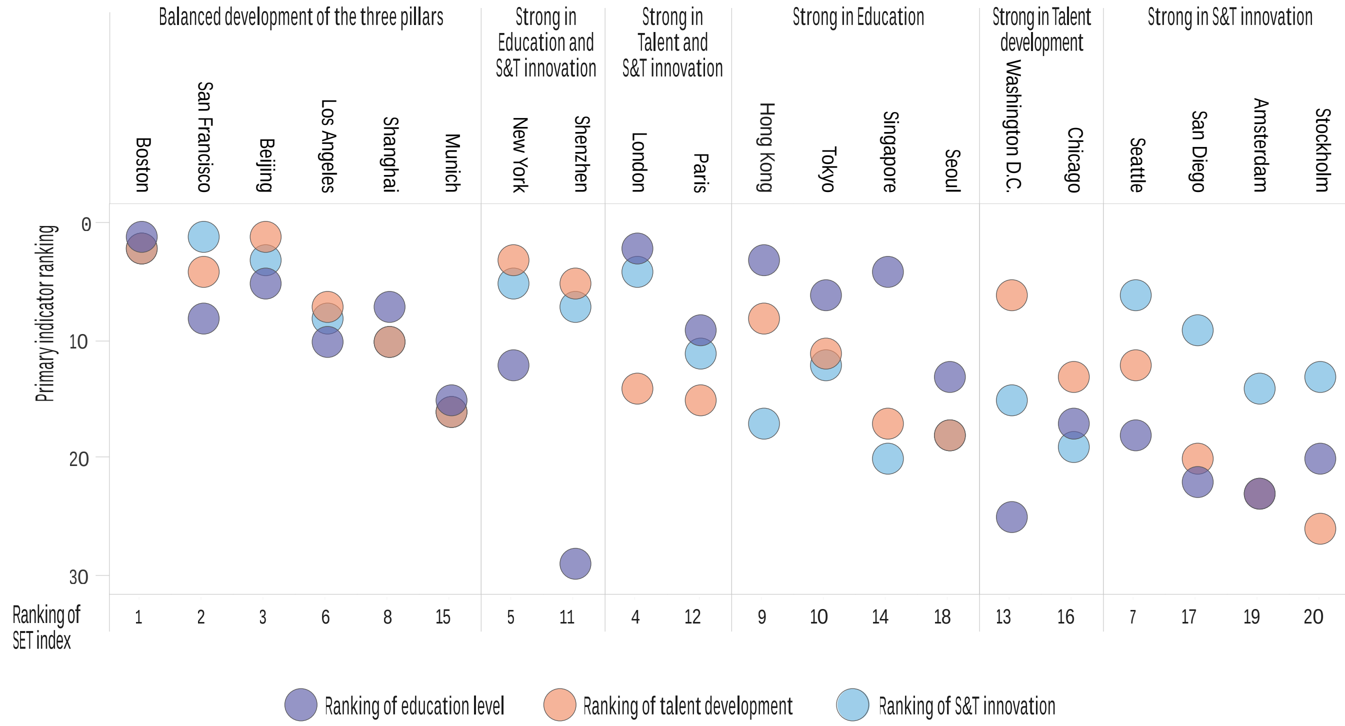


Figure 2.2.1 Comparison of city innovation models and rankings of representative cities across the three dimensions of education level, talent development, and S&T innovation

Cities leading in the overall SET Index rankings generally excel in all three innovation elements. Boston ranks first among global innovation cities by SET Index score, closely followed by San Francisco and Beijing. These three metropolitan areas form the first tier of global innovation cities. They are also characterized by their high rankings in all the three dimensions of the index: education level, talent development, and S&T innovation.

Boston, world-famous for its colleges and universities, is a metropolitan area home to prestigious institutions like Harvard University and Massachusetts Institute of Technology (MIT). These institutions not only make Boston a crucial hub for global education and research, but also attract numerous high-level research talents. Additionally, the city hosts R&D centers or regional headquarters of many world-leading biomedical companies such as Novartis, Merck, Pfizer, and Biogen, demonstrating its vibrant biomedical industry development. San Francisco is also a major global center for science, education, and culture, with nearby top universities like Stanford and UC Berkeley playing key roles in supplying talent to America's electronics and computer industries. Stanford University laid crucial foundations for the formation and rise of Silicon Valley, the world-renowned high-tech R&D base, incubating numerous tech giants like Google, HP, Cisco, and SpaceX, while the thriving industry continues to attract high-tech talent. Beijing, as China's most concentrated hub of higher education resources, hosts 23% of the country's "Double First-Class" universities (34 in total) and numerous research institutes, including national institutions like the Chinese Academy of Sciences, and Chinese Academy of Engineering. It is also home to headquarters of leading Chinese tech companies like Baidu, Xiaomi, Lenovo, and ByteDance.

These three cities have demonstrated a path to innovation by leveraging their top educational resources, concentrated research institutions and high-tech industries to create knowledge, technology, and information accumulation, and attract talent, thereby enhancing their innovation capabilities.

In the SET Index ranking, cities in the upper and middle reaches usually perform well in two dimensions, with only slight weaknesses in the other dimension. For example, although Hong Kong ranks relatively low in S&T innovation, it performs well in education level and talent development. Shenzhen, in which education level is a weakness, performs strongly in talent development and S&T innovation, putting it at 11th for the total score. As core cities of the Guangdong-Hong Kong-Macao Greater Bay Area, Shenzhen and Hong Kong have close exchanges for resource sharing, which is conducive to the coordinated development of education, talents and S&T in the region. This reflects an example of cities complementing each other with their own advantages for mutual

2.2 Comprehensive analysis

benefit and promoting coordinated innovation development of the region or beyond.

Of course, there are also cities with unique strengths, which show differentiated innovation development paths. For example, Singapore is known for its excellent education system; Washington D.C. has advantages in talent attraction and development; and Seattle stands out for its strong technological innovation capabilities. These cities have leveraged their strengths—whether in educational resources, talent accumulation, or high-tech industry strength—to drive progress in other dimensions, forging their unique innovation paths.

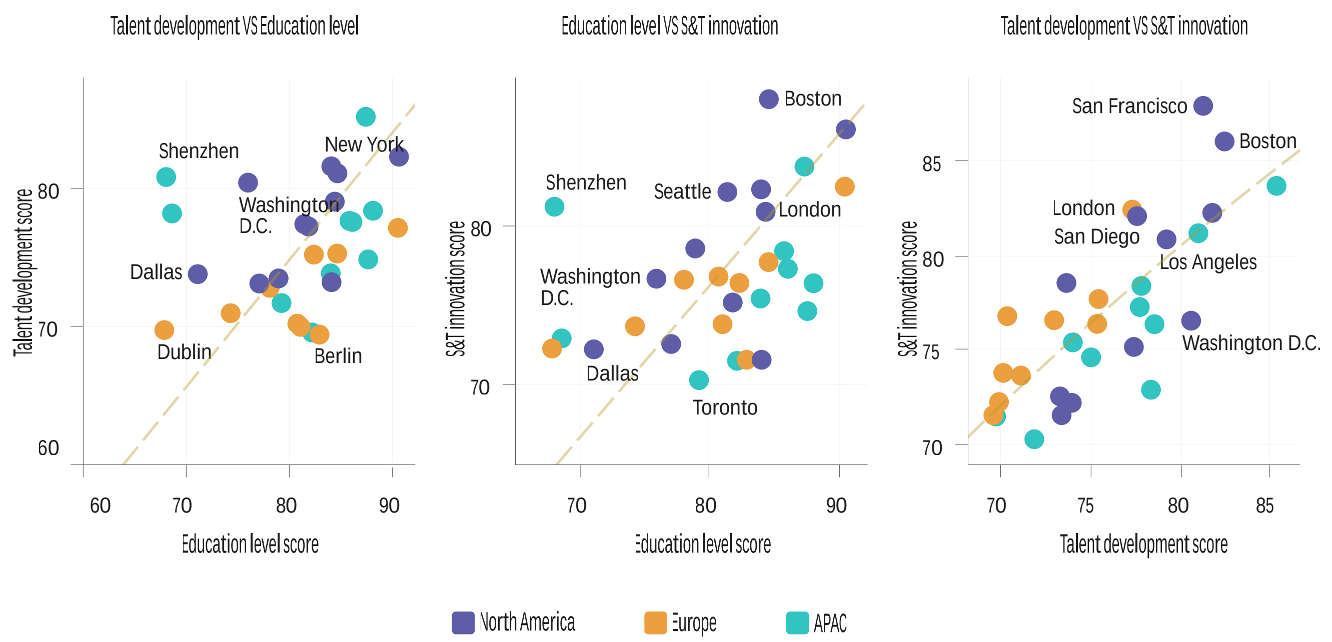


Figure 2.2.2 Scatter plots of 30 global innovation cities' scores for education level, talent development and S&T innovation

The synergistic development of S&T, education, and talent is reflected in their interrelationships. As shown on the scatter plot showing scores on these three dimensions for 30 global innovation cities (see Figure 2.2.2), these three elements generally show positive correlations, demonstrating their coordinated and mutually reinforcing relationships.

Notably, the correlation between talent development and S&T innovation is particularly strong, while the connection between education level and talent development is weaker. This might be because achieving a high level of education and cultivation of high-quality talent usually takes a long time. Some cities may explore alternative approaches to accelerate local talent development, for example by stimulating talent inflow. For example, Shenzhen, an emerging city, shows strong talent potential by actively attracting and cultivating young talent, despite its relatively low education score. This strategy helps boost Shenzhen's technological progress and industrial development, promoting its S&T innovation.

Overall, high-quality education lays a solid foundation for innovation. Cities at the forefront of innovation typically boast first-class universities and research institutions. These institutions not only nurture high-quality talent, but also drive research and development, boosting the city's S&T innovation capabilities. Talent development is the core force driving innovation. The world's most innovative cities excel at attracting and retaining top-tier professionals. This concentration of talent helps spread and apply knowledge and technologies, fueling the growth of the city's innovation ecosystem. S&T capacity is crucial for industrial strength. Cities known for their innovation often lead in research, allowing them to make significant technological advances and drive industrial growth. A strong foundation in scientific research also supports sustainable technological development in cities, enhancing innovation capabilities. By developing these three key areas, cities can build a thriving innovation ecosystem and strengthen their global standing.

CHAPTER 3

Education Level

PART 03

Education serves as the cornerstone for innovation, with both basic education and higher education playing a role. The SET Index shows that Asian cities excel in basic education, whereas European and American cities lead in higher education.

The evaluation of education levels encompasses both basic—the primary and secondary school levels—and higher education. According to the SET Index, Boston leads in overall education among the 30 global cities, closely followed by London, and with Hong Kong in third place (see Figure 3.1.1). Interestingly, five of the top 10 cities come from Asia, highlighting the competitiveness of the strong education systems in Asia. Notably, Chinese cities such as Hong Kong, Beijing, and Shanghai rank among the world's top 10, thanks to their well-established, robust primary, secondary, and higher education systems.

Ranking of education level	City	Education level score	Basic education score	Higher education score
1	Boston	90.45	81.6	96.3
2	London	90.37	83.9	94.7
3	Hong Kong	87.96	80.2	93.1
4	Singapore	87.48	87.9	87.2
5	Beijing	87.24	84.9	88.8
6	Tokyo	85.96	87.6	84.9
7	Shanghai	85.68	81.9	88.2
8	San Francisco	84.50	79.0	88.2
9	Paris	84.47	76.4	89.8
10	Los Angeles	84.25	79.6	87.4
11	Toronto	83.94	83.6	84.2
12	New York	83.90	80.4	86.2
13	Seoul	83.85	87.2	81.7
14	Berlin	82.77	81.2	83.8
15	Munich	82.21	79.3	84.1
16	Sydney	82.04	77.9	84.8
17	Chicago	81.70	78.5	83.8
18	Seattle	81.29	79.0	82.8
19	Zurich	80.92	79.7	81.7
20	Stockholm	80.62	76.6	83.3
21	Melbourne	79.10	79.8	78.6
22	San Diego	78.80	77.6	79.6
23	Amsterdam	77.95	78.4	77.6
24	Austin	76.93	75.5	77.9
25	Washington D.C.	75.85	81.5	72.1
26	Copenhagen	74.15	78.1	71.5
27	Dallas	70.97	77.3	66.7
28	Guangzhou	68.48	75.0	64.1
29	Shenzhen	67.92	75.0	63.2
30	Dublin	67.73	73.6	63.8

Figure 3.1.1 Ranking by education levels and scores on secondary indicators of education levels for 30 global innovation cities

Comparing the top 15 cities in basic education and higher education (see Figure 3.1.2) shows the different educational advantages of the world's major innovative cities. In general, Asian cities are stronger in basic education. The top four cities in basic education are all in Asia, showcasing the emphasis placed on foundational education in these regions. However, when it comes to higher education, the positions of the three Asian cities that rank highest in basic education drop by eight or more places. European and American cities lead in higher education. For instance, Boston and Paris have a notably higher ranking in higher education than basic education. London stands out as a European city demonstrating a high level of attainment in both basic and higher education. So do Beijing and Shanghai, as well as New York.

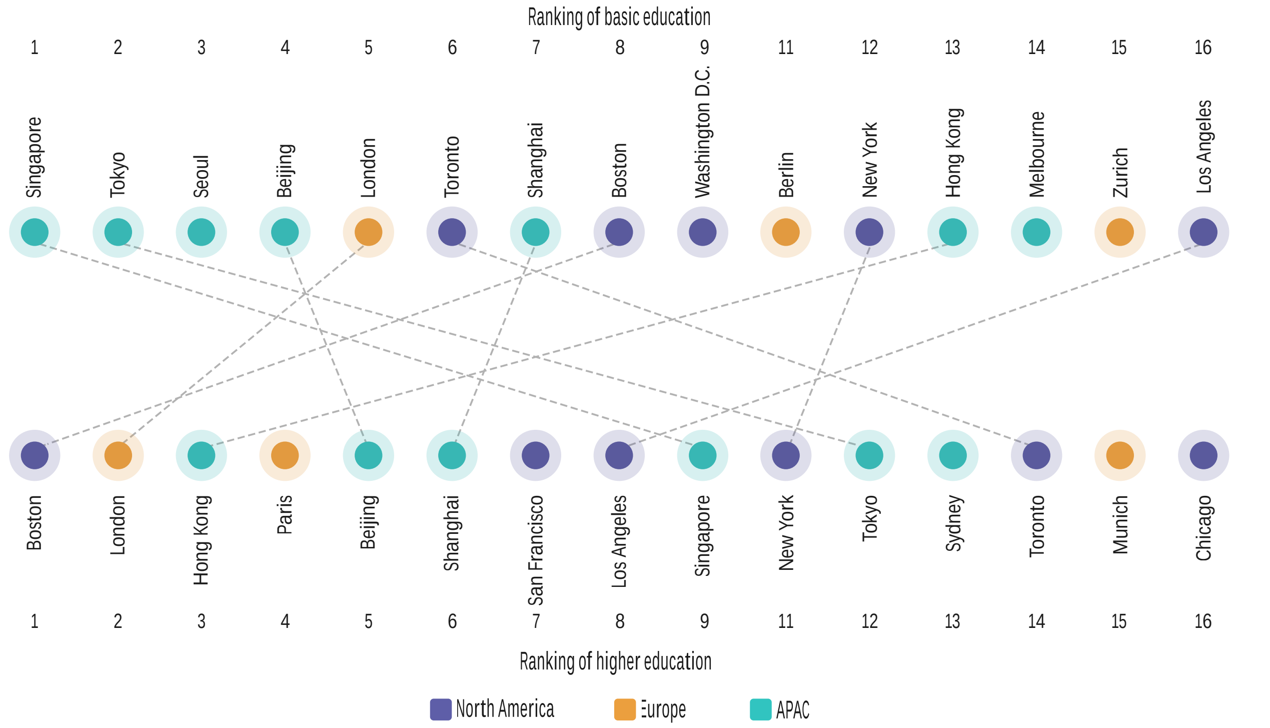


Figure 3.1.2 Top 15 cities in basic education and in higher education

3.2 Basic education

Asian cities hold an advantage in STEM education at the primary and secondary school levels, while the residents of most Western cities appear to have a higher average education level.

High-quality basic education is essential for nurturing innovative talent and enhancing a society's innovation capacity. In this report, we evaluate the basic education level of cities using three indicators: the average education level of residents, the quality of STEM (science, technology, engineering and mathematics) education in primary and secondary schools, and the international science competition awards for secondary schools.

Asian cities generally excel in international science competitions, as evidenced by the numerous awards won by their high school students in the International Olympiad in Mathematics, Physics, Chemistry, Biology, and Information. These cities also perform better on STEM education quality in primary and secondary schools, as measured by the average scores on the Program for International Student Assessment (PISA) tests in mathematics and science, compared with Western cities, and they lead in scores for basic education (see Figure 3.2.1). However, for most Chinese cities, the average education level of residents still lags behind European and American cities, both in terms of the average years of education for adults and the proportion of the population with higher education.

Ranking of Basic education	City	Basic education score	Average education level of residents	Quality of STEM education in primary and secondary schools	International science competition awards for secondary schools
1	Singapore	87.89	83.00	87.96	100.00
2	Tokyo	87.56	89.47	76.08	100.00
3	Seoul	87.15	90.01	73.82	100.00
4	Beijing	84.94	69.89	100.00	100.00
5	London	83.86	95.76	66.62	80.00
6	Toronto	83.58	95.47	71.15	72.50
7	Shanghai	81.91	68.81	100.00	87.50
8	Boston	81.64	95.08	61.99	77.50
9	Washington D.C.	81.53	97.87	61.99	70.00
10	Berlin	81.19	96.80	65.97	65.00
11	New York	80.44	91.68	61.99	80.00
12	Hong Kong	80.23	81.78	77.80	80.00
13	Melbourne	79.84	89.03	64.43	80.00
14	Zurich	79.73	94.21	67.09	62.50
15	Los Angeles	79.57	88.95	61.99	82.50

Figure 3.2.1 Heat map of the top 15 cities in basic education and scores on the tertiary indicators

Average education level of residents

When considering the average education level of residents of the top 15 cities by basic education score (Figure 3.2.2), European cities perform well in average years of education for adults, while North American cities score higher for share of population with higher education. Specifically, Washington, DC and Berlin rank highest among the 30 cities in the average years of schooling for adults aged 25+; Toronto and Melbourne have the highest shares of population with higher education.

Figure 3.2.2

The scores for the mean years schooling of adults aged 25+ and of the share of population with higher education, for the top 15 cities in basic education

3.3 Higher education

When it comes to higher education, Asia-Pacific cities are steadily advancing in developing world-class disciplines and universities. Chinese cities, in particular, with the establishment of new research institutions, are emerging as significant contributors to global higher education.

Higher education provides a critical source of talent for scientific research and technological development. In this report, a city's higher education level is assessed using three indicators: the performance of world-class disciplines, the number of world-class universities, and the growth rate of the number of research institutions. The performance of world-class disciplines is measured by the median ranking of the top 200 disciplines in the world in S&E fields, and the S&E discipline ranking growth index (for more details on these indicators, see Appendix 1).

On the above indicators, Boston, London and Hong Kong score highest. These three cities have a clear lead, with scores above 93. Among the top 15 cities in higher education, 6 are from the Asia-Pacific (APAC) region; while another 6 cities are from the North American region; only 3 are European cities (see Figure 3.3.1). European or American cities and APAC cities score similarly in terms of the performance of world-class disciplines and the number of first-class universities. In terms of the growth of research institutions, Chinese cities perform well, with Shanghai, Hong Kong and Beijing leading among the top 15 cities in higher education. This shows that cities in the APAC region are making consistent progress in developing world-class academic disciplines and top-tier universities, contributing to the diversity and balanced development of higher education globally. Notably, Chinese cities are emerging as significant contributors in global higher education, thanks to their vigorous efforts to expand their research institutions.

Ranking of higher education	City	Higher education score	Performance of world-class disciplines	Number of world-class universities	Growth rate of the number of research institutions
1	Boston	96.33	99.95	92.00	75.26
2	London	94.70	93.12	100.00	83.59
3	Hong Kong	93.10	90.29	100.00	88.28
4	Paris	89.83	86.29	100.00	74.75
5	Beijing	88.77	91.07	84.00	87.51
6	Shanghai	88.19	89.51	84.00	96.23
7	San Francisco	88.16	95.03	76.00	71.80
8	Los Angeles	87.37	86.11	92.00	75.92
9	Singapore	87.21	92.73	76.00	82.67
10	New York	86.21	92.01	76.00	72.02
11	Tokyo	84.89	89.47	76.00	78.69
12	Sydney	84.80	82.33	92.00	73.76
13	Toronto	84.17	88.28	76.00	79.80
14	Munich	84.13	88.56	76.00	75.28
15	Chicago	83.83	87.92	76.00	77.76

Figure 3.3.1 Heat map of the top 15 cities in higher education and scores on the tertiary indicators

3.3 Higher education

Number of World-class universities

The number of world-class universities to which a city is home is an important indicator of its higher education resources. This report measures the development of world-class universities in cities by counting the number of universities ranked among the top 200 in the Times Higher Education (THE) World University Rankings. As shown in Figure 3.3.2, out of the 30 evaluated cities, Hong Kong, London, and Paris had the highest number of world-class universities, with each hosting 5 institutions. Los Angeles, Boston, Sydney, and Berlin follow with 4 world-class universities each. Beijing, Shanghai, Seoul, and Stockholm each have 3 universities in the top ranks.

Although North American cities may not have the highest number of top universities, the institutions they do have typically rank very high. For instance, Harvard University and MIT, for Boston, and Stanford University and UC Berkeley, for San Francisco, are all ranked in the global top 10. This underscores the exceptional quality and reputation of US universities, and that their advantage in high-quality higher education should not be underestimated.

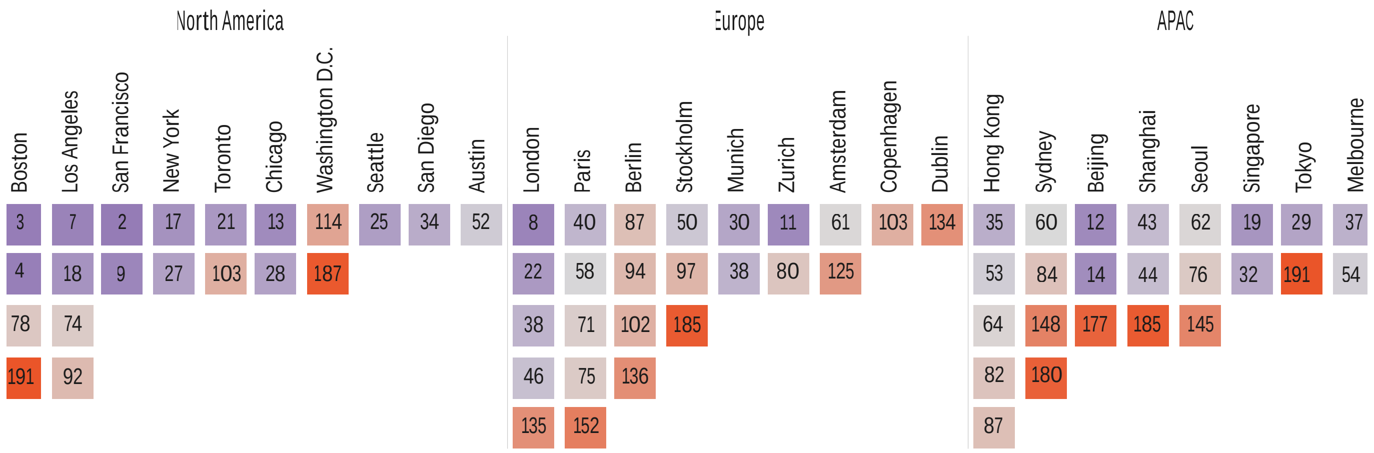


Figure 3.3.2 Number of world-class universities in the 30 global innovation cities in higher education, 2024.
(One square represents one university, and the number inside the square indicates the ranking of the university.)

Growth rate of the number of research institutions

Growth in the number of research institutions is indicative of the healthy development of a city's higher education resources. Of the top 15 cities with the fastest growth in research institutions over the past five years, APAC and European cities generally outpace North American cities in institutional expansion (see Figure 3.3.3). In particular, Chinese cities, including Shenzhen, Shanghai, and Guangzhou, top this list, while Hong Kong and Beijing also rank among the top six. Shenzhen's rapid growth in research institutions can be attributed to the many high-level research centers established either by local leading enterprises or through university-industry collaboration. Examples include the New Cornerstone Science Foundation Laboratory initiated by Tencent, focusing on cutting-edge basic research; the National Center for Applied Mathematics Shenzhen, the first national-level mathematics center in Shenzhen; and the State Key Laboratory of Radio Frequency Heterogeneous Integration. These institutions help to promote deep integration between academia and industry, contributing to the improvement of Shenzhen's higher education.

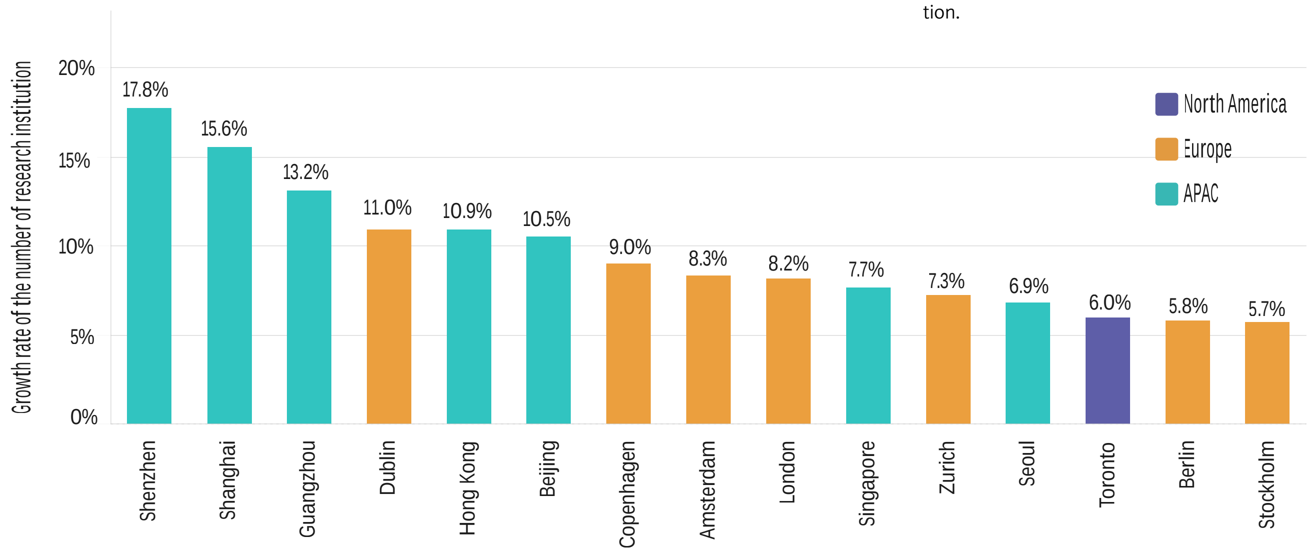


Figure 3.3.3 Top 15 cities by growth rate of the number of research institutions, 2019–2024

CHAPTER 4

Talent Development

PART 04

China and the United States are global leaders in talent development, with cities in both countries monopolizing the top 10 rankings. Chinese cities excel in talent potential, while American cities have an edge in the size of the top-tier research talent pool.

Talent is a crucial driver of a city's innovation development. Among the 30 global cities assessed in this report, Beijing has a clear lead, ranking first in talent development with a score of 85.26; Boston ranks second, and New York follows in third place (see Figure 4.1.1). Notably, all Chinese cities evaluated in the report are in the top 10 in talent development, indicating China's success in building its talent pool for S&T innovation.

Ranking of talent development	City	Talent development score	Research talent score	Industrial talent score	Talent potential score
1	Beijing	85.26	83.8	92.3	78.8
2	Boston	82.37	89.6	81.0	75.6
3	New York	81.69	86.4	83.1	74.6
4	San Francisco	81.18	80.8	86.8	75.1
5	Shenzhen	80.91	71.3	77.1	96.5
6	Washington D.C.	80.51	88.2	82.5	69.2
7	Los Angeles	79.14	83.6	79.1	74.0
8	Hong Kong	78.47	76.5	76.8	82.7
9	Guangzhou	78.28	73.8	77.4	84.5
10	Shanghai	77.74	78.2	75.0	80.5
11	Tokyo	77.66	77.5	88.6	65.0
12	Seattle	77.51	77.4	79.3	75.5
13	Chicago	77.33	78.7	77.1	76.0
14	London	77.24	87.8	72.0	71.1
15	Paris	75.37	85.9	75.7	62.7
16	Munich	75.29	71.8	79.0	75.0
17	Singapore	74.95	72.4	78.3	74.0
18	Seoul	73.94	76.7	72.8	72.0
19	Dallas	73.88	73.7	72.3	76.0
20	San Diego	73.58	69.6	76.8	74.4
21	Toronto	73.30	77.3	71.4	70.9
22	Austin	73.22	65.9	76.3	78.2
23	Amsterdam	72.90	74.4	72.5	71.6
24	Melbourne	71.80	78.4	67.4	69.2
25	Copenhagen	71.05	74.5	69.4	69.0
26	Stockholm	70.30	73.4	70.0	67.0
27	Zurich	70.07	72.5	63.2	75.2
28	Dublin	69.83	66.9	70.8	72.2
29	Sydney	69.66	78.2	62.6	67.9
30	Berlin	69.52	74.2	63.3	71.3

Figure 4.1.1 Talent development rankings and scores of secondary indicators of talent development of 30 global innovation cities

Looking at regional distribution, China and the United States stand out in S&T talent development, with all top 10 cities, by score in talent development, located in these two countries (Figure 4.1.2). European cities generally fall in the middle and lower ranks. It is noteworthy that within each region, there are wide disparities between cities, showing uneven performance in talent development, with scores displaying polarization.

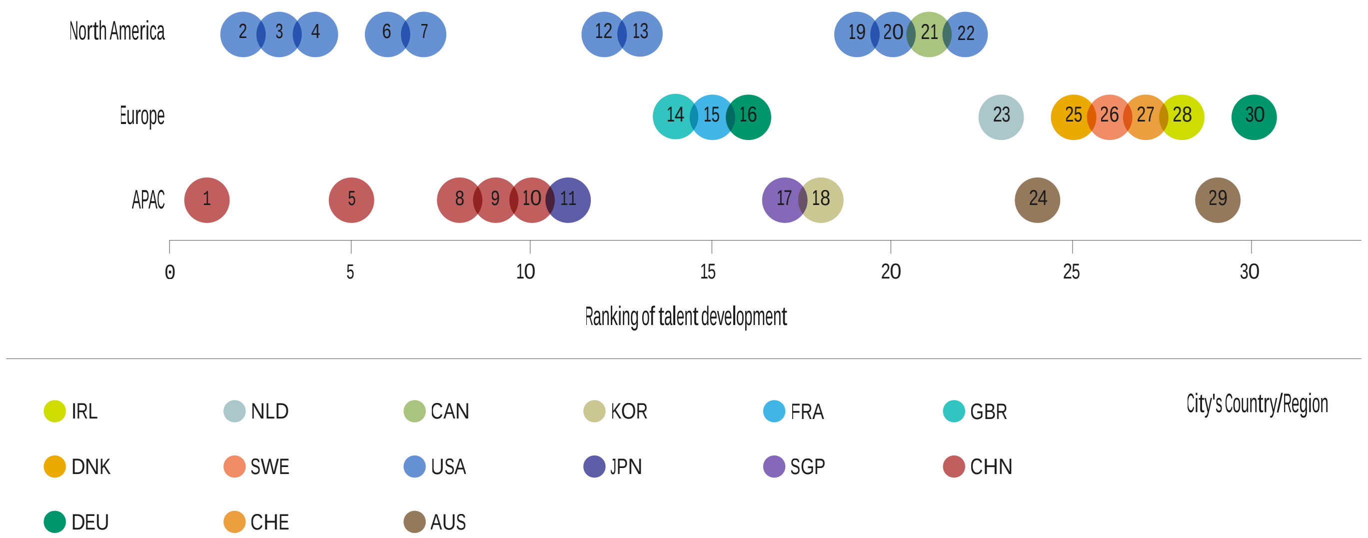


Figure 4.1.2 Regional distribution of talent development rankings of 30 global innovation cities

Talent development advantages by city

The talent development capacity of a city is measured by three secondary indicators, namely research talent, industrial talent and talent potential (for details on these indicators, see Appendix 1). The scores of secondary indicators in talent development (see Figure 4.1.3) show that Beijing and leading innovation cities in the US, such as San Francisco, New York, and Boston, demonstrate strengths in both industrial talent and research talent. In Europe, Paris and London have notable advantages in research talent, while in Asia, Tokyo stands out in industrial talent. Furthermore, it is worth noting that Chinese cities such as Shenzhen, Guangzhou, Hong Kong, and Shanghai excel in talent potential, indicating their momentum for continued growth in talent development.

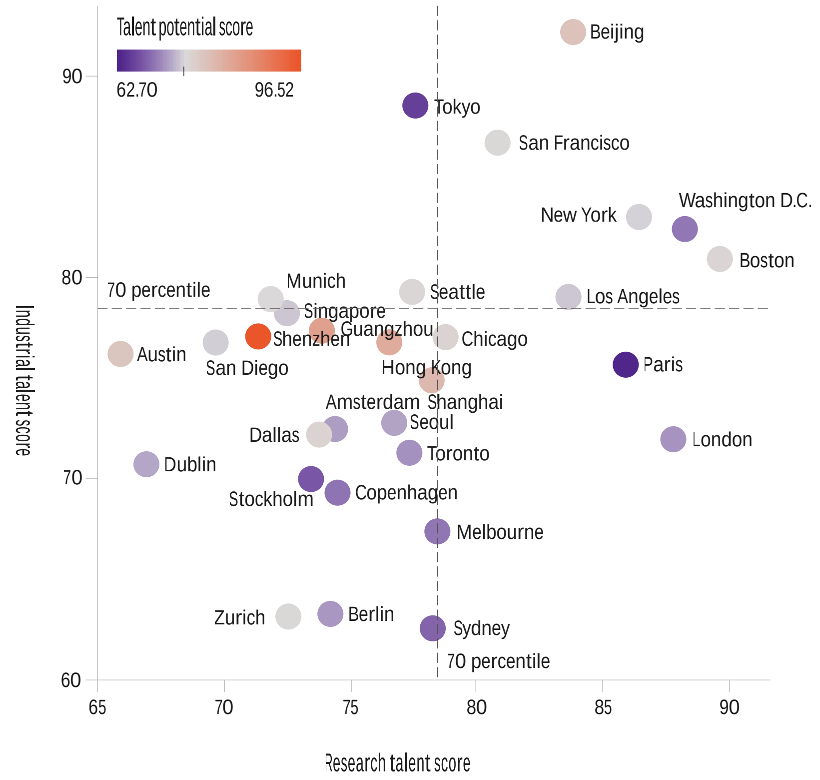


Figure 4.1.3
Bubble chart of the scores of secondary indicators of talent development for 30 global innovation cities

Leading cities for research talent are primarily concentrated in Europe and North America, where they show advantages in average research talent quality and the pool of top-tier researchers. Chinese cities, like Beijing and Shanghai, demonstrate an edge in the scale of their research talent pool.

Active researchers are not only the source of knowledge creation in a city, but also the main force for cultivating future innovative talents. The SET Index primarily measures a city's research talent strength by evaluating the competitiveness of S&E researchers and the number of top-tier researchers. This helps reveal a city's general strength in research talent, as well as its performance in attracting and nurturing top-class research talent. The competitiveness of research talent is derived from two sub-indicators: the total number of researchers in S&E fields, and the median h-index of S&E researchers, respectively reflecting the size of a city's research talent pool and the average academic impact of its researchers.

As shown in Figure 4.2.1, Boston, Washington DC, and London rank as the top three cities by research talent scores. These three cities maintain dominant positions in both the competitiveness of S&E researchers and the number of top-tier S&E researchers, with particularly strong advantages in the latter indicator.

Among the top 15 cities for research talent, Beijing and Shanghai are the only two cities in China. Their competitive advantage in S&E research talent primarily lies in the scale of their research talent pool. The remaining cities in the top 15, such as Paris, Washington DC, and Los Angeles, demonstrate their competitive advantage mainly through higher median h-index of their researchers, an indicator that reflects the average academic impact level of research talent.

Ranking of research talent	City	Research talent score	Competitiveness of S&E researchers	Number of top-tier S&E researchers
1	Boston	89.60	86.13	100.00
2	Washington D.C.	88.21	86.64	92.93
3	London	87.75	84.98	96.08
4	New York	86.39	83.37	95.48
5	Paris	85.87	87.20	81.88
6	Beijing	83.78	86.67	75.14
7	Los Angeles	83.60	82.63	86.49
8	San Francisco	80.79	81.07	79.97
9	Chicago	78.73	79.16	77.43
10	Melbourne	78.41	80.53	72.04
11	Sydney	78.22	80.18	72.35
12	Shanghai	78.18	82.28	65.87
13	Tokyo	77.53	77.59	77.38
14	Seattle	77.41	78.81	73.20
15	Toronto	77.30	78.11	74.87

Figure 4.2.1 Heat map of the top 15 cities by research talent score and scores on the tertiary indicators

S&E talent pool and top-tier researchers

Figure 4.2.2 shows the performance of the top 15 cities in terms of the number of S&E researchers and top-tier researchers. In terms of total S&E researchers, Asian cities occupy the top three places. Among them, Beijing ranks first with more than 300,000 active researchers,[2] and Shanghai ranks second with more than 120,000 active researchers in the S&E field. Tokyo ranks third with more than 60,000 S&E researchers.

In terms of the number of top-tier researchers, European and American cities lead. This report uses Stanford University's 2023 ranking of top 2% highly cited scientists to measure the number of top-tier researchers in each city. As shown in Figure 4.2.2, Boston has the largest number of the top 2% highly cited scientists in the world, with a total of more than 5,500. London and New York follow closely behind, with about 5,000 highly cited scientists.

Overall, among the top 15 cities in research talent scores, US cities' advantage primarily lies in their accumulation of top-tier researchers. Asian cities, benefiting from their larger urban populations, demonstrate clear advantages in terms of the total quantity of S&E researchers.

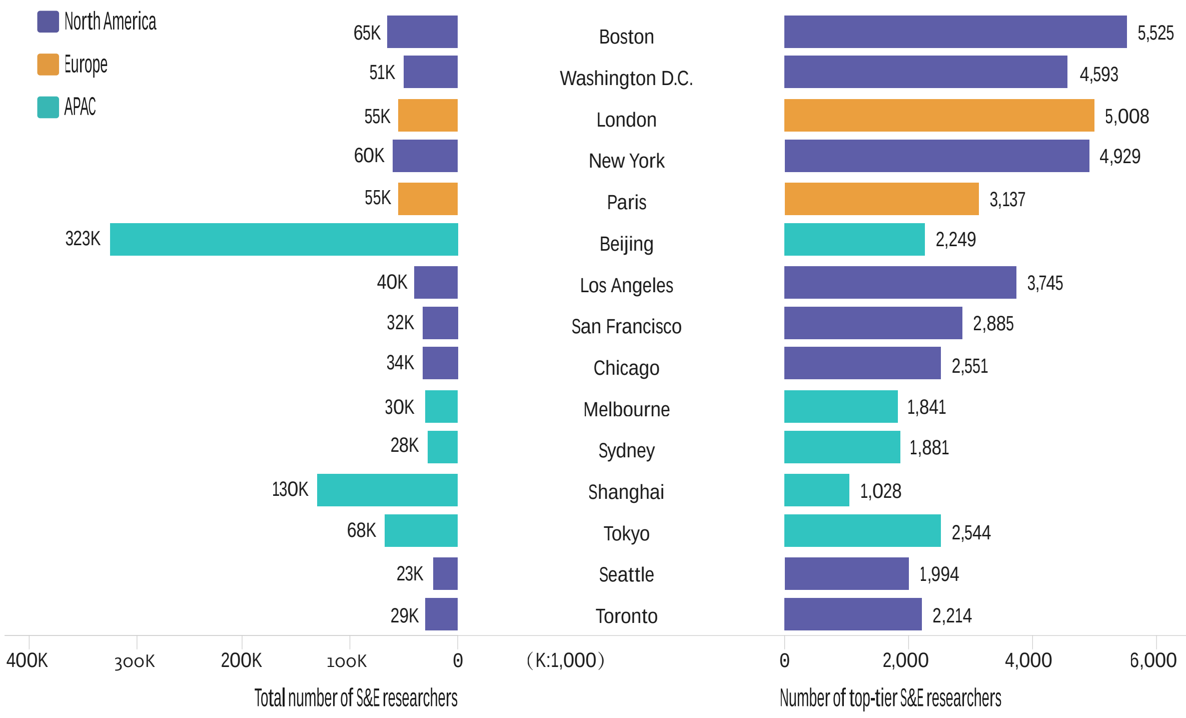


Figure 4.2.2 Total number of S&E researchers and number of top-tier S&E researchers, for the top 15 cities by research talent score, 2019–2023

[2] Active scientific research talents refer to researchers who have published at least three papers in the past five years and at least one paper in the past three years.

Leading cities in industrial talent are primarily concentrated in Asia and North America. Beijing ranks first in overall industrial talent due to its advantage of scale. US cities showcase their strength in industrial talent through a high proportion of employees in high-tech industries.

Industrial talent plays a crucial role in technological research, development, and transformation, serving as the backbone for a city's technological innovation and industrial advancement. The SET Index assesses a city's industrial talent strength through three indicators: total number of employees in the world's top 1,000 innovative companies, proportion of employees in high-tech industries among the top 1,000 innovative companies, and number of top-tier talents in the engineering field. For details on how these indicators are calculated, see Appendix 1.

Due to data availability limitations, the industrial talent data is restricted to companies ranked in the top 1,000 in the EU Innovation Scoreboard. This approach aims to reflect the scale and distribution of industrial talent based on the talent profiles of a city's most innovative companies.

As shown in Figure 4.3.1, Beijing, Tokyo, and San Francisco rank as the top three cities, with Beijing showing a significant lead in industrial talent scores. Looking at the geographical distribution of the top 15 cities in industrial talent, North American cities dominate with eight positions, and most rank in the top 10. Asian cities also show strong performance with six positions. However, apart from Beijing and Tokyo, which rank at the top, other Asian cities like Singapore, Guangzhou, and Shenzhen rank 10th or lower. Among European cities, only Munich made it to the top 15, ranking 9th.

Examining the performance of the top 15 cities across the three indicators, Beijing and Tokyo demonstrate clear advantages in terms of industrial talent scale. Beijing leads by a significant margin in total global employees at top 1,000 innovative companies, owing to it being the headquarters for major Chinese state-owned enterprises such as China Mobile and Sinopec. Tokyo, which serves as the headquarters for major Japanese multinational automotive, electronics, and telecommunications companies, ranks second in total global employees at top 1,000 innovative companies.

In addition, Beijing also has an outstanding advantage in the number of top-tier talents in the engineering field. Most American cities and some Asian cities (Singapore and Guangzhou) have a notable advantage in the proportion of employees working in high-tech industries.

Ranking of industrial talent	City	Industrial talent score	Total number of employees in top 1,000 innovative companies	Proportion of employees in high-tech industries among the top 1,000 innovative companies	Number of top-tier talents in the engineering field
1	Beijing	92.25	100.00	74.18	100.00
2	Tokyo	88.60	99.64	86.85	81.64
3	San Francisco	86.76	78.56	97.40	84.92
4	New York	83.06	81.20	85.08	82.95
5	Washington D.C.	82.47	69.45	98.33	80.33
6	Boston	80.98	71.59	84.24	85.57
7	Seattle	79.34	66.90	99.22	73.77
8	Los Angeles	79.09	63.25	90.66	82.30
9	Munich	78.99	73.05	97.13	69.84
10	Singapore	78.29	60.84	100.00	75.08
11	Guangzhou	77.42	62.57	99.75	71.80
12	Shenzhen	77.13	82.59	91.01	62.62
13	Chicago	77.10	76.65	91.60	66.56
14	Hong Kong	76.84	60.00	96.01	75.08
15	San Diego	76.83	62.10	100.00	70.49

Figure 4.3.1 Heat map of the top 15 cities by industrial talent score and scores on the tertiary indicators

Proportion of employees in high-tech industries among the top 1,000 innovative companies

Singapore and San Diego performed well in the proportion of employees in high-tech industries[3] among the world's top 1,000 innovative companies (see Figure 4.3.2). Almost all the talents in the top 1,000 innovative companies in these two cities come from high-tech industries, with Singapore mainly concentrated in the software and computer services industry, while San Diego is mainly in the pharmaceutical and biotechnology industry. In addition, Guangzhou, Seattle, and Washington DC also performed well in this indicator.

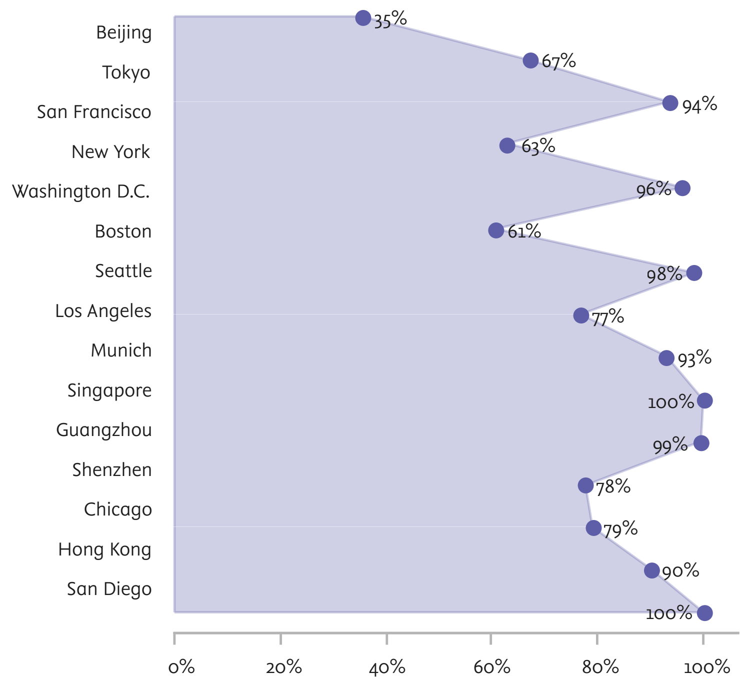


Figure 4.3.2
Proportion of employees in high-tech industries in the top 15 cities by industry talent ranking, out of the top 1,000 innovative companies (2023)

Number of top-tier talents in the engineering field

This report uses the number of newly elected fellows of the Institute of Electrical and Electronics Engineers (IEEE)[4] in the past five years to measure a city's number of top-tier talents in the engineering field. As seen in Figure 4.3.3, the top 15 cities in terms of the number of top-tier talents in the engineering field are mainly located in the APAC and North American regions. Beijing stands out as the city with the largest number of IEEE fellows. This is closely linked to the concentration of first-class research institutions and innovative enterprise R&D centers in the city, particularly its advantage in the scale of talent specializing in engineering application technology. Boston, San Francisco and New York rank in the second tier, with each having between 30 to 40 IEEE Fellows. It is important to note that IEEE Fellowship selection tends to favor electrical engineering, computer science, and related fields. Therefore, this indicator does not fully represent a city's high-level talent in other engineering disciplines such as mechanical engineering and civil engineering.

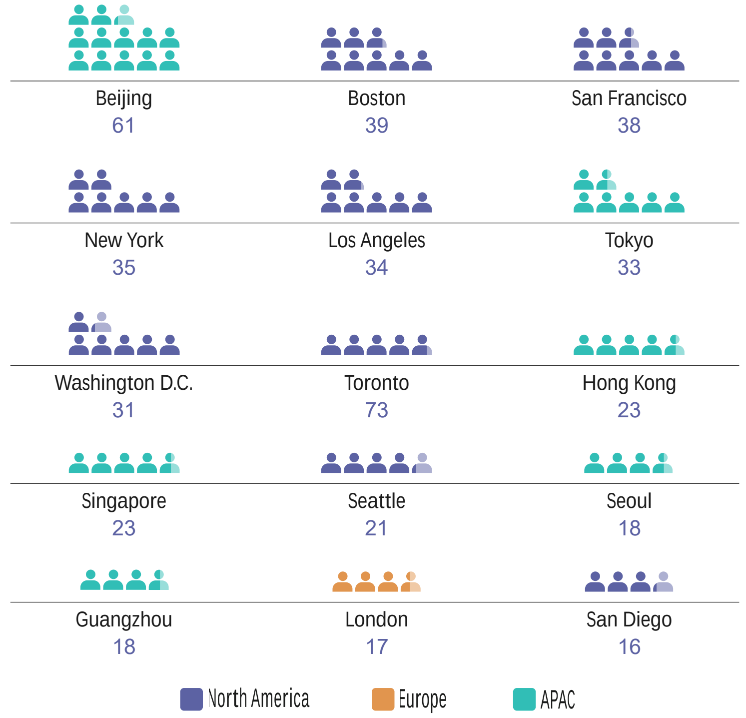


Figure 4.3.3 Top 15 cities by number of IEEE fellows, 2020–2024

[3] The high-tech industries referred to in this report include aerospace and defense, alternative energy, automotive and parts, electronic and electrical equipment, financial services, medical equipment and services, mobile communications, pharmaceuticals and biotechnology, software and computer services, technology hardware and equipment. See Appendix 1 for details.

[4] IEEE Fellow is the highest honor awarded by IEEE and is given to members who have made outstanding contributions in the fields of engineering, science and technology. Most of them are industry leaders and innovators, playing a key role in technological development and industrial innovation.

4.4 Talent potential

Chinese cities occupy the top five spots in rankings of talent potential, highlighting their strengths in nurturing the growth of young talent and optimizing talent structures. European and American cities, on the other hand, show strengths in attracting talent. Shenzhen holds the top spot in talent potential, reflecting the effectiveness of its talent development efforts.

Talent potential refers to a city's ability to cultivate and attract young, high-quality talent. Cities with high talent potential show strong prospects for sustaining and growing their talent pools. The SET Index assesses a city's talent potential through three indicators: proportion of active young S&E researchers, growth rate of young S&E researcher activity, and proportion of inflow S&E researchers, to reflect the performance of these cities in talent structure, talent growth and talent attraction.

Figure 4.4.1 shows the scores across three indicators for the top 15 cities by talent potential ranking. The top five are all Chinese cities. The remaining top 15 cities, with the exceptions of Zurich and Munich, are all located in the United States. While European and American cities generally have an edge in attracting talent, Chinese cities are more competitive in the proportion of active young S&E researchers and fostering young researcher growth.

Shenzhen ranks highest in talent potential, achieving excellent performance across all three indicators. Shenzhen particularly stands out, ranking first in the proportion of inflow S&E researchers and the growth rate of young S&E researcher activity.

Ranking of talent potential	City	Talent potential score	Proportion of active young S&E researchers	Growth rate of young S&E researcher activity	Proportion of inflow S&E researchers
1	Shenzhen	96.52	91.31	100.00	100.00
2	Guangzhou	84.46	100.00	86.31	68.01
3	Hong Kong	82.68	80.32	90.94	80.91
4	Shanghai	80.49	96.07	81.43	64.45
5	Beijing	78.83	92.10	82.42	63.77
6	Austin	78.25	70.45	67.86	91.24
7	Dallas	75.96	69.22	65.07	88.15
8	Chicago	75.96	68.67	72.60	84.93
9	Boston	75.58	68.50	70.52	85.19
10	Seattle	75.49	66.51	69.87	87.27
11	Zurich	75.22	69.35	68.72	84.36
12	San Francisco	75.15	64.50	66.66	90.03
13	Munich	75.04	76.52	66.08	78.04
14	New York	74.58	68.96	69.23	82.88
15	San Diego	74.41	62.64	64.54	91.10

Figure 4.4.1 Heat map of the top 15 cities by talent potential score and scores on the tertiary indicators

4.4 Talent potential

Proportion of active young S&E researchers

Young scientific research talent is crucial for a city's scientific and technological innovation. Cities with a higher proportion of young researchers often benefit from greater innovation vitality and long-term growth potential.

Figure 4.4.2 shows the 15 cities with the highest share of active young researchers in S&E fields. Asian cities, especially Chinese cities, generally have a high proportion of active young researchers. Specifically, Guangzhou, Shanghai, Beijing and Shenzhen rank high among the 30 innovation cities, with the share of active young S&E researchers at 44.7%, 41.8%, 39.0%, and 38.4%, respectively. In contrast, the share of active young researchers in European and American cities typically hovers around 20%, while senior researchers may make up as much as 50% of the S&E research workforce. These data reflect structural differences in research talent between Chinese and Western cities. Chinese cities appear to have younger research workforce, more optimal for sustaining their research talent pools.

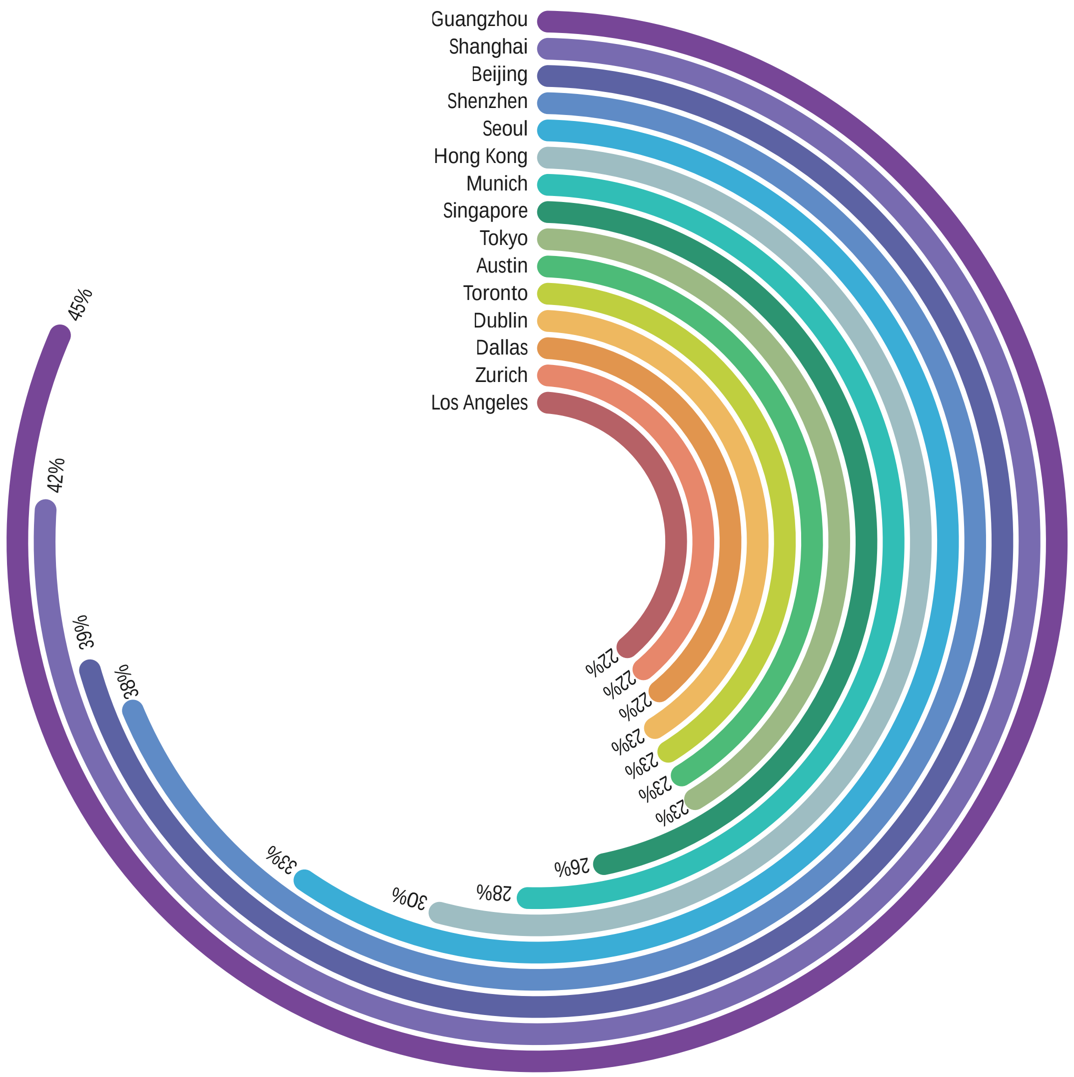


Figure 4.4.2 Top 15 cities with the highest proportion of active young researchers in S&E fields, 2019–2023

4.4 Talent potential

The proportion of inflow S&E researchers

The influx of talent brings new knowledge, skills, and innovation to a city. This not only optimizes the talent structure and promotes a city's talent development but also indirectly advances scientific and technological innovation and industrial transformation.

The proportion of inflow S&E researchers in a city refers to the proportion of incoming research talent out of the total number of S&E researchers in a city during a specific period. Figure 4.4.3 shows the top 15 cities with the highest proportion of inflow researchers between 2019 and 2023. Shenzhen tops the list of cities with a proportion of 23.9%, reflecting Shenzhen's strong ability to attract S&E researchers over the past five years. Hong Kong is the only other Chinese city in the top 15, with an inflow share of 14.9%, ranking 12th. The rest of the cities on the list are mainly North American cities. Austin, San Diego and San Francisco are the cities with the highest inflow rate in the United States, ranging between 19% and 20%. Only three European cities are in the top 15, and their proportion of inflow researchers ranks in the lower half of the list.

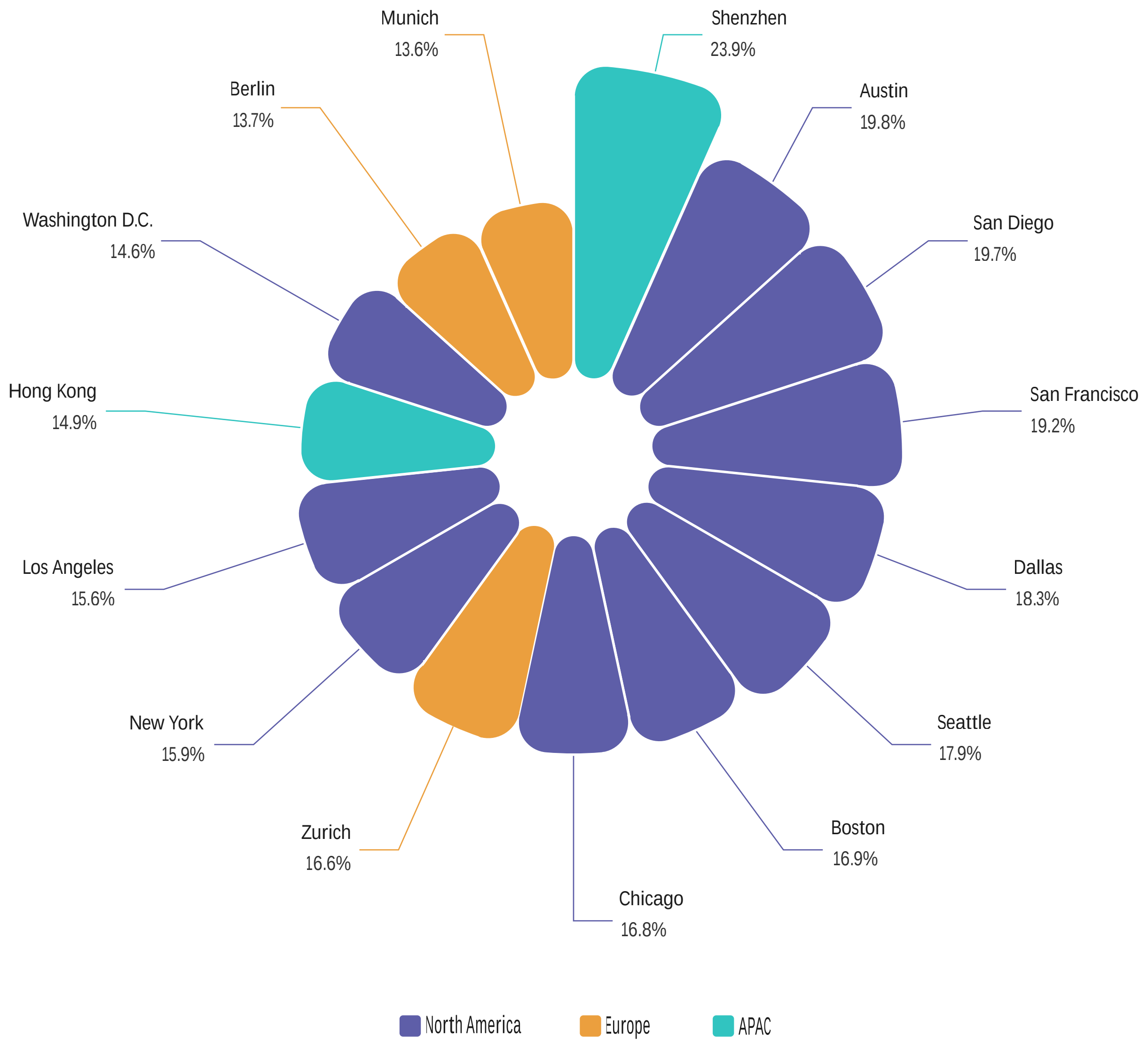


Figure 4.4.3 Top 15 cities with the highest proportion of inflow researchers in S&E fields, 2019–2023

4.5 In focus: Talent development for cities

Aligning talents with industrial advantages and building a talent innovation and entrepreneurship ecosystem are crucial to a city's talent development. Cities show distinct regional characteristics in research talent concentration: European and American cities have talent concentrated in the fields of medicine and biochemistry, while APAC cities have a strong presence in computer science, engineering, and materials science. Beijing and Boston have become global hubs for the flow of research talent, and Shenzhen demonstrates a strong ability to attract talent.

Amid high-quality development and innovation-driven growth, competition for talent has intensified, with various regions actively implementing innovative talent policies. First-tier and regional central cities are increasingly effective in attracting, cultivating, and spreading talent. Understanding the distribution characteristics and mobility trends of talent in global innovation cities is crucial for innovative talent development. This focused analysis examines research talent aggregation and mobility trends in the 30 global innovation cities through two key observations: the distribution of researchers by disciplines and their mobility patterns. The aim is to provide valuable insights to support a city's talent development.

Understanding a city's talent concentration advantages and enhancing platforms and mechanisms that attract talent are important pathways for maximizing the benefits of talent clustering effects.

The concentration of research talent fosters the integration of talent, industry, innovation, and entrepreneurship chains. Cities should leverage their talent advantages by combining them with industry projects, capital, and resources to develop comparative advantages and promote positive cycles of talent development.

Analyzing the disciplinary distribution of research talent in cities helps understand each city's focus areas and reveals their strengths in research talent concentration through comparisons. The report uses researcher relative activity index (RAI)[5] to compare the proportion of researchers in specific disciplines within a city to the global average. This method quantitatively assesses talent concentration levels in academic fields and reflects a city's ability to attract and concentrate high-quality researchers in particular disciplines.

Figure 4.5.1 shows the top five disciplines with the highest proportion of researchers in the 30 innovation cities from 2019 to 2023. As shown in the figure, researchers in these 30 innovation cities are predominantly concentrated in the medical field, accounting for around 40% of all researchers. This concentration is particularly notable in New York and Amsterdam, where medical researchers make up 60% of their cities' research workforce.

Biochemistry, Genetics, and Molecular Biology represents the second-largest field in terms of talent distribution, accounting for approximately 15% of researchers across these cities. Notably, San Diego stands out with 26% of its researchers in this field, which is nearly 2.5 times the global average. This high concentration is closely tied to San Diego's thriving biomedical industry.

Looking at regional talent distribution characteristics, Asian cities, particularly Chinese cities, show a more concentrated talent distribution in Materials Science, Engineering, and Computer Science. This concentration aligns well with these Chinese cities' education strengths in these disciplines. Specifically, Shenzhen and Hong Kong demonstrate notably high proportions of researchers in Computer Science, reaching 20% and 19% respectively, which is twice the global average. These percentages rank among the highest among the 30 innovation cities, highlighting Shenzhen and Hong Kong's significant advantages in attracting and retaining computer science researchers.

Through the establishment of close networks connecting industrial parks, leading companies, and universities, Shenzhen and Hong Kong have effectively promoted the coupled development of education, research, and industry, forming a self-reinforcing ecosystem for talent aggregation. High-quality science and technology industrial parks, such as Shenzhen Bay Technology Park, Hong Kong Science Park, and Cyberport, serve as important platforms for talent aggregation. These parks not only provide incubation space and support services for startups and entrepreneurs but also facilitate cooperation, exchange, and technology sharing among enterprises. Meanwhile, core leading companies like Huawei, Tencent, and SenseTime have driven the development of upstream and downstream industry chains, creating conditions to attract top technical talent from both domestic and international markets. Universities such as the Hong Kong University of Science and Technology, the Chinese University of Hong Kong, and Shenzhen University play crucial linking roles in this network. They serve as important sources of innovation, offering research environments and resources that attract high-end innovative talent. Additionally, professionals cultivated by these universities can quickly integrate into local industrial development, providing continuous human resource support for enterprises.

Some cities show distinctive concentrations of researchers in their niche research fields. For example, unlike other cities, Neuroscience ranks among the top five disciplines for talent concentration in New York and Amsterdam. Although the proportion of researchers in this field is only 4% and 3% respectively, these figures are 2.6 and 2.2 times of the global average, indicating that Neuroscience is a distinctive field of research talent concentration in these two cities. Additionally, Earth and Planetary Sciences emerges as a distinctive field with high talent concentration in Washington DC, Los Angeles, and Beijing. This specialization sets these cities apart in terms of their researcher distribution.

5 The RAI (relative activity index) is used to compare the concentration of researchers in specific disciplines within these cities relative to the global average. The RAI of researchers in discipline Y in city X = (the number of researchers in discipline Y in city X / the total number of researchers in city X) / (the number of researchers in discipline Y in the world / the total number of researchers in the world).

Region	City	Medicine	Biochemistry, Genetics and Molecular Biology	Neuroscience	Agricultural and Biological Sciences	Engineering	Computer Science	Physics and Astronomy	Earth and Planetary Sciences	Materials Science	Chemistry
	New York	1.83	1.52	2.56			0.59	0.52			
	Chicago	1.79	1.27				0.54	0.71			0.67
	Toronto	1.74	1.13			0.54	0.74			0.48	
	Boston	1.60	1.75			0.38	0.73	0.92			
	San Diego	1.36	2.47			0.47	0.52	0.75			
North America	San Francisco	1.31	1.66			0.40	0.88	1.49			
	Seattle	1.29	1.15		0.73	0.42	1.94				
	Washington D.C.	1.29	1.29		1.04			0.92	1.95		
	Los Angeles	1.27	1.29				0.85	1.31	1.80		
	Dallas	1.12	1.24			0.90	0.94			0.91	
	Austin	0.72	0.87			1.02	1.42	1.26			
	Amsterdam	1.82	1.03	2.20			0.79	0.96			
	London	1.67	1.14			0.49	0.82	0.64			
	Dublin	1.54	0.75			0.54	1.06	0.67			
Europe	Stockholm	1.32	1.58			0.60	0.79	0.88			
	Copenhagen	1.30	1.42		0.88	0.45		0.96			
	Paris	1.09	1.26			0.59	0.85	1.93			
	Berlin	1.07	1.24				0.86	1.30			1.06
	Munich	1.03	1.15			1.08	1.47	1.65			
	Zurich	0.87	1.25			0.75	1.21	1.33			
	Sydney	1.46	0.80		0.68	0.60	0.89				
	Melbourne	1.45	1.02		0.62	0.57	0.79				
	Tokyo	1.24	1.11			1.02	0.92	1.48			
	Seoul	0.97	1.18			1.27	1.16			1.89	
APAC	Guangzhou	0.97	1.44		1.04	0.88				1.25	
	Singapore	0.93	0.99			1.20	1.63			1.68	
	Shanghai	0.85	1.32			1.27	0.99			1.59	
	Hong Kong	0.67	0.89			1.32	2.11			1.51	
	Shenzhen	0.62	1.23			1.21	2.20			1.94	
	Beijing	0.53				1.33	1.25		2.21	1.26	

RAI 0.38 1.0 2.56

Figure 4.5.1 Top five disciplines for each of 30 global innovation cities, by their number of active researchers, along with their relative activity index (RAI). (Color coding: gray indicates the global average; red is above the global average; blue is below the global average).

Focusing on talent mobility trends and fostering ecosystems for talent innovation and entrepreneurship that enhance talent capacity and aggregation are vital supports for a city's high-quality, innovative development.

In the age of globalization and the knowledge economy, the competition for talent has intensified. Talent mobility impacts a city's innovation capacity, development potential, and indicates its ability to attract and retain talent. This section focuses on S&E talent mobility s of top-ranked innovative cities, seeking to identify cities excelling in attracting talent and to map the main pathways of talent movement between cities.

Figure 4.5.2 shows the major source cities for the top 15 cities in talent development ranking. Considering the size of the talent flow and the diversity of cities linked with, Beijing and Boston stand out as global hubs for research talent; they are the main providers of research talent for a variety of cities, playing crucial hub roles in global science and technology talent mobility.

Comparing the inflow and outflow of talent, Shenzhen demonstrates the most prominent talent attraction effect, with the number of researchers flowing into Shenzhen significantly exceeding the number flowing out. Beijing, Hong Kong, and Guangzhou are the main source cities for Shenzhen's S&E researchers, with over 5,000 researchers moving from these three cities to Shenzhen in the past five years. Notably, there is frequent talent movement between Hong Kong and Shenzhen, reflecting active talent exchange within the Guangdong-Hong Kong-Macau Greater Bay Area.

Looking at the top five source cities for the 15 cities, the main talent flow for Chinese and American cities still occurs primarily within the countries. For instance, the cities with the highest number S&E researchers flowing in and out of Boston are still American cities.

Overall, these talent mobility trends highlight the cities' attractiveness within their innovation ecosystems and offer valuable insights for other cities to enhance their talent retention and attraction capabilities. Understanding these trends allows cities to better design and implement effective talent policies, foster ecosystems conducive to innovation and entrepreneurship, and promote high-quality innovation development.

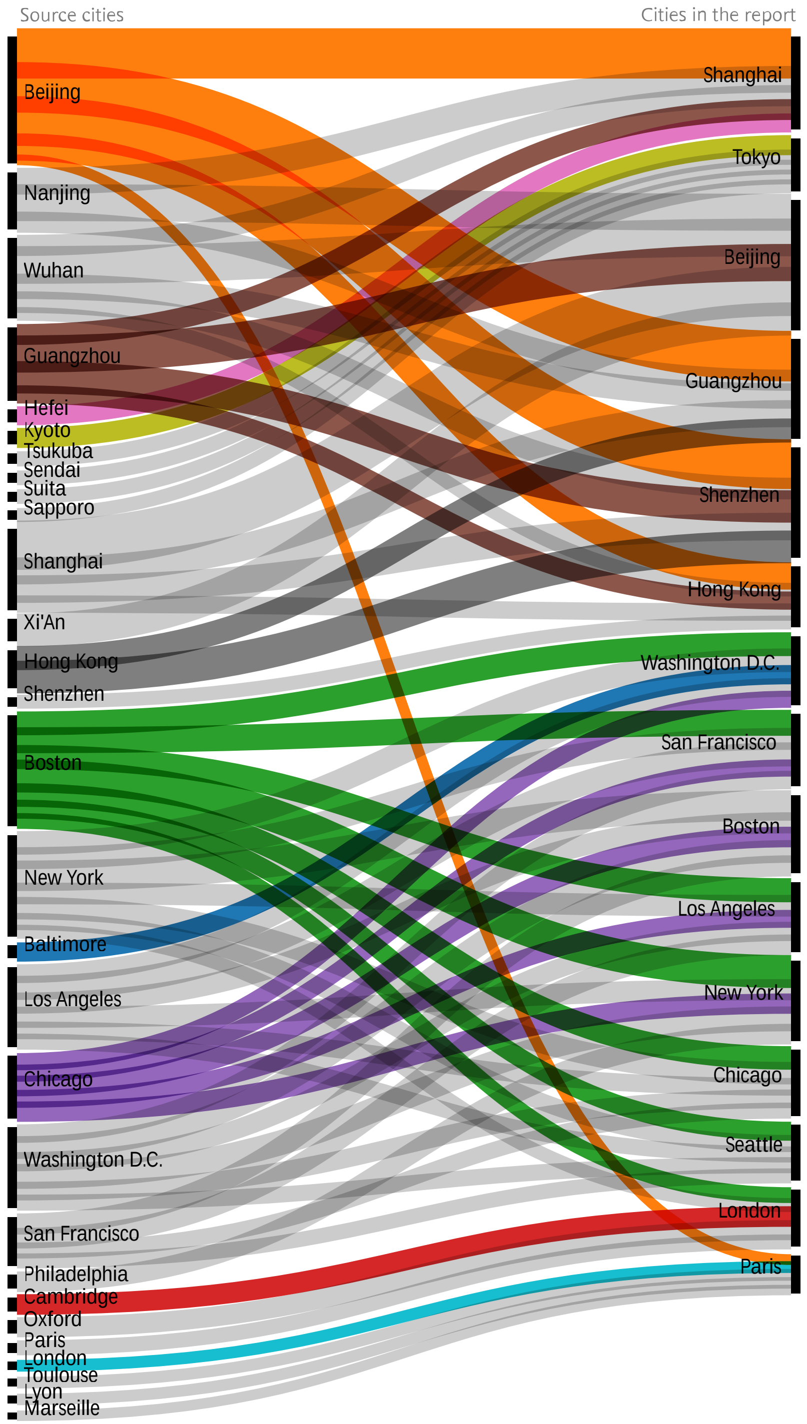
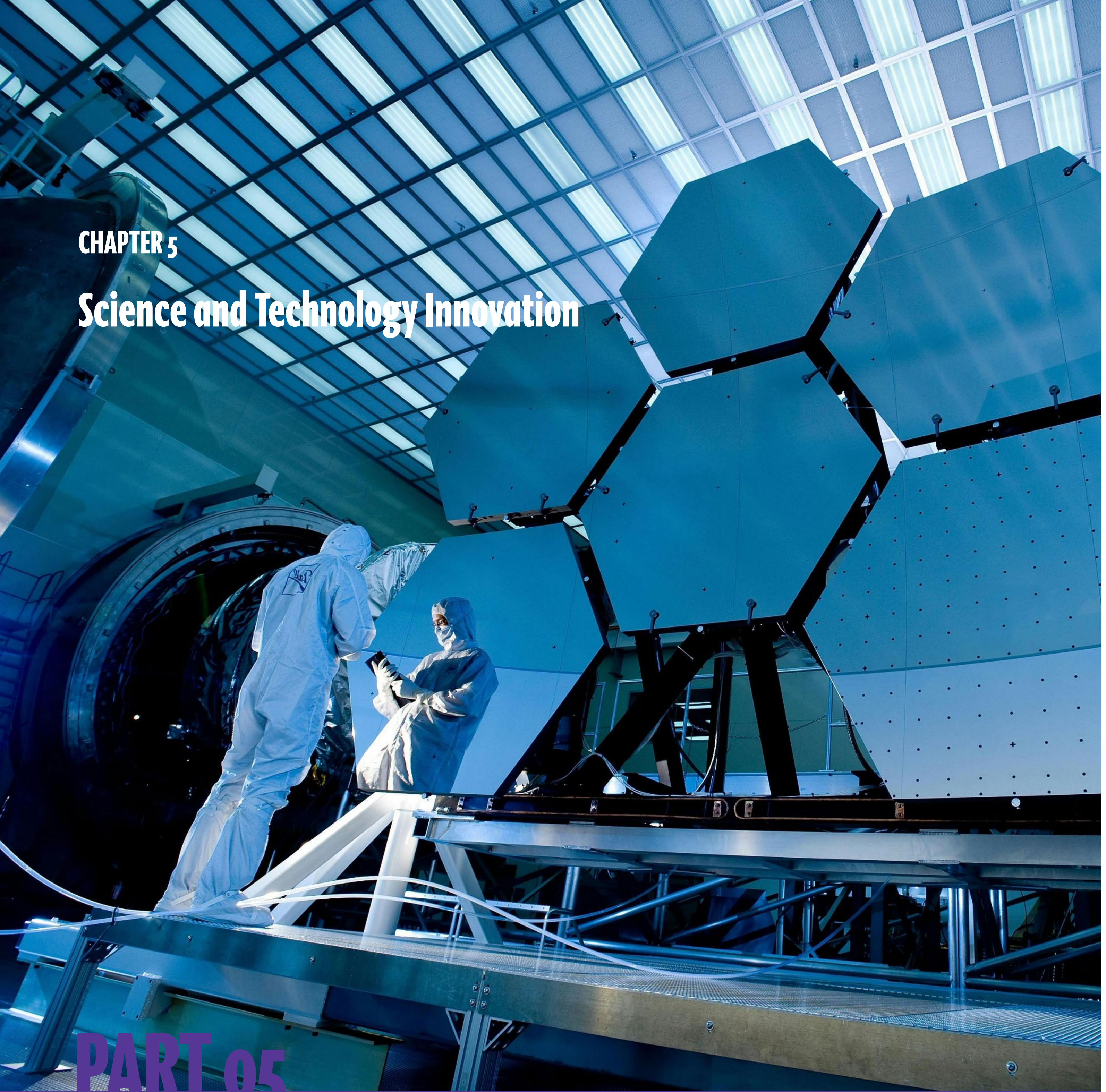


Figure 4.5.2 Top 5 source cities for talent inflow into the top 15 cities by talent development score, 2019–2023. Note: only source cities ranking in the top 5 for this direction of talent flow and with at least 100 researchers going to the linked city on the right are shown on the left. Line thickness represents the logarithmic value of the number of incoming researchers.



CHAPTER 5

Science and Technology Innovation

PART 05

5.1 S&T innovation rankings

San Francisco, Boston and Beijing hold the top three positions in S&T innovation. US cities performed well overall, occupying six of the top 10 spots and demonstrating the country's strength in technological innovation. Three Chinese cities ranked in the top 10, while other Chinese cities ranked in the upper and middle levels, indicating their emergence on the global technological innovation stage.

Science serves as the foundation for technological development, which in turn is a crucial element for industrial advancement. Technological progress is derived from scientific discoveries, while industrial development is contingent on the innovation and application of technology. The evaluation of a city's S&T innovation capabilities encompasses four aspects: scientific research, technological progress, industrial development, and innovation ecosystems. Given the availability of quantitative data and the strategic requirements of high-quality development, this section focuses on evaluating S&T innovation output, with an emphasis on high-quality research or technological invention output, and enterprises of high innovation levels.

Ranking of S&T innovation	City	S&T innovation score	Scientific research score	Technological progress score	Industrial development score	Innovation ecosystems score
1	San Francisco	87.93	89.6	79.6	96.8	81.3
2	Boston	86.05	93.2	81.5	86.5	76.9
3	Beijing	83.72	84.5	80.9	86.8	80.5
4	London	82.46	87.6	82.3	77.3	83.0
5	New York	82.30	87.3	76.4	83.2	82.4
6	Seattle	82.13	84.6	79.6	84.2	76.2
7	Shenzhen	81.22	79.6	85.3	81.7	72.3
8	Los Angeles	80.90	85.3	78.3	81.5	73.8
9	San Diego	78.60	76.2	80.8	80.0	75.0
10	Shanghai	78.44	80.6	75.6	80.7	74.0
11	Paris	77.75	80.3	78.0	72.7	84.5
12	Tokyo	77.33	70.0	85.6	72.9	87.8
13	Stockholm	76.85	78.3	79.8	71.0	81.2
14	Amsterdam	76.65	78.6	79.0	72.6	75.8
15	Washington D.C.	76.61	84.2	71.5	73.9	77.3
16	Munich	76.45	75.7	82.3	70.3	79.7
17	Hong Kong	76.43	82.8	71.4	77.2	70.1
18	Seoul	75.47	73.7	82.0	70.5	76.1
19	Chicago	75.23	81.8	70.5	73.8	73.9
20	Singapore	74.69	82.5	70.8	69.9	77.2
21	Zurich	73.87	80.5	74.1	66.3	75.8
22	Copenhagen	73.74	78.5	71.5	69.2	79.6
23	Guangzhou	72.98	76.2	73.7	71.8	64.9
24	Austin	72.63	71.0	68.6	79.0	70.5
25	Dublin	72.34	70.8	75.5	69.3	76.7
26	Dallas	72.29	76.8	71.4	68.9	71.9
27	Berlin	71.65	79.6	69.6	64.0	77.1
28	Toronto	71.64	79.1	68.8	67.0	71.7
29	Sydney	71.57	80.9	66.9	66.9	71.6
30	Melbourne	70.37	81.4	65.0	64.2	72.1

Figure 5.1.1 Ranking of 30 global innovation cities by S&T innovation score and scores on secondary indicators of S&T innovation

Figure 5.1.1 presents the scores and rankings of the 30 global innovation cities in terms of S&T innovation. San Francisco and Boston occupy the top positions with scores of 87.93 and 86.05, respectively, reflecting their strengths as global innovation powerhouses. Beijing, with a population of tens of millions, has a score of 83.72, demonstrating the advantage of scale in S&T innovation.

With respect to regional distribution (Figure 5.1.2), North American cities demonstrate the highest levels of S&T innovation, with six of the top 10 cities being in the United States. Three Chinese cities are among the top 10, indicating that Chinese cities have a notable presence in the field of innovation, though most Chinese cities are ranked in the middle. Among European cities, London emerges as the leader, followed by Paris, which occupies a relatively high position. The remaining European cities are predominantly in the middle and lower ranks.

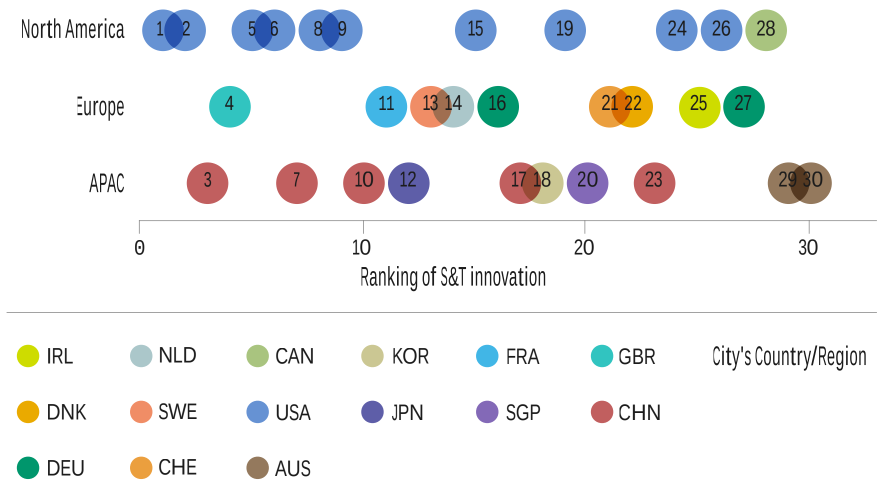


Figure 5.1.2 Regional distribution of the 30 global innovation cities by S&T innovation rank

Categorization of cities by type of S&T innovation

Based on the advantages of each city in scientific research, technological progress, and industrial development, global innovation cities can be divided into the following categories:

All-around innovation cities: These cities, such as Boston, San Francisco, and Beijing, have performed well in scientific research, technological progress and industrial development, which shows that if a positive feedback loop of knowledge, technology and industry can be achieved, it will be a continuous driving force for the city's future innovation.

Research-driven industrial cities: These cities, such as New York, Seattle, and Los Angeles, have strong research capabilities and booming industries, and they focus on driving industrial upgrades based on scientific research. They typically prioritize the utilization of scientific research to catalyze economic transformation.

Research and technology-driven cities: Represented by European cities like London, Stockholm, and Amsterdam, these cities have performed well in research and technology density, but their industrial applications need to be improved to do better in transforming research results into economic benefits.

Technology-driven industrial cities: This type of cities, like Shenzhen and San Diego, have a high technology density and can quickly transform their technological advantages into local industrial achievements.

In addition, some cities may have a single advantage in a certain aspect of S&T innovation. For example, Washington DC, Hong Kong, and Singapore have strong scientific research capabilities and world-leading higher education resources, but their performance in technological progress and industrialization is average; Tokyo, Munich, and Seoul are very active in technological progress, but their scientific research and industrial development in the innovation sector still needs to be strengthened.

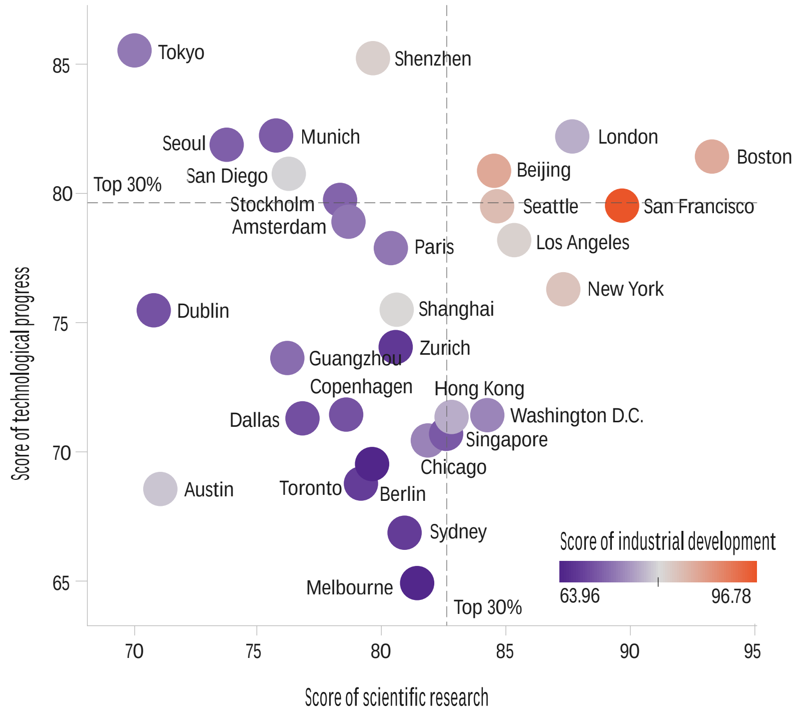


Figure 5.1.3 Bubble chart of scores of 30 global innovation cities in scientific research, technological progress and industrial development

American innovation cities lead the development of global science, occupying four of the top five rankings in scientific research. The scientific research level of European cities is unevenly distributed, with London in the leading echelon, and Paris and Zurich in the middle; the scientific research level of Chinese cities is on the rise. Notably, Beijing and Hong Kong are in the top 10.

Scientific research, although it may not immediately translate into commercial products or technologies, serves as a driving force for technological breakthroughs and advancements, and is key to high-quality development. The evaluation of the scientific research level of global innovation cities is based on the city's research output in the field of science and engineering (S&E) [6] including five indicators: high-quality S&E research output, growth in high-quality S&E research output, [7] academic impact of S&E research output, proportion of S&E research output cited by patents, and multidisciplinary score of S&E research output.

In terms of scientific research, Boston, San Francisco, and London are the top three cities, with Boston in the lead. Of the top 10 cities in scientific research rankings, six are in the United States, with four cities even ranking in the top five, demonstrating the edge US cities hold in scientific research. Among Chinese cities, Beijing and Hong Kong rank 7th and 9th respectively, while Shanghai ranks 14th and Shenzhen ranks 17th. Among European cities, other than London, Zurich and Paris rank 15th and 16th respectively, placing them in the middle range.

Based on the city's tertiary indicator scores, American cities perform better in terms of high-quality S&E research output, academic impact, and multidisciplinary score. European cities do not stand out for the number of high-quality S&E publications (except London and Paris, whose high-quality publication volume is relatively high), but their average academic impact and multidisciplinary score are at the top. Chinese mainland cities are relatively prominent in the growth of high-quality S&E research output and the proportion of S&E research output cited by patents. Among them, Shenzhen's compound annual growth rate of the top 1% highly cited publications reached 15.9%, ranking at the forefront of the 30 innovative cities, and other Chinese cities also had a growth rate of more than 8%.

Ranking of scientific research	City	Scientific research score	High-quality S&E research output	Growth in high-quality S&E research output	Academic impact of S&E research output	Proportion of S&E research output cited by patents	Multidisciplinary score of S&E research output
1	Boston	93.24	100.00	85.99	96.96	80.45	98.80
2	San Francisco	89.62	92.98	78.04	100.00	81.26	100.00
3	London	87.62	88.96	85.15	92.21	64.47	93.01
4	New York	87.26	95.20	83.80	89.31	70.09	82.95
5	Los Angeles	85.28	90.30	79.82	89.03	70.14	90.07
6	Seattle	84.59	83.63	74.08	99.83	76.79	89.60
7	Beijing	84.47	89.77	98.46	67.04	83.92	66.09
8	Washington D.C.	84.20	92.04	78.78	83.73	67.11	93.27
9	Hong Kong	82.76	67.21	82.55	98.56	85.82	81.34
10	Singapore	82.54	71.33	79.41	94.39	89.53	88.41
11	Chicago	81.81	82.76	76.79	88.93	66.30	86.92
12	Melbourne	81.37	75.47	78.61	89.57	63.21	94.39
13	Sydney	80.87	75.44	79.04	88.41	64.52	90.14
14	Shanghai	80.55	82.11	89.86	69.58	85.30	69.11
15	Zurich	80.51	80.51	71.26	91.46	71.70	89.94

Figure 5.2.1 Heat map of the top 15 cities by scientific research score and scores on the tertiary indicators

[6] Science and engineering fields: including physical science, health science, and life science related subjects.

[7] It is measured by combining the compound annual growth rate and the number of top 1% highly cited publications, aiming to balance the data fluctuations of smaller cities with small publication volumes.

High-quality S&E research output

High-quality S&E research output is here proxied by the number of papers published in three globally renowned journals: Cell, Nature, and Science (abbreviated as CNS) in S&E fields. Publications in these three journals represent major breakthroughs and cutting-edge advances.

As shown in Figure 5.2.2, Boston researchers have published 2,520 CNS articles, ranking Boston first and as the sole city with more than 2,000 CNS articles. New York and San Francisco ranked second and third with 1,771 and 1,504 CNS articles, respectively. It is noteworthy that a total of seven cities have more than 1,000 CNS articles in the past five years, with the top five being in the United States, reflecting the country's strength in the world's top scientific research output. Among Asian cities, only Beijing has more than 1,000 CNS articles, and London is the only European city with more than 1,000 CNS articles.

This next analysis examines the disciplinary focus of each city's top scientific research, based on CNS publication share by subject from each global innovation city from 2019 to 2023. The fields of common interest across the various innovation cities include: "Biochemistry, Genetics and Molecular Biology," "Ecology, Evolution, Behavior and Systematics," and "Physics and Astronomy." These findings suggest a shared interest for the world's most influential research in exploring fundamental laws of life and the mysteries of the universe.

Compared to European and American cities, Chinese cities have fewer top research results in "Ecology, Evolution, Behavior and Systematics," but show a comparatively higher prevalence in "Chemistry" and "Materials Science." Additionally, cities also have their own distinctive and advantageous strengths in specific sub-fields. For instance, Dallas and Guangzhou have more top research output in "Cell Biology"; New York, San Francisco, Seattle, Stockholm and Melbourne in "Immunology"; Boston, New York, San Diego, London, Munich in "Neuroscience"; Dublin and Hong Kong in "Medicine", and Washington DC, Los Angeles, Austin, Paris, Tokyo, and Sydney in "Space and Planetary Science."

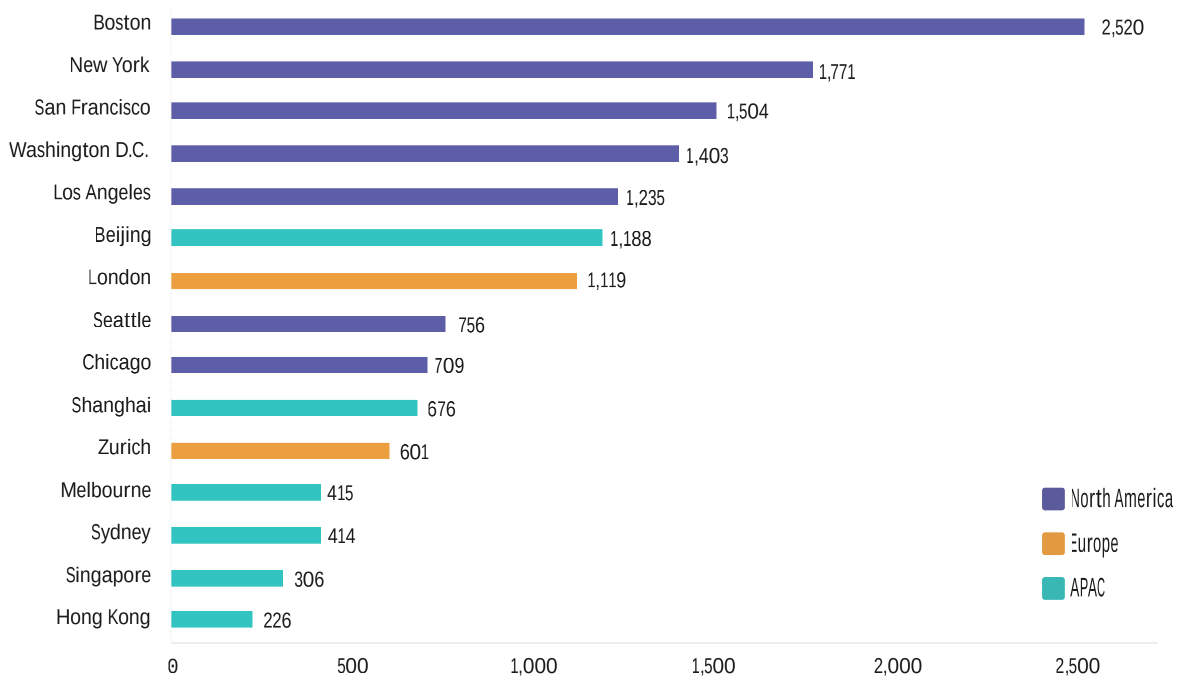


Figure 5.2.2 Number of papers published in Cell, Nature, or Science in the fields of science and engineering for the top 15 cities by scientific research scores (2019–2023)

Multidisciplinary score and academic impact of S&E research output

The multidisciplinary score is based on the diversity of disciplinary backgrounds of co-authors of publications, which measures the degree of cross-disciplinary team collaboration in scientific research. The academic impact of a city's research output is measured by the field-weighted citation impact (FWCI). As shown in Figure 5.2.3, based on the performance of the 30 global innovation cities on these two indicators, FWCI is positively correlated with the multidisciplinary score of S&E research output, indicating that cross-disciplinary collaboration can help improve academic impact.

Between 2019 and 2023, San Francisco's multidisciplinary score of S&E research output was 1.21, ranking first among the 30 innovation cities, and its FWCI reached 2.10 (2.1 times the global average); Boston's multidisciplinary score was 1.20, ranking second, and its FWCI also reached 2.0.

Except for Singapore, Hong Kong and Shenzhen, the multidisciplinary score of other Asian cities ranked at the bottom of all cities, and the average academic impact of these cities also ranked at the bottom.

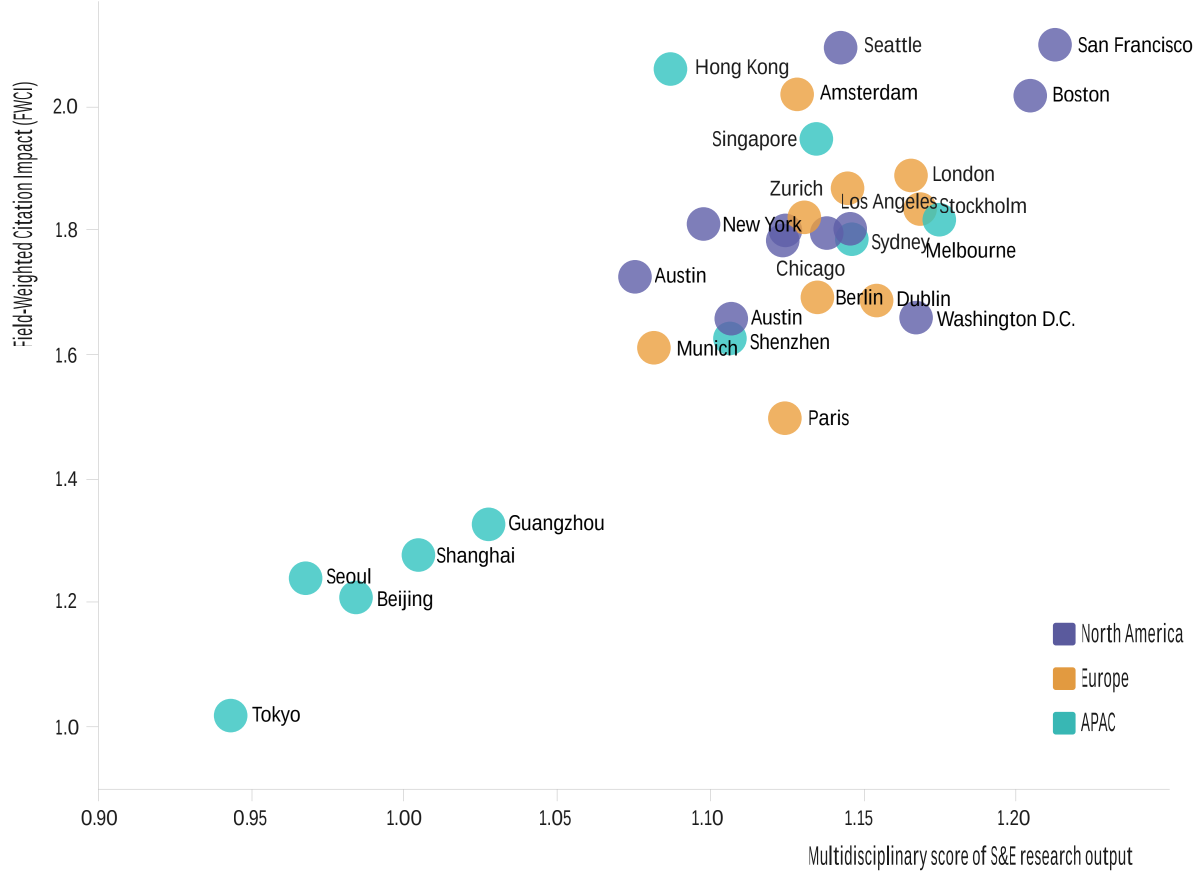


Figure 5.2.3 Scatter plot of multidisciplinary score and field-weighted citation impact (FWCI) of the S&E research output of 30 global innovation cities, 2019–2023

5.3 Technological progress

In terms of technological progress, Tokyo, Shenzhen and Munich rank among the top three, with Tokyo and Shenzhen having a significant lead. Although most Chinese cities have large patent volumes, the average technical impact of patents is limited. But the rapid growth of high-impact patents originating from Chinese cities indicate that these cities are improving their proficiency in emerging technologies.

Technological innovation refers to the process of creating and applying new or improved technologies, products, processes, systems and services through research and development activities. Technological progress is an important driving force for promoting the development of high-tech industries and for industrial advancement. As a legal tool, patents encourage individuals and enterprises to invest in technological innovation and R&D by granting inventors exclusive rights for a certain period of time. Therefore, patent activities are usually used as an indicator of technological progress.

The SET Index will measure a city's technological progress through the following four indicators, including: number of granted PCT patent families, number of granted PCT patent families per capita, patent technology impact, and growth rate of high tech-impact patents, to reflect the scale, density, influence and growth potential of the city's patent activities (for descriptions of these indicators, see Appendix 1). When measuring patents, this report focuses on a city's high-quality patents. The Patent Cooperation Treaty (PCT) is currently one of the most important channels for international patent applications, so PCT granted patents are used to reflect a city's technological innovation capabilities and development levels. Patent technology impact measures the citation of patents by other patents. Although patent citation does not necessarily serve as an indicator of patent quality, it may reflect the guiding value of a technology to subsequent technologies, and thus, can indicate a city's mastery of fundamental technologies. Furthermore, emerging technologies are also cited with relatively high frequency.

Based on the above indicators, Tokyo, Shenzhen and Munich rank as the top three cities in technological progress. Tokyo and Shenzhen score similarly, with a large lead over the others. Munich's technological progress score is close to that of London and Seoul, which are ranked 4th and 5th. Among the top 10 cities in technological progress, four are Asian cities (Tokyo, Shenzhen, Seoul, and Beijing), reflecting Asian cities' strength in technological progress.

According to the tertiary indicator analysis (Figure 5.3.1), European cities demonstrate higher patent technology density, with superior per capita performance in granted PCT patent families, although their total volume is relatively modest, as shown by Munich, Stockholm, and Paris. Asian cities, particularly Tokyo and Shenzhen, excel in the total volume of granted PCT patent families but show relatively limited patent technology impact, indicating that Asian cities still need to enhance their capability on fundamental and emerging technologies. Notably, Chinese cities, represented by Shenzhen, Beijing, and Shanghai, exhibit exceptional growth in patents with high technology impact, with all Chinese cities except Hong Kong maintaining compound annual growth rates above 19.5% for granted patent families in the top 10% of technological impact. North American cities, such as Boston, San Francisco, and San Diego, display prominent patent technology impact, demonstrating their continued leadership in fundamental and emerging technologies.

Ranking of technological progress	City	Technological progress score	Number of granted PCT patent families	Number of granted PCT patent families per capita	Patent technology impact	Growth rate of high tech-impact patents
1	Tokyo	85.61	100.00	92.85	64.69	65.84
2	Shenzhen	85.31	93.85	91.69	61.53	95.76
3	Munich	82.32	83.02	100.00	69.03	60.00
4	London	82.28	78.11	76.96	99.92	68.73
5	Seoul	81.96	93.09	87.22	64.50	70.87
6	Boston	81.50	75.90	81.50	94.60	68.35
7	Beijing	80.95	89.16	83.76	62.96	88.76
8	San Diego	80.83	78.27	87.01	80.88	71.15
9	Stockholm	79.82	78.73	94.47	69.59	65.26
10	San Francisco	79.60	75.30	79.96	89.09	69.83
11	Seattle	79.58	79.31	87.80	75.28	66.59
12	Amsterdam	78.98	66.29	81.15	100.00	64.30
13	Los Angeles	78.26	73.29	68.38	100.00	70.96
14	Paris	77.95	83.40	82.43	71.12	62.53
15	New York	76.36	72.32	63.38	100.00	70.32

Figure 5.3.1 Heat map of the top 15 cities by technological progress score and scores on the tertiary indicators

Number of granted PCT patent families and patent technology impact

Figure 5.3.2 shows the number of granted PCT patent families and patent technology impact for the top 15 cities in terms of technological progress scores. As shown in the figure, from 2014 to 2023, Tokyo ranked first with approximately 165,600 granted PCT patent families, followed by Shenzhen with about 70,000 granted PCT patent families in second place, and Seoul ranked third with around 63,000 granted PCT patent families. The number of granted PCT patent families in other cities was notably lower compared to the top three cities. Among European cities, Paris and Munich had the highest number of granted PCT patent families, while Seattle and San Diego led among North American cities.

Amsterdam has the highest patent technology impact, with a normalized patent citation impact of 19.96, a substantial lead. It is followed by Los Angeles, New York, London, and Boston, all of which have a normalized patent citation impact of more than 5.0. The high-impact patent technologies in Amsterdam are concentrated in three areas: semiconductor devices, discharge lamp or discharge tube technology, and metal material plating technology. In contrast, patents with high technology impact in American cities are predominantly concentrated in biopharmaceuticals, advanced computer technology, and communication technology. Machine learning and anti-tumor preparations emerge as the most prevalent high-impact technology subcategories across various innovative cities in the United States.

The high-impact technological fields vary among Asian cities. For instance, Shenzhen's high tech-impact areas include computer digital data processing, computer algorithm models, and image propagation technology in electrical communications. Tokyo, on the other hand, has a relatively high technology impact on the domains of optical components, semiconductor devices, macromolecular compound compositions, and transportation-related climate change mitigation technologies.

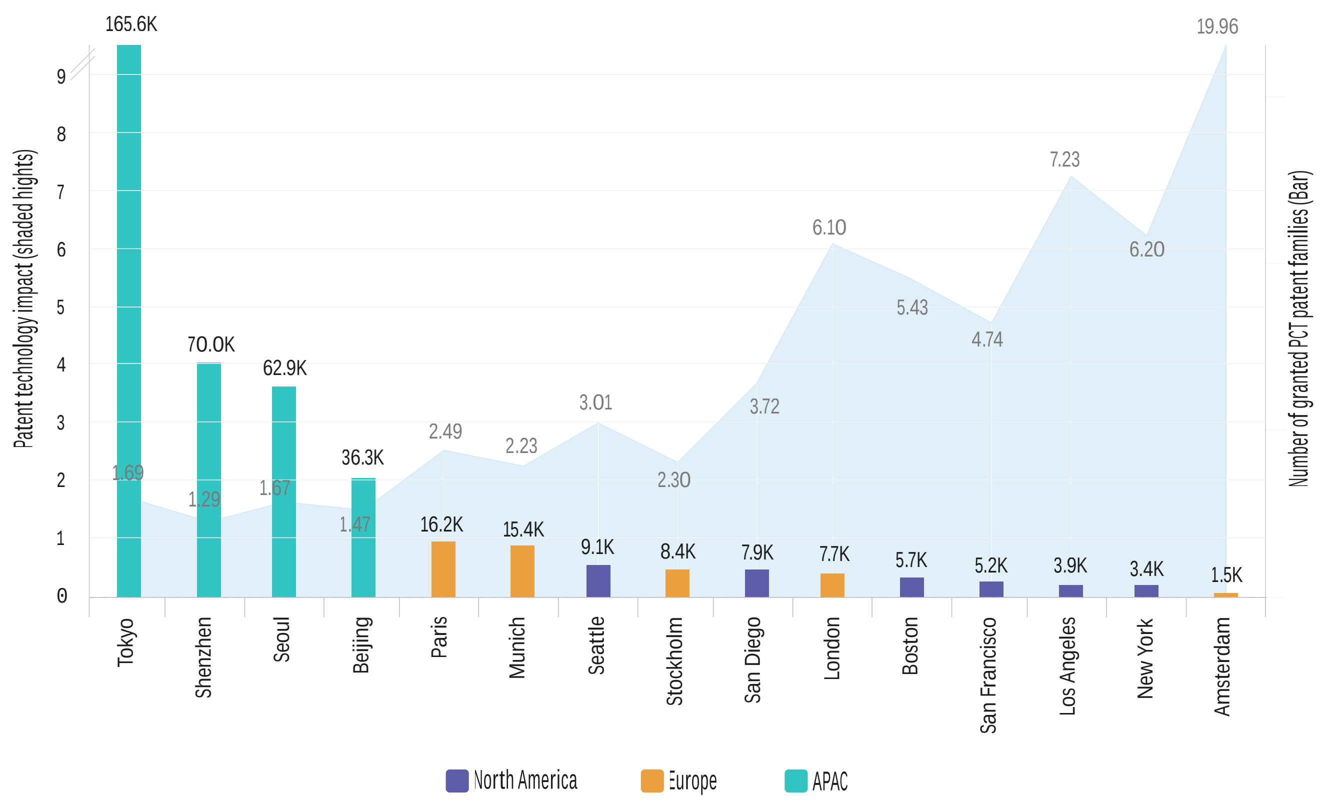


Figure 5.3.2 Number of granted PCT patent families (bars) and patent technology impact of granted patent families (shaded hights) in the top 15 cities by technological progress score (Patent application years: 2014–2023)

San Francisco, Beijing and Boston stand out as the cities exhibiting the most industrial vitality, with San Francisco having a notable lead over the others, given its strengths in innovative companies, unicorn companies and start-ups.

Industrial transformation is a pivotal step in the process of converting scientific research outcomes and technological innovations into tangible products and services. It facilitates the dissemination of these outcomes to a broader population, thereby fostering societal, economic, and cultural prosperity. Consequently, the industrial development of a city is a key aspect for assessing its capacity to operationalize scientific and technological innovation outcomes.

Enterprises are key players driving innovation in industries, so the SET Index evaluates the industrial development of global innovation cities based on the following indicators: number of top 1,000 innovative companies, R&D investment intensity of the top 1,000 innovative companies, performance of unicorn companies (considers existing and newly added unicorn companies in the recent five years), and average valuation of start-ups. This approach helps to capture the state of leading enterprises, high-growth start-ups, and early-stage innovative companies in each city.

In terms of industrial development (Figure 5.4.1), San Francisco, Beijing and Boston are the top three cities; San Francisco scored 96.78, leading the world. San Francisco's innovative industries cover high-tech industries such as the Internet, semiconductors, computers, digital electronics, biotechnology, and digital media. Beijing and Boston ranked second and third, and their scores were close. Seattle and New York ranked fourth and fifth. This distribution highlights the global industry innovation landscape, with clear leadership from US cities, strong performance from Chinese cities, and European cities maintaining significant but comparatively lower positions in industrial development.

A detailed analysis of the tertiary indicators suggests that different cities show distinct patterns of strength in industrial development. For example, San Francisco, Beijing, and Shanghai show balanced performance on three tertiary indicators, including the top 1,000 innovative enterprises, unicorn companies, and start-ups. Specifically, Beijing is strong in the number of top 1,000 innovative companies but has lower R&D investment intensity of these companies. Boston, New York, Los Angeles, and London excel in the number of top 1,000 innovative companies and the performance of unicorn companies. San Diego and Shenzhen show strength in the top 1,000 innovative companies and the valuation of start-ups. Seattle and Austin demonstrate exceptional performance in start-up performance.

Ranking of industrial development	City	Industrial development score	Number of top 1,000 innovative companies	R&D investment intensity of the top 1,000 innovative companies	Performance of unicorn companies	Average valuation of start-ups
1	San Francisco	96.78	100.00	91.14	100.00	93.89
2	Beijing	86.79	98.71	66.79	86.94	87.51
3	Boston	86.48	93.85	82.94	92.72	77.22
4	Seattle	84.20	76.72	76.45	75.99	100.00
5	New York	83.24	90.48	74.06	95.28	70.54
6	Shenzhen	81.72	88.08	70.80	67.81	96.19
7	Los Angeles	81.53	83.12	83.29	87.95	73.45
8	Shanghai	80.70	85.03	70.10	81.13	81.90
9	San Diego	79.96	83.12	89.04	69.25	85.13
10	Austin	78.97	70.19	82.44	72.88	88.94
11	London	77.30	86.15	65.13	89.02	65.14
12	Hong Kong	77.24	67.71	100.00	65.42	85.68
13	Washington D.C.	73.94	77.90	69.94	72.01	75.10
14	Chicago	73.83	82.40	63.85	72.27	74.23
15	Tokyo	72.89	99.21	64.72	65.66	67.60

Figure 5.4.1 Heat map of the top 15 cities by industrial development score and scores on the tertiary indicators

Number of the top 1,000 innovative companies

The term "top 1,000 innovative companies" refers to the top 1,000 companies identified in the 2023 "Industrial R&D Investment Scoreboard" released by the European Commission. These companies are widely recognized as the most innovative entities globally, playing a pivotal role in the promotion of industrial advancement.

As illustrated in Figure 5.4.2, San Francisco leads with 73 top 1,000 innovative companies, followed by Tokyo and Beijing. For other Asian cities, Shenzhen holds sixth position with 25 top 1,000 innovative companies, among which Huawei, Tencent, ZTE, and BYD are among the top 100 in the world in terms of innovation. European cities do not hold an advantage in terms of the number of top 1,000 innovative companies.

A further analysis of the industries in which these top 1,000 companies operate reveals the industry-specific strengths of each city. For instance, Beijing's leading companies are concentrated in the construction industry; Shenzhen's are in computer hardware and equipment; San Francisco's are in the software and computer service industry; New York, Chicago, Los Angeles and Boston all have a concentration in biopharmaceuticals; and Tokyo's leading companies are distributed in diverse industries. While there is an absence of biopharmaceutical companies among the top 100 innovative companies globally in Chinese cities, it is noteworthy that the biopharmaceutical sector represents a growth opportunity for Chinese cities.

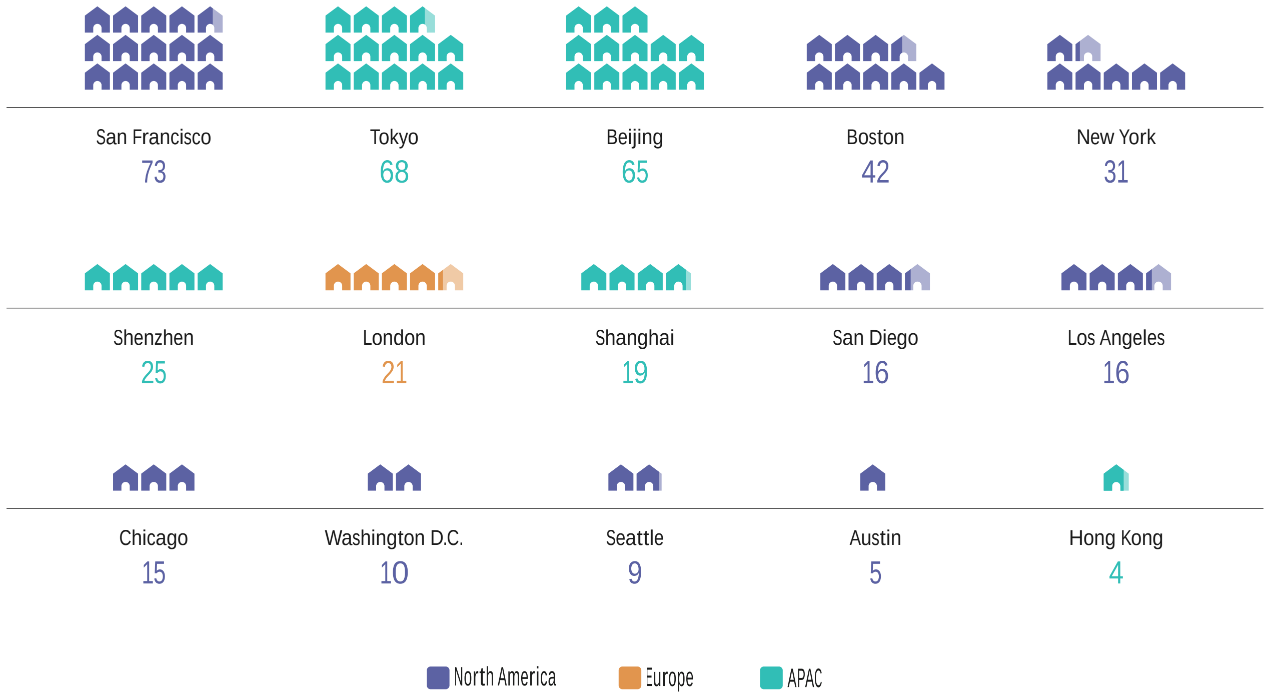


Figure 5.4.2 Number of top 1,000 innovative companies in the top 15 cities by industrial development score

Tokyo, Paris and London rank highest in innovation ecosystem, with Tokyo having the largest number of large scientific facilities and relatively active collaboration between academia and industry. Paris and London score high in terms of open collaboration and economic foundation. With the exception of Beijing, innovation ecosystem scores of Chinese cities are in the middle and lower reaches.

Fostering innovation requires a robust innovation ecosystem. An open, inclusive, and collaborative environment serves as an efficient catalyst for innovation, while a strong economic foundation provides the financial support needed for innovation development.

The innovation ecosystem of cities are evaluated through the following four indicators: number of large scientific facilities, extent of academic-corporate research collaboration, diversity of cross-regional collaboration and the GDP performance. These indicators reflect the strength of scientific research infrastructure, links between industry and academia, links between regions, and the level of economic development of each city.

In terms of innovation ecosystem scores, Tokyo, Paris and London score highest. Tokyo lead in terms of large scientific facilities, topping the list of 30 innovation cities with 12 large facilities. It also performs well in academic-corporate research collaboration and the activity of cross-regional collaboration. Paris and London score high in terms of the diversity of cross-regional collaboration and the GDP performance.

In terms of regional distribution, 5 of the top 10 cities in innovation ecosystem are located in Europe. These European cities excel in the diversity of cross-regional collaboration, academic-corporate research collaboration, and GDP performance. Among North American cities, New York, San Francisco, and Washington DC rank in the top 10 for innovation ecosystem scores, placing 4th, 5th, and 10th, respectively. Each of these cities has distinct advantages: New York stands out in cross-regional collaboration and the presence of large scientific facilities. San Francisco is particularly strong in academic-corporate research collaboration and has a notable number of large scientific facilities. Washington DC excels in cross-regional collaboration, academic-corporate research collaboration, and GDP performance.

In Asia, aside from Tokyo, Beijing and Singapore demonstrate the best performance in innovation ecosystem, ranking 7th and 11th, respectively. Beijing performs well in cross-regional collaboration and the availability of large scientific facilities. Conversely, Singapore shows strong results across multiple areas, including cross-regional collaboration, academic-corporate research collaboration, and GDP performance.

Ranking of innovation ecosystems	City	Innovation ecosystems score	Number of large scientific facilities	Extent of academic-corporate research collaboration	Diversity of cross-regional collaboration	GDP performance
1	Tokyo	87.77	100.00	89.62	84.34	77.12
2	Paris	84.49	76.67	81.95	94.73	84.60
3	London	83.02	70.00	78.97	100.00	83.10
4	New York	82.41	90.00	79.81	83.57	76.25
5	San Francisco	81.30	90.00	88.26	76.30	70.63
6	Stockholm	81.19	70.00	87.12	85.41	82.23
7	Beijing	80.54	90.00	73.95	88.40	69.81
8	Munich	79.73	63.33	95.15	80.30	80.15
9	Copenhagen	79.63	60.00	88.17	85.89	84.46
10	Washington D.C.	77.28	63.33	80.09	83.04	82.67
11	Singapore	77.18	63.33	80.66	82.79	81.92
12	Berlin	77.15	70.00	77.14	84.37	77.09
13	Boston	76.87	63.33	83.52	84.94	75.69
14	Dublin	76.69	60.00	71.54	78.90	96.33
15	Seattle	76.17	60.00	95.06	75.45	74.18

Figure 5.5.1 Heat map of the top 15 cities by innovation ecosystem score and scores on the tertiary indicators

Figure 5.5.2 shows the correlation analysis between the innovation ecosystem scores of various cities and their scores in scientific research, technological progress, and industrial development. Overall, the innovation ecosystem score has a positive effect on the three key aspects of S&T innovation, and this trend is more pronounced in China and North America. This indicates that broadening collaboration, solidifying the integration of industry and academia, strengthening scientific infrastructure, and enhancing economic development have a positive impact on innovation in cities. However, Tokyo appears to be an exception, whose performance in scientific research does not align positively with its innovation ecosystem score. With dense large-scale scientific facilities, Tokyo has a solid foundation for scientific research. However, in recent years, Japan's international influence in scientific research has been waning.

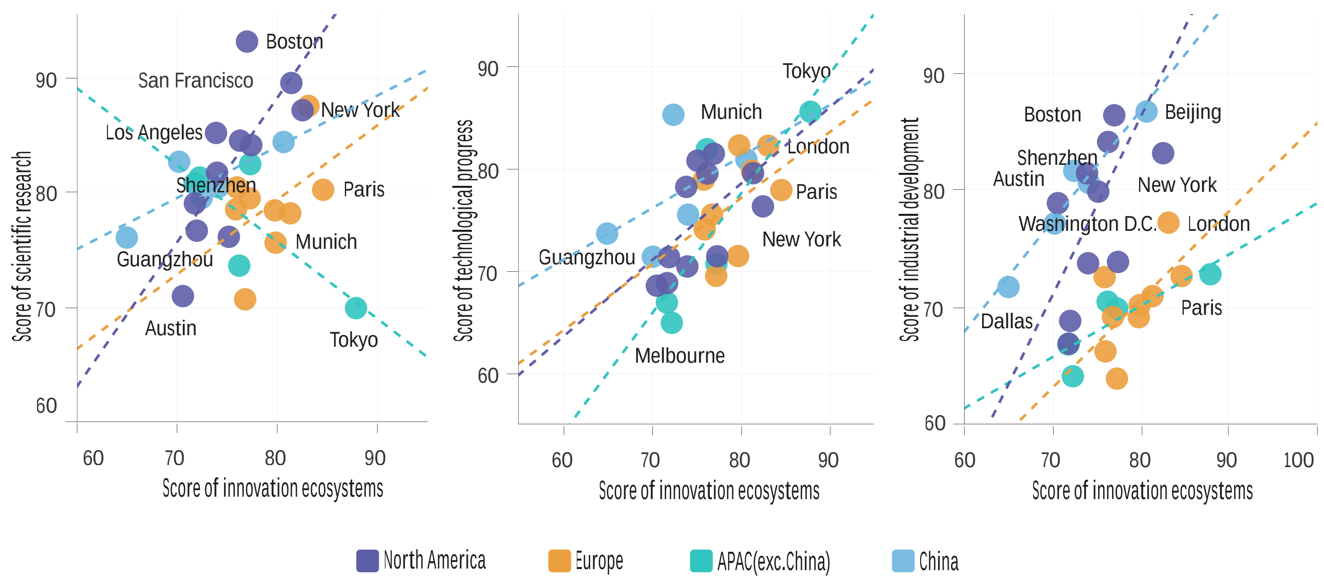


Figure 5.5.2 Scatter plot of correlation between the innovation ecosystem scores of 30 global innovation cities and their scientific research, technological innovation, and industrial development scores

Cross-regional collaboration – the diversity of collaborating cities

The diversity of cross-regional collaboration assesses the diversity of collaborating cities in scientific research, as captured through the lens of co-authored research publications. The analysis reveals a positive correlation between the diversity of cross-regional collaboration among 30 global innovation cities and the growth of their high-quality S&E research output (see Figure 5.5.3). This indicates that leading scientific research, exemplified by high-quality research results, attracts further scientific collaboration. In turn, extensive scientific collaboration consolidates resources and talent, further enhancing the production of high-quality research output.

Out of the 30 innovation cities, London, Paris, and Beijing are the top three in terms of the diversity of their cross-regional collaboration. European cities generally score higher in cross-regional collaboration, which is related to the geographical proximity of European cities. Capital cities such as Seoul, Beijing, and Tokyo, also play an important role in promoting cooperation within the country and in neighboring regions.

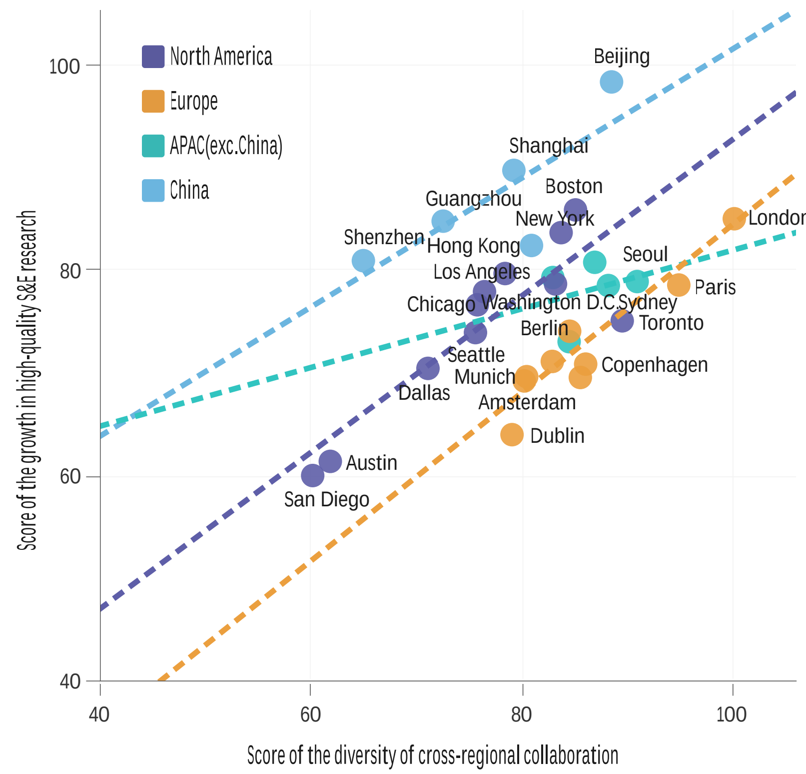


Figure 5.5.3 Scatter plot of the growth scores of high-quality S&E research output and cross-regional collaboration diversity scores of 30 global innovation cities (2019–2023)

5.5 Innovation ecosystems

Cross-sector collaboration: academic-corporate research collaboration

Academic-corporate collaboration refers to research collaboration between at least one academic institution and at least one company. This indicator calculates the proportion of papers jointly published by companies and academic institutions in a city's scientific research output.

As shown in Figure 5.5.4, among the 30 innovation cities, 7 cities have an academic-corporate research collaboration rate in the S&E field of more than 10%, and 10 cities have an academic-corporate research collaboration rate of more than 9%, which is considerably higher than the global average level (2.7%), reflecting the more obvious integration of industry and academia in innovation cities. Among the innovation cities, San Diego has the highest academic-corporate collaboration rate in the S&E field, with 16.5% of its S&E research output stemming from collaboration between companies and academia, followed by Munich and Seattle, with 14.4% and 14.3% respectively. Among Asian cities, Tokyo has the highest academic-corporate research collaboration rate in the S&E field, at 12.1%, followed by Shenzhen, at 9.5%.

San Diego serves as a prime example of an active academic-corporate collaboration ecosystem, characterized by the dynamic interconnection and interaction between local high-tech companies and prestigious universities. Based on mining the publication data of this city, the most active collaborating companies are General Atomics,[8] International Applications Corporation (SAIC),[9] and Qualcomm Incorporated, as well as biopharmaceutical innovation companies Ionis Pharmaceuticals, Illumina Inc.,[10] and AntiCancer Inc.[11] Along with other innovative companies, they have established strong collaborative ties with scientific research institutions such as the University of California, San Diego, and San Diego State University. This collaboration has yielded many high-quality scientific research outputs, while concurrently fostering the emergence of a series of successful commercial products and services, which is conducive for enhancing local industries.

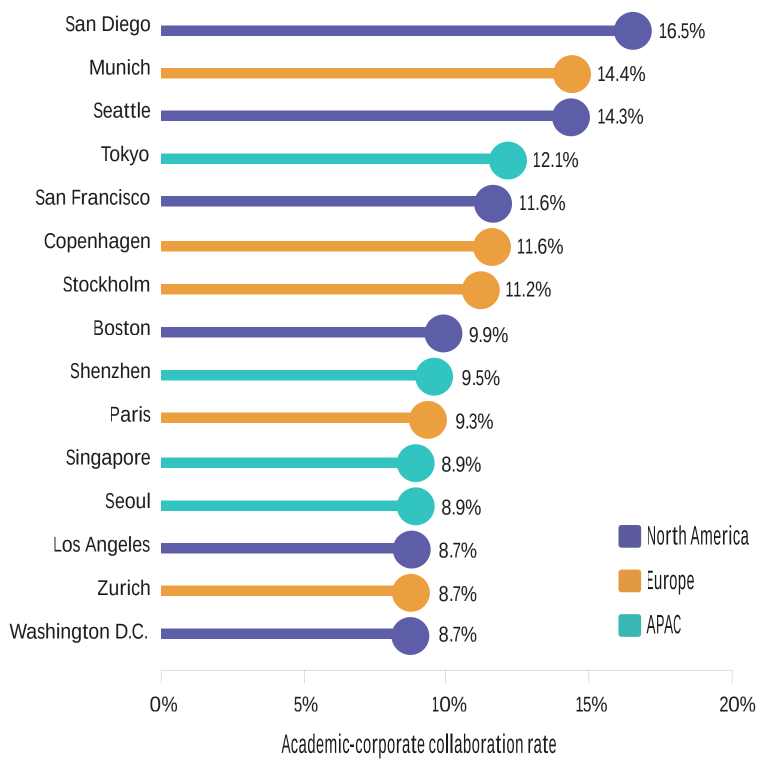


Figure 5.5.4 Top 15 innovation cities by academic-corporate research collaboration rate, out of the 30 global innovation cities (2019–2023)

[8] General Atomics is an American technology company, mainly engaged in the nuclear energy and defense industry fields.

[9] SAIC is a leading provider of technology, engineering and enterprise information technology (IT) services primarily to the US government.

[10] Illumina is a company that provides gene sequencing and chip technologies.

[11] AntiCancer Inc is a bioengineering company founded in 1984 by Dr. Robert M. Hoffman, a professor at the University of California, San Diego (UCSD).

5.6 In focus: Strengthening academic-corporate ties

The establishment of a strong relationship between academic institutions and companies has been identified as a pivotal factor for transferring knowledge and technology from research settings to practical applications. This collaboration bridges the gap between theoretical research and real-world use, and has been shown to accelerate the transformation and application of scientific and technological advancements, benefiting society as a whole.

A close examination of the extant research on the 30 global innovation cities reveals a positive correlation between the academic-corporate collaboration rate and industrial development scores of each city (see Figure 5.6.1). Specifically, cities with higher academic-corporate collaboration rates tend to exhibit stronger advantages in industrial development, which shows that active collaboration between industry and academia can help improve local industrial development.

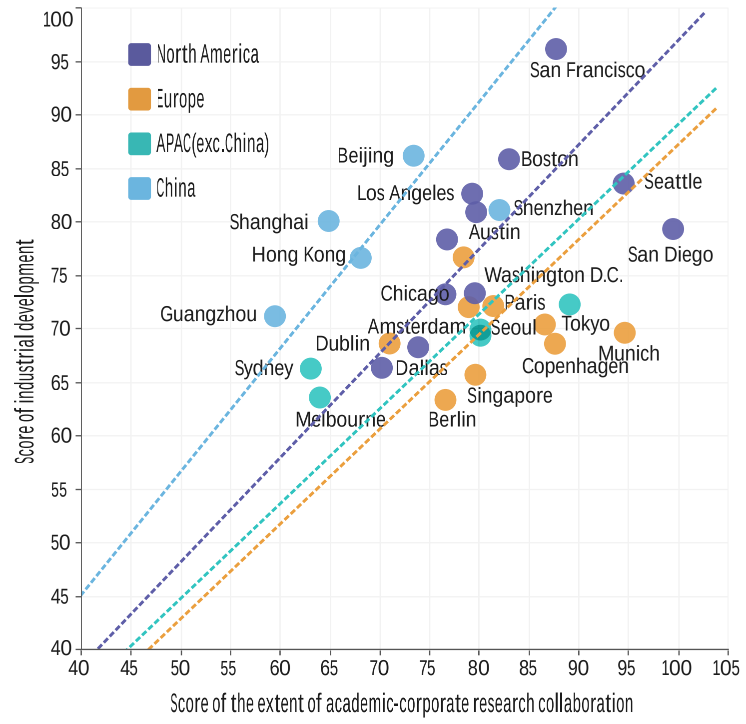


Figure 5.6.1
Scatter plot of academic-corporate collaboration scores and industrial development scores of 30 global innovation cities (2019–2023)

Case study: Boston, a city with active academic-corporate collaboration

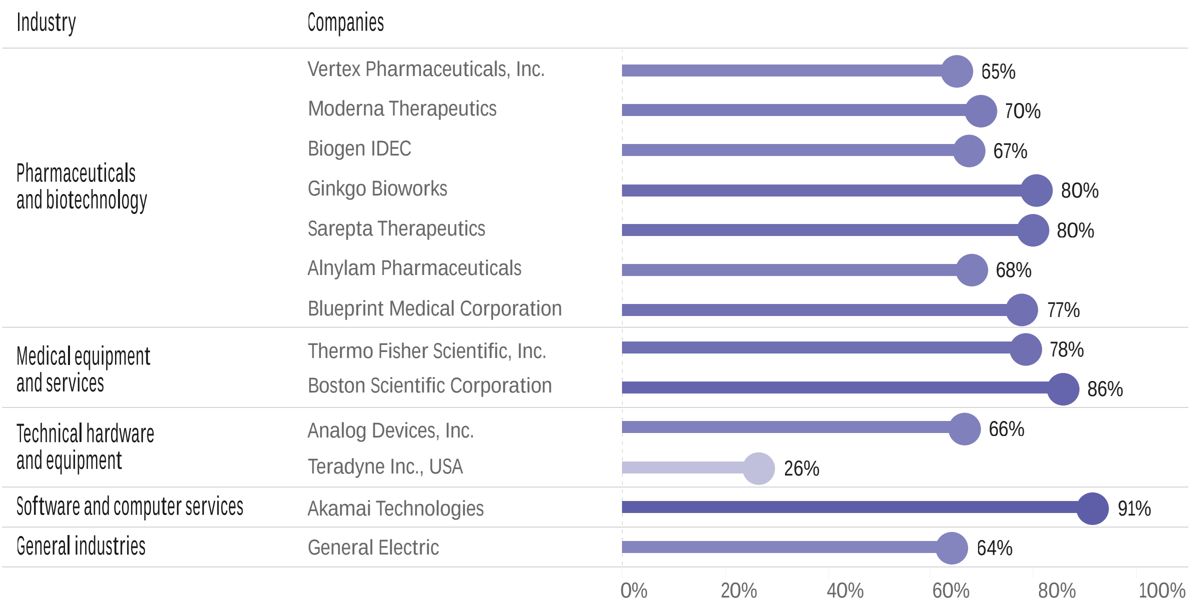


Figure 5.6.2 Academic-corporate collaboration rate among the top 500 global innovation companies in Boston (2019–2023)[12]

The city of Boston, a leading global innovator, serves as a prime example of this phenomenon. Boston has attracted numerous world-renowned innovative companies, making it a prominent hub for advanced technological development and innovation. These companies' research and development activities heavily rely on academic-corporate collaboration. According to the EU scoreboard ranking, over 60% of the research outputs from the top 500 innovative companies in Boston stem from collaborations with academic institutions (see Figure 5.6.2).

[12] Refers to the ranking of innovative companies on the Industry R&D Investment Scoreboard (2023)

This demonstrates the active academic-corporate partnerships in Boston and underscores the importance of such collaboration for enhancing corporate innovation capabilities.

Further analysis of these companies' academic partners (see Figure 5.6.3) reveals that, in addition to closely working with local top universities such as Harvard University and the Massachusetts Institute of Technology (MIT), innovative enterprises actively seek partnerships with high-level research institutions globally. While local universities are significantly effective in promoting academic-corporate collaboration and are convenient for partnerships, companies are also willing to transcend geographical boundaries to find the most suitable collaborators in pursuit of broader innovation resources and support. This open collaboration model helps companies maintain a competitive edge in the fierce global market and continuously drive technological innovation.

For instance, at Moderna Therapeutics, 70% of the company's research outputs are published in collaboration with academic institutions, making academic-corporate collaboration a crucial part of its innovation strategy. The company has a wide array of partnerships that yield fruitful results, such as collaborating with Harvard University on immunology research to provide clinical trial support; working with Duke University to focus on mRNA technology platforms and infectious disease research; partnering with Emory University to specialize in the development of mRNA-based vaccines for influenza and other infectious diseases; jointly conducting research on coronavirus vaccines, protein engineering, and vaccine design with the University of Washington; and collaborating with the Broad Institute to focus on genomics research, including cancer immunotherapy and gene editing therapies. Through these collaborations, Moderna is able to leverage foundational research from academia, accelerate drug development processes, and explore new therapeutic avenues.

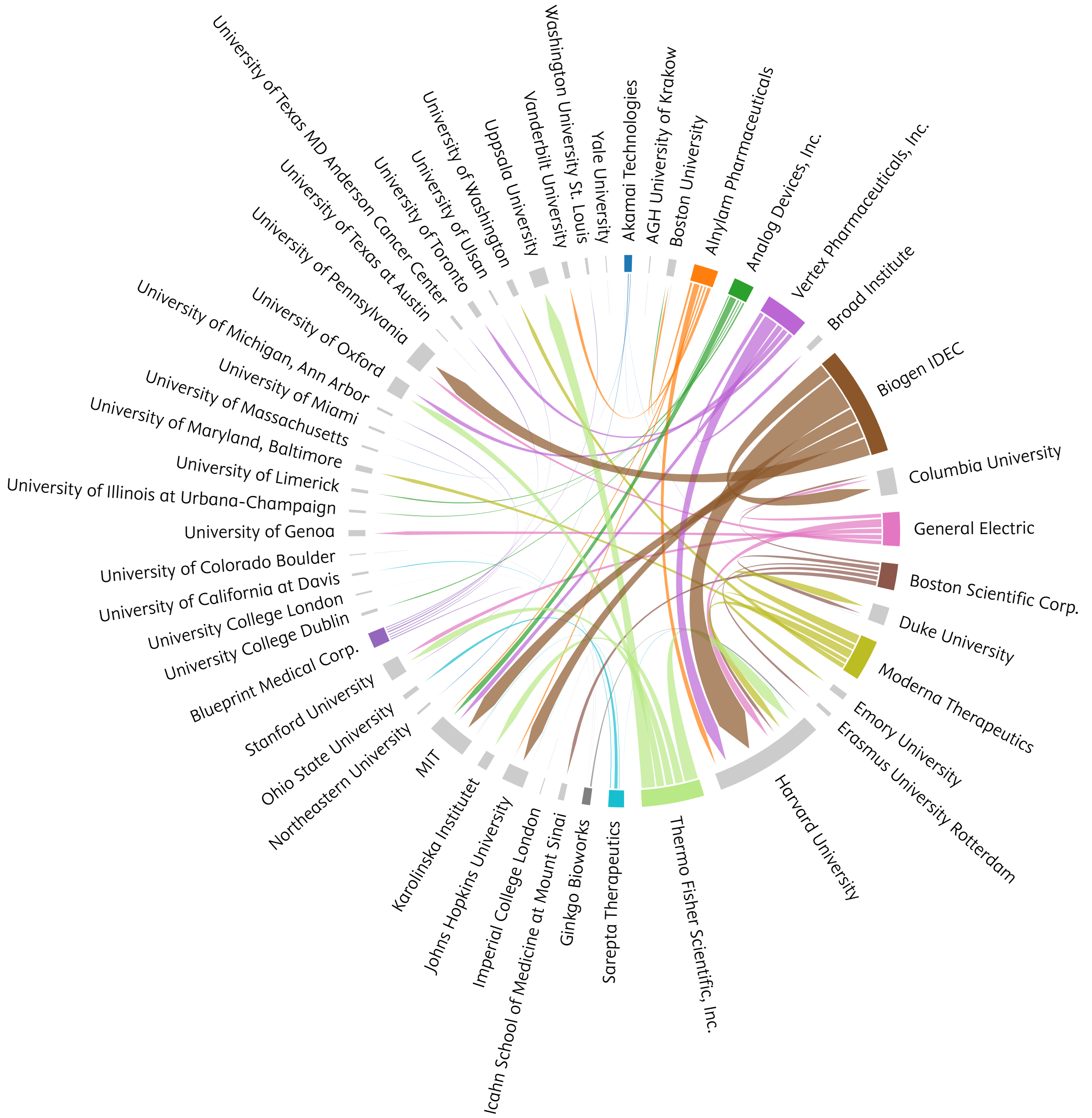


Figure 5.6.3 The top five academic institutions in academic-corporate collaboration for the top 500 global innovation companies in Boston (2019–2023)

Suggestions for improving academic-corporate collaboration

The flourishing development of the biomedical industry in the Boston area is attributed to its unique "government-academic-corporate" collaboration model. In this model, top research institutions cultivate advanced outcomes and top-tier talent, companies commercialize scientific and technological achievements and promote technology dissemination, while the government drives industrial development through funding, policy support, and intermediary services. This close collaboration effectively enhances the innovation capability of Boston's biomedical industry, accelerates the transition from laboratory to market, and solidifies its leading position in the global life sciences field. Based on Boston's development experience, the report summarizes the following recommendations to promote academic-corporate research collaboration:

01 Establish long-term and stable collaborative relationships

According to social network theory, long-term and stable collaborative relationships can promote the establishment of trust and the efficiency of technology transfer.[13] Enterprises and academic institutions should focus on establishing sustainable partnerships by signing long-term collaboration agreements, setting up joint laboratories or research centers, and ensuring the sharing of resources and information, thereby enhancing the depth and breadth of collaboration. For example, AstraZeneca collaborated with Tufts University to establish a cardiovascular disease research center to accelerate the development of innovative drugs in the cardiovascular field; MIT and Novartis established the Novartis-MIT Center for Continuous Manufacturing, focusing on the development of new drug manufacturing technologies.

03 Optimize talent mobility and training systems

Human capital is core for promoting S&T innovation. Effective personnel exchanges can accelerate the speed of knowledge dissemination and technology transformation.[15] At the same time, personnel mobility also fosters collaboration between industry and academia. Universities and research institutions should open more internship positions and postdoctoral stations to attract outstanding students and young scientists to participate in practical projects. Meanwhile, companies should actively engage in talent cultivation by establishing scholarships and mentorship programs to cultivate high-quality professional talent for the future. For example, Pfizer offers internship opportunities for students at Harvard University, allowing them to gain practical experience in Pfizer's R&D departments; Novartis regularly invites professors from MIT as visiting scholars to engage in short-term or long-term research collaborations; Vertex actively attracts postdoctoral researchers from Harvard and MIT for short-term research work; and Sanofi collaborates with Brandeis University to provide cooperative education opportunities for students.

02 Strengthen policy support and incentive mechanismss

Public policies play an important role in guiding and promoting academic-corporate collaboration. The government can reduce the cost of companies participating in research activities through legislation, financial subsidies, tax incentives and other means, and encourage more entities to invest in industry-university cooperation.[14] For instance, the US government revised laws to recognize the commercialization of research outcomes by US universities and research institutions, providing patent protection that greatly enhances the enthusiasm for academic-corporate collaboration. At local level, the Boston government provides financial support for research outcomes, various tax incentive policies, financing options, and grants, such as establishing the "Massachusetts Innovation Economy Partnership," R&D tax credits, and the "Massachusetts Emerging Technology Fund," which effectively promotes local academic-corporate collaboration.for Continuous Manufacturing, focusing on the development of new drug manufacturing technologies.

04 Build information communication platforms to promote information sharing

Information asymmetry is one of the key factors hindering academic-corporate collaboration. A good communication platform helps break down information barriers and improve collaboration efficiency.[16] From the perspective of promoting collaboration, modern information technologies, such as big data and cloud computing, can be utilized to build a technology trading platform that combines online and offline elements, providing real-time updates on scientific achievements and market demand; regularly hosting academic-corporate collaboration matchmaking events, forums, and other activities to enhance mutual understanding and explore potential collaboration opportunities. For example, Biogen, along with MIT, Harvard University's Broad Institute, and Partners HealthCare, established an alliance to create and share a COVID-19 biobank to[17] strengthen research and treatment related to the novel coronavirus.

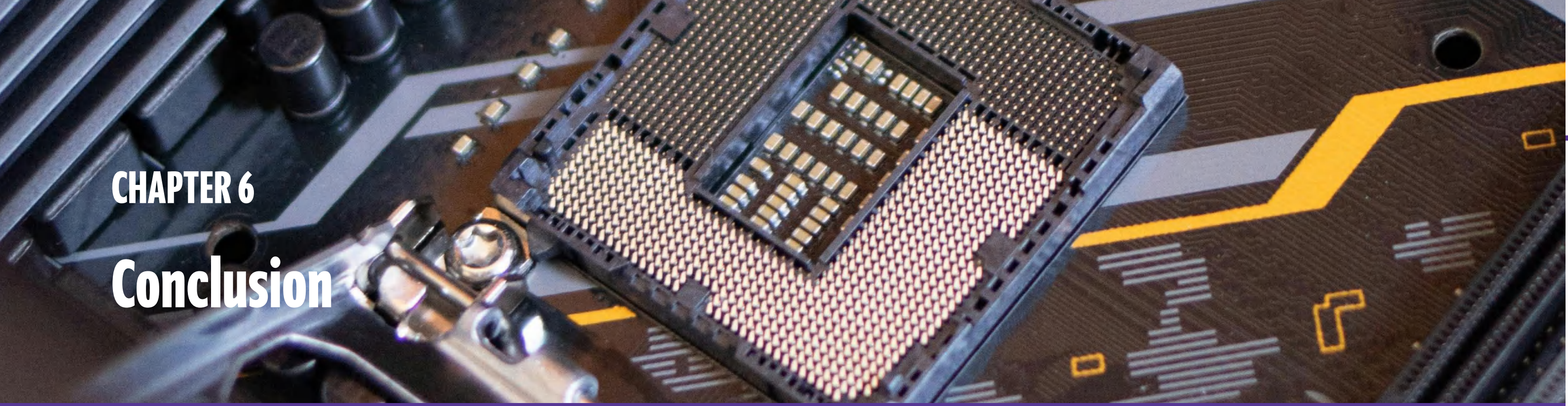
[13] Burt, RS (2005). Brokerage and Closure: An Introduction to Social Capital . Oxford University Press.

[14] Djankov, S., La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2002). The Regulation of Entry. The Quarterly Journal of Economics , 117(1), 1-37. DOI: 10.1162/003355302753399437

[15] Cohen, WM, & Levinthal, DA (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128-152. DOI: 10.2307/2393553

[16] Bode, C., Herzog, C., Hook, D., McGrath, R., & Wade, A. (2023). A Guide to the Dimensions Data Approach. Digital Science.

[17] https://investors.biogen.com/news-releases/news-release-details/biogen-broad-institute-mit-and-harvard-partners-healthcare



CHAPTER 6

Conclusion

There are many ways to rank the innovation capacities of cities, and there are multiple such city rankings, each with a slightly different focus. This report presents just one such method, introducing the SET Index to evaluate global innovation cities across three dimensions: education level, talent development, and S&T innovation. Using multi-dimensional indicators, this report aims to objectively depict the development characteristics of each city amidst the global wave of innovation, identify opportunities and challenges, and provide insights for urban innovation development.

Based on the comprehensive evaluation of the SET Index over 2019–2023, the top three cities in global innovation are Boston, San Francisco, and Beijing. These cities exemplify the successful strategy of promoting innovation through the coordinated development of S&T, education, and talent. As leaders in global technological innovation, these three cities leverage their top-tier educational resources, concentrated high-tech industries, and research institutions to attract a large pool of high-quality talent. Additionally, by cultivating an environment rich in knowledge, technology, and information, they enhance their overall technological innovation capabilities, setting a benchmark for other global innovation cities.

The report also finds that major global innovation cities, despite being at different stages of development and having varying roles in their respective countries, exhibit relative advantages in education level, talent development, and S&T innovation based on their unique resources and characteristics. This diversity reveals different innovation models and development paths. Most cities show advantages in either two dimensions, or excel in one particular dimension. Therefore, a key issue for cities and regions is to leverage their own advantages and address relative shortcomings to achieve better development.

In terms of education level, Asian cities have advantages primarily in basic education; however, in higher education, major cities in the US and Europe still lead globally. An advanced higher education system is a key factor in nurturing and attracting innovative talent. Leading global innovation cities such as Boston, New York, and London excel in attracting top talent due to their many prestigious universities, greatly enhancing their local technological innovation capabilities. China has set education development as a national strategy, achieving continuous breakthroughs in higher education, but the distribution of educational resources in Chinese cities remains uneven. As these cities strive to become global education hubs, it is imperative to overcome bottlenecks and improve the balance of educational resource distribution, as well as the quality and influence of higher education.

In terms of talent development, Asian cities have the advantage of scale in the pool of innovative talent; European and American cities excel at attracting top talent. Beijing and Tokyo, because of their population size and density, have a clear advantage in terms of the total amount of research and industrial talent, and significantly lead other cities. Metropolises in Europe and the United States, such as Boston, London and New York, are home to a large number of top researchers due to their dense and high-quality higher education resources. In the pursuit of innovation, many cities are actively exploring ways to tap their talent potential, by focusing on building a pool of young innovative talent and enhancing their attraction to new talent. Chinese cities are doing particularly well in retaining and developing young research talent. China's Shenzhen and Guangzhou have the fastest growing pools of young researchers among the 30 global innovation cities. In addition, many emerging technology hubs in the US have shown a clear advantage in attracting global quality talent, with Austin, San Diego, and San Francisco all ranking at the top of the list in terms of the proportion of talent inflow.

In the context of S&T innovation, the alignment of research, technology, and industry is of paramount importance. Exemplary innovation cities demonstrate leadership in scientific research, technological progress, and industrial development, with Boston and Beijing serving as notable examples. However, there are also cities that drive industrial innovation based on research foundations, those that boost industrial development through technological progress, or those with clear research and technological advantages that have not yet been widely transformed into industrial development. The diverse advantages and disadvantages among cities mirror their distinct roles and resource endowments in national and regional innovation development. Consequently, individual cities should develop their own innovation paths based on their unique characteristics.

The promotion of an open and collaborative environment, coupled with a robust economic foundation, is instrumental in fostering a favorable innovation ecosystem, which in turn provides crucial support for innovation development. European cities have demonstrated particular strengths in openness and collaboration, while American cities have exhibited a propensity to establish robust economic foundations for innovation, as evidenced by their high GDP. To enhance their competitiveness and influence in the global innovation landscape, Chinese cities need to proactively foster collaboration, establish an open and mutually beneficial innovation ecosystem.

In summary, the coordinated development of education, talent, and S&T is a systematic project that requires cities not only to focus on improving the education quality and talent cultivation but also to emphasize the integration of scientific research and industrial application, forming a complete innovation chain. This will promote sustainable healthy development of society, placing cities in a strong position to take advantage of global innovation trends.

Appendix 1 Indicator description

SET Index Definition and Data Source

1.Education level

1.1 Basic Education

1.1.1 Average education level of the residents

This indicator includes two underlying indicators: the mean years schooling of adults aged 25+ and the share of population with higher education. The average years of education received by adults refers to the average number of years of education received by adults aged 25 and above in the assessed city. Due to the availability of data, the city-level data is represented by regional data. The share of population with higher education refers to the percentage of the population aged 25 and above in the assessed city whose highest educational achievement is higher education level. The level of higher education refers to levels 5-8 of the 2011 International Standard Classification of Education (ISCED 2011).

Data source: GlobalDataLab (https://globaldatalab.org/shdi/table/msch/?levels=1+4&interpolation=0&extrapolation=0) and THE GLOBAL TALENT COMPETITIVENESS INDEX 2022 (https://www.insead.edu/sites/insead/files/assets/dept/fr/gtci/GTCI-2022-report.pdf)

1.1.2 Quality of STEM education in primary and secondary schools

This indicator includes two tertiary indicators: the average scores of mathematics and science in the Programme for International Student Assessment (PISA) test. Due to the availability of data, the city-level data is represented by country data. Since China did not participate in the 2022 PISA test due to the epidemic, this report uses the 2018 PISA test results for data accessibility and comparability.

Data source: PISA 2018 (https://www.oecd-ilibrary.org/education/pisa-2018-results-volume-i_5f07c754-en;jsessionid=Oz8Jbpf1Urm-OS5JrIKTniMnNPkekqMbuSrcZ9Ut.ip-10-240-5-43)

1.1.3 International science competition awards for secondary schools

Refers to the total number of gold medals won by the assessed cities in the International Olympiads in mathematics, physics, chemistry, biology, and information between 2019 and 2024.

Data source: Home page of Olympic competition official website

1.2 Higher Education

1.2.1 Performance of world-class disciplines

This indicator includes two tertiary indicators: the median ranking of the top 200 disciplines in the world in science and engineering (S&E) fields, and the discipline ranking growth index. The median ranking refers to the median position of universities in a city that are within the top 200 globally, as ranked by THE 2024, in clinical and health, life sciences, physical sciences, computer science, and engineering. The growth index measures the improvement of these universities in the rankings from THE 2020 to 2024 for the same five disciplines. The calculation of the growth index is primarily based on the changes in median and average rankings of the city's top 200 disciplines over the period. Additionally, it accounts for the difficulty of improving different rankings. Cities with already high rankings receive extra points for further improvements, reflecting the relative challenge of advancing in high-level discipline construction.

Data source: THE 2020, 2024 subject rankings: https://www.timeshighereducation.com/cn/world-university-rankings/by-subject)

1.2.2 Number of world-class universities

Refers to the number of universities in the city that are among the top 200 in the world in the THE 2024 university rankings.

Data source: THE 2024 University Rankings (https://www.timeshighereducation.com/cn/world-university-rankings/2024/world-ranking)

1.2.3 Growth rate of the number of research institutions

Refers to the compound annual growth rate (CAGR) of the number of Scopus-indexed institutions in the assessed city between 2019 and 2023, calculated as follows:

$$CAGR = (\frac{v_e}{v_b})^{\frac{1}{n}} - 1$$

Among them, V_b -----beginning value, that is, the number of institutions with Scopus AF-ID in a certain city in 2019, V_e ----- end value, that is, the number of institutions with Scopus AF-ID in a certain city in 2023, n-----number of periods.

Data source: Scopus

2.Talent Development

2.1 Research talents

2.1.1 Competitiveness of S&E researchers

This indicator includes two sub-indicators: the total number of talents in S&E fields and the median h-index of the researchers. The total number of talents in S&E fields refers to the total number of active scientific researchers in S&E field in the city between 2019 and 2023. Active scholars in S&E fields refer to scholars who have published at least 3 papers in S&E fields between 2019 and 2023, and have published at least one paper in S&E field in the past three years. The median h-index of researchers in S&E fields refers to the median h-index of active scientific researchers in the respective field in the city between 2019 and 2023. The h-index means that among all the papers published by scholars, h papers have been cited at least h times.

Data source: Scopus

2.1.2 Number of top-tier S&E researchers

This indicator refers to the number of Stanford University's top 2% most cited scientists in the world (Lifetime Scientific Impact List) in 2023 in the city. The number of highly cited scholars in a city is based on the location of their current affiliated institution.

Data source: official website of the list, Scopus

2.2 Industrial Talent

2.2.1 Total number of employees in top 1,000 innovative companies

This indicator refers to the total number of global employees of the top 1,000 global innovative companies listed in the 2023 EU Industrial R&D Investment Scoreboard. These top companies are counted based on the city of their location.

Data source: 2023 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/scoreboard/2023-eu-industrial-rd-investment-scoreboard)

2.2.2 Proportion of employees in high-tech industries among the top 1,000 innovative companies

This indicator refers to the proportion of high-tech industries employees in the top 1,000 innovative companies in the city to the total number of employees in the top 1,000 companies in the city. The high-tech industries referred to in this report include aerospace and defense, alternative energy, automotive and parts electronic and electrical equipment, financial services, medical equipment and services, mobile communications, pharmaceuticals and biotechnology, software and computer services, technology hardware and equipment, etc.

Data source: 2023 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/scoreboard/2023-eu-industrial-rd-investment-scoreboard)

2.2.3 Number of top-tier talents in the engineering field

This indicator refers to the newly elected members of the Institute of Electrical and Electronics Engineers (IEEE) in the city between 2020 and 2024. The number of IEEE members in a city is determined using the city information provided on the IEEE official website. For scholars whose city information is not available, the city is identified based on the location of their current affiliated institution.

Data source: IEEE official website (https://services27.ieee.org/fellowsdirectory/menuCHRONOLOGICAL.html?beginYr=2024&endYr=2024)

2.3 Talent potential

2.3.1 Proportion of active young S&E researchers

Refers to the proportion of young active researchers in S&E fields in the evaluated cities between 2019 and 2023. Young active researchers in S&E fields refer to researchers whose academic age (the span between the first publication of a paper and the year of the most recent publication) in the field is five years or less, and researchers who should have published at least three papers in S&E fields between 2019 and 2023, and have published at least one paper in the field in the past three years.

Data source: Scopus

2.3.2 The growth rate of young S&E researcher activity

It refers to the compound annual growth rate (CAGR) of the number of active young researchers in S&E fields in the assessed cities between 2019 and 2023.

Data source: Scopus

2.3.3 Proportion of inflow S&E researchers

Refers to the proportion of active researchers in S&E fields who flowed into the city between 2019 and 2023 to the total number of active S&E researchers in the city. The method for determining the inflow of talent into City A requires meeting the following conditions simultaneously: 1) The scholar has a record of publishing papers before 2019, but with no publishing record located in City A; 2) The location of the scholar's most recent publication between 2019 and 2023 is City A.

Data source: Scopus

3. S&T innovation

3.1 Scientific Research

3.1.1 High-quality S&E research output

Refers to the total number of top journal articles in Cell, Nature, and Science published by the assessed cities in S&E fields between 2019 and 2023.

Data source: Scopus

3.1.2 Growth in high-quality S&E research output

It includes two sub-indicators: the number of the top 1% highly cited papers and the compound annual growth rate (CAGR) of highly cited papers between 2019 and 2023. The top 1% of highly cited papers refer to the number of papers in S&E fields that ranked in the top 1% of citations worldwide between 2019 and 2023.

Data source: Scopus

3.1.3 Academic impact of S&E research output

Refers to the Field-Weighted Citation Impact (FWCI) of S&E papers published by the assessed cities between 2019 and 2023. FWCI is calculated by comparing the number of citations actually received by a publication with the number of citations expected for 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, a score of 2.11 means the entity's publications have been cited 111% more than the world average. An FWCI of less than 1.00 indicates that the entity's publications have been cited less than would be expected based on the global average for similar publications; for example, an FWCI score of 0.87 means the publications have been cited 13% less than the world average.

In general, the FWCI is defined as follows:

$$FWCI = \frac{C_i}{E_i}$$

with

Ci= citations received by publication i

Ei= expected number of citations received by all similar publications in the publication year plus following 3 years

When a similar publication is allocated to more than one subject, the harmonic mean is used for the calculation.

To calculate mean FWCI for the publication set, we use the formula:

$$\overline{FWCI} = \frac{1}{N}\sum_{i=1}^{N}\frac{C_i}{E_i}$$

Where N = the number of Scopus-indexed publications in the publication set

FWCI uses an unweighted variable 5-year window. The mean FWCI value for 2012 publications, for example, is calculated for documents published in 2012 using their citations from 2012 to 2017. For recent output with less than five years since publication, all citations available at the date of data extraction are used in the calculation. For instance, if an article is published in 2016, and the data are extracted in 2018, the article's FWCI is calculated using the article's 2016–2018 citations.

Data source: Scopus

3.1.4 Proportion of S&E research output cited by patents

It refers to the proportion of papers in S&E fields published in the city between 2019 and 2023 that were cited by international patents (international patents here refer to patents issued by the five major patent offices: WIPO, USPTO, EPO, JPO, and UKPO).

Data source: Scopus, LexisNexis

3.1.5 Multidisciplinary score of S&E research output

Refers to the degree of multidisciplinary teamwork of publications in S&E fields in the city between 2019 and 2023. The index is based on the diversity of disciplinary backgrounds of document co-authors.[18] This indicator was developed to account for the number of distinct disciplines, the cognitive distance that separates them, and the balance between them. A paper co-authored by authors whose previous papers were distributed across subfields of science in a similar pattern (i.e., having similar relative frequency across subfields) would score lower than papers bringing together authors with different backgrounds (as measured by the subfields from their prior publications), even if those authors, individually, have published in a less diverse set of subfields. In other words, there are differences between the backgrounds of each co-author that increases multi-disciplinary integration and not having individual authors with more diverse backgrounds. Nevertheless, authors having diverse backgrounds may be more likely to increase the multi-disciplinary integration of one paper, but only if this diversity is sufficiently different from the subfields of the remaining authors. As a result of this approach, a single-author publication, no matter the diversity of its author's background, will always receive the minimum score, because the indicator is intended to capture diversity across different authors.

Data source: Scopus

3.2 Technological progress

3.2.1 Number of granted PCT patent families

PCT patent families refer to patent families filed under the Patent Cooperation Treaty. This report counts the authorized PCT patent families applied for by the assessed cities from 2014 to 2023. The simple patent family rule is applied, and the patents are attributed to cities based on the applicant's address.

Data source: LexisNexis

3.2.2 Number of granted PCT patent families per capita

Refers to the number of granted PCT patent families per 10,000 people in the assessed city.

Data source: LexisNexis

3.2.3 Patent technology impact

This indicator refers to the normalized value of how often patents from the evaluated city are cited by other patents. It uses a method similar to the field-weighted citation impact (FWCI) for publications, standardizing citation data to eliminate differences caused by various publication years and technical fields. The field technology classification follows the third level (IPC3) of the International Patent Classification (IPC). This evaluation method aims to more objectively reflect the relative strength and influence of the city's patent technology innovation.

Data source: LexisNexis

3.2.4 Growth rate of high tech-impact patents

This refers to the compound annual growth rate (CAGR) of patent families from the evaluated city, filed between 2014 and 2023, that rank within the top 10% globally in terms of citations.

Data source: LexisNexis

3.3 Industrial Development

3.3.1 Number of top 1,000 innovative companies

Refers to the number of the top 1,000 global R&D investment companies in the assessed city.

Data source: 2023 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/scoreboard/2023-eu-industrial-rd-investment-scoreboard)

3.3.2 R&D investment intensity of the top 1,000 innovative companies

Refers to the median intensity of R&D investment of the top 1,000 global R&D investment companies in the assessed city.

Data source: 2023 EU Industrial R&D Investment Scoreboard (https://iri.jrc.ec.europa.eu/scoreboard/2023-eu-industrial-rd-investment-scoreboard)

3.3.3 Performance of unicorn companies

It includes the total number of unicorn companies in the assessed cities and the number of newly established unicorn companies in the cities in the past five years (2019–2023).

Data source: Dealroom (https://dealroom.co/)

3.3.4 Average valuation of start-ups

Average market valuation of startups provided by Dealroom (US$ million)

Data source: Dealroom (https://dealroom.co/)

3.4 Innovation Ecosystems

3.4.1 Number of large scientific facilities

The number of operational large scientific facilities in the evaluated cities. The large scientific facilities counted in this report fall into two categories: The first category consists of specialized research facilities, which are research installations built for major scientific and technological objectives in specific disciplines. The second category includes public experimental platforms, which are large-scale public experimental facilities with strong support capabilities serving basic research, applied basic research, and applied research across multiple disciplines. The specific fields include energy, materials, geography, astronomy, biology, environment, nuclear physics, and

[18] Henrique Pinheiro, Etienne Vignola-Gagné, David Campbell; A large-scale validation of the relationship between cross-disciplinary research and its uptake in policy-related documents, using the novel Overton altmetrics database. Quantitative Science Studies 2021; 2 (2): 616–642. doi: https://doi.org/10.1162/qss_a_00137.

high-energy physics. To ensure indicator independence, supercomputers and scientific facilities with supercomputing characteristics are not included in the statistical scope of large scientific facilities.

Data source: International Science and Technology Innovation Center Index 2024 (https://www.ncsti.gov.cn/kjdt/ztbd/cxzs2024/)

3.4.2 Extent of academic-corporate research collaboration

This refers to the proportion of academic-corporate collaborative publications in S&E fields among all publications in the field from the evaluated cities between 2019 and 2024. Academic-corporate collaborative publications are those with multiple authors, where at least one author is affiliated with an academic institution and at least one author is affiliated with industry. This indicates that such publications are the result of academic-corporate collaboration.

Data source: Scopus

3.4.3 Diversity of cross-regional collaboration

This index measures the diversity of each city's S&E publications resulted from cross-regional (inter-city) research collaboration, thereby reflecting the breadth of collaboration partners and the visibility of scientific research collaboration. The calculation of the index refers to the Margalef index for calculating biodiversity.[19] The calculation formula is as follows:

The diversity index of cross-city collaboration =

ln(number of collaborative cities) / ln (number of collaborative insititutions)

Cross-city collaboration publications refers to papers published by multiple authors where at least one author is affiliated with a local research institution and at least one author is affiliated with a research institution from another city. This indicates that such publications are the result of cross-city collaboration.

Data source: Scopus

3.4.4 GDP performance

It includes two sub-indicators: per capita GDP and GDP growth rate.

GDP per capita is the logarithm of the city's gross national income per capita in 2022 at purchasing power parity in 2011 (in thousands of US dollars). City data are substituted with the GDP per capita of the region to which the city belongs.

The GDP growth rate uses the real GDP growth rate of each city in 2022 calculated at the purchasing power parity in 2015 (with 2015 as the real GDP base). In order to eliminate the impact of price level differences between countries on the purchasing power of different currencies and the impact of price changes on GDP, this study uses the GDP deflator of each country to convert nominal GDP into real GDP with 2015 as the base period, and then generates GDP time series data calculated in US dollars using constant prices and constant purchasing power in 2015, and then calculates GDP growth. Due to missing data, Paris, Berlin, Munich, Dublin, Amsterdam, Stockholm, Zurich, Tokyo, and Seoul use the GDP growth rate of 2021, and Toronto uses the GDP growth rate of 2020.

Data sources:

(1) GDP per capita data are derived from GlobalDataLab

(2) GDP growth rate calculation data come from: International Science and Technology Innovation Center Index 2024 (https://www.ncsti.gov.cn/kjdt/ztbd/cxzs2024/)

[19] Death, R. (2008). Margalef's Index. Encyclopedia of Ecology, 2209–2210. https://doi.org/10.1016/b978-008045405-4.00117-8

Appendix 2 Data standardization

The SET indicator system contains indicators with different dimensions, therefore standardization of all raw data is required first. This report mainly adopts the min-max method and sets the base score of evaluated cities to 60 points, making the score range of tertiary indicators for evaluated cities [60, 100]. This means the top-ranked city scores 100 points while the last-ranked city scores 60 points. The formula is as follows:

$$Y_{aj} = 60 + \frac{X_{aj} - X_{min}}{X_{max} - X_{min}} * 40$$

Y_{aj} is the score of the city j 's a^{th} tertiary indicator that is normalized by min — max method and standardized to [60,100]. X_{aj} is the original value of the city j 's a^{th} tertiary indicator. the X_{min} is the minimum value of the a^{th} tertiary indicator of all cities. X_{max} is the maximum value of the a^{th} tertiary indicator of all cities.

The SET score of city j is Y_j , Y_j is the weighted score of all tertiary indicators of the city, w is the weight of the i^{th} tertiary indicator, Y_{ij} is the value of the city j 's i^{th} tertiary indicators mapped to [60,100] , n = 38, is the total number of tertiary indicators, i = 1 means the calculation starts from the first tertiary indicator.

$$Y_j = \sum_{i=1}^{n} w_i Y_{ij}$$

Appendix3 City scope

In this report, metropolitan areas are referred to as "cities." The scope of these 30 innovation cities is listed in the following table:

City in the report	Metropolitan Statistical Area (MSA)/ Functional Urban Area (FUA)	Principal cities
Amsterdam	Greater Amsterdam	Amsterdam
		Diemen
		Haarlem
		Almere
		Amstelveen
Austin	Austin-Round Rock-San Marcos, TX	Austin
		San Marcos
		Georgetown
		Round Rock
Beijing	Beijing	Beijing
Berlin	Berlin	Berlin
		Potsdam
Boston	Boston-Cambridge-Newton, MA-NH	Boston
		Cambridge
		Waltham
		Medford
		Chestnut Hill
		West Roxbury
		Framingham
		Wellesley
		Somerville
		Quincy
		Newton
Chicago	Chicago-Naperville-Elgin, IL-IN	Chicago
		Aurora
		Evanston
		North Chicago
		DeKalb
		Des Plaines
		Downers Grove
		Naperville
		Schaumburg
		Skokie
		Gary
		Hoffman Estates
		Elgin
		Bolingbrook
Copenhagen	Greater Copenhagen	Copenhagen
		Lyngby
		Roskilde
		Herlev
		Frederiksberg
		Hvidovre
		Horsholm
		Ballerup

Appendix3 City scope

Dallas	Dallas-Fort Worth-Arlington, TX	Dallas
		University Park
		Arlington
		Richardson
		Denton
		Fort Worth
		Grapevine
		Plano
		Irving
Dublin	Greater Dublin	Dublin
		Maynooth
		Dun Laoghaire
Guangzhou	Guangzhou	Guangzhou
Hong Kong	Hong Kong	Hong Kong
London	Greater London	London
		Uxbridge
		Brentford
		Middlesex
		Kingston upon Thames
		Richmond
		Harrow
		Twickenham
		Romford
		Sutton
		Croydon
Los Angeles	Los Angeles-Long Beach-Anaheim, CA	Anaheim
		Arcadia
		Burbank
		Carson
		Claremont
		Cypress
		Costa Mesa
		Fountain Valley
		Fullerton
		Gardena
		Glendale
		Irvine
		Long Beach
		Los Angeles
		Newport Beach
		Orange
		Pasadena
		Riverside
		Santa Ana
		Santa Monica
		Thousand Oaks
		Torrance
		Tustin

Melbourne	Greater Melbourne	Melbourne
		Clayton
		Geelong
		Hawthorn
		East Melbourne
		Malvern
		Frankston
Munich	Munich Metropolitan Region	Munich
		Augsburg
		Neubiberg
		Planegg
		Gerlingen
		Freising
		Ottobrunn
New York	New York-Newark-Jersey City, NY-NJ	New York
		Newark
		New Brunswick
		Jersey City
		Lakewood
		White Plains
Paris	Greater Paris	Paris
		Gif-sur-Yvette
		Palaiseau
		Villejuif
		Orsay
		Versailles
		Saint-Denis
		Villetaneuse
		Le Kremlin-Bicetre
		Maisons-Alfort
		Boulogne-Billancourt
		Fontenay-aux-Roses
		Gentilly
		Bobigny
		Clichy
		Rueil-Malmaison
		Nanterre
		Suresnes
		Issy-les-Moulineaux
		Le Plessis-Robinson
		Clamart
		Colombes
		Garches
		Neuilly-sur-Seine
		Jouy-en-Josas
		Courbevoie
		Meudon
		Bondy
		Fontainebleau

Paris	Greater Paris	Ivry-sur-Seine
		Antony
		Cachan
San Diego	San Diego-Chula Vista-Carlsbad, CA	San Diego
		Carlsbad
		Chula Vista
		Encinitas
San Francisco	San Francisco-Oakland-Fremont, CA	San Francisco
		Berkeley
		Oakland
		Livermore
		Redwood City
		San Ramon
		San Mateo
		San Rafael
		Pleasanton
		Walnut Creek
		South San Francisco
		Fremont
Seattle	Seattle-Tacoma-Bellevue, WA	Seattle
		Redmond
		Tacoma
		Bellevue
		Bothell
		Renton
		Everett
		Auburn
		Kent
Seoul	Seoul Metropolitan Area	Seoul
		Suwon
		Seongnam
		Incheon
		Goyang
		Yongin
		Hwaseong
Shanghai	Shanghai	Shanghai
Shenzhen	Shenzhen	Shenzhen
Singapore	Singapore	Singapore
Stockholm	Metropolitan Stockholm	Stockholm
		Sodertalje
		Solna
		Danderyd
		Huddinge
Sydney	Greater Sydney	Sydney
		Callaghan
		Kensington
		Penrith
		Liverpool
		Parramatta

Sydney	Greater Sydney	North Ryde
		Bankstown
		Blacktown
		Mosman
Tokyo	Greater Tokyo Area	Tokyo
		Yokohama
		Chiba
		Hachioji
		Sagamihara
		Fuchu
		Mitaka
		Kawasaki
		Saitama
		Koganei
		Musashino
		Urayasu
		Matsudo
		Tachikawa
		Ichikawa
Toronto	Greater Toronto	Toronto
		Hamilton
		Oshawa
		Mississauga
		Markham
		Burlington
		Brampton
Washington D.C.	Washington-Arlington-Alexandria, DC-VA-MD-WV	Washington, D.C.
		Bethesda
		College Park
		Rockville
		Silver Spring
		Gaithersburg
		Greenbelt
		Fairfax
		Reston
		Falls Church
		Frederick
		North Bethesda
		Alexandria
		McLean
Zurich	Greater Zurich	Zurich
		Winterthur
		Birmensdorf
		Ruschlikon
		Wadenswil
		Baden
		Rapperswil
		Schlieren

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