THIRD APRA MONITORING REPORT 2021 -

Focus on India

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Scientific and technological activities in China

from a regional perspective

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Introduction

The Asia-Pacific region has developed very dynamically in science, research and innovation in recent years. This results in great opportunities for Germany, both scientifically and economically. In some cases, there is already intensive cooperation in science and technology, but in some cases these exchange relations are still less pronounced or have not followed the dynamics in the region over the past decade.

This results in new framework conditions for Germany that could make it necessary to adapt science, research or innovation policy. In order to record relevant development dynamics in the APRA region and compare them with those in established science and innovation nations, continuous monitoring of developments is necessary. In terms of evidence-based policy, it is essential for a large number of decision-makers to have comprehensive quantitative and qualitative information available to assess the situation. On the one hand, this is necessary to recognise the strengthening of possible competitors at an early stage, and on the other hand, and more importantly, to be able to identify opportunities for expanding existing partnerships and initiating new ones.

The German Federal Ministry of Education and Research (BMBF) has been monitoring the dynamic development of science, research and innovation in the Asia-Pacific Research Area for several years in order to be able to adequately adjust its own actions to new developments. The project "Monitoring the Asia-Pacific Research Area" is part of these activities and has already produced two detailed reports. On the one hand, this third report updates central observations of the previous publications, but on the other hand also expands them with additional, supplementary analyses.

This monitoring report on the Asia-Pacific Research Area (APRA) is the third in an annual series that aims both to produce scientifically sound findings and to inform policy makers about relevant developments. The Asia-Pacific Research Area is defined by the following countries [1]or scientific areas: Australia, China, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand and Vietnam. In addition to Germany, France, Canada, the United Kingdom and the USA are also examined for comparative purposes.

In the first chapter, the report addresses India's role as an emerging science and technology nation. Similar to the analyses on China in the first report of this series, the scope, orientation and current developments of India's scientific and technological activities are first quantitatively classified in order to create a framework for the following qualitative observations.

[1] The term "countries" in this context includes states, provinces and territories. It does not reflect the position of the federal government with regard to the status of a country or region.

In a second chapter, aspects of the effectiveness or efficiency of the transfer of academic knowledge to the economy are dealt with. Previous reports had shown that the countries of the APRA area were able to significantly increase their scientific activities. It remains to be seen, however, to what extent such activities can currently contribute to the economic-technological performance of economies that were historically characterised by external technology acquisition and–, for various reasons, –a decoupling of science and the economy. Although a considerable increase in patent activities can be observed, especially in China, opinions still differ about their technological content. In a first step, therefore, a general assessment of the efficiency level of the economies of the APRA -region is made, followed by considerations of the global relevance of patent activity in recent years. In the following, technology transfer systems and common processes of science-business cooperation are explained, as well as relevant programmes for their political promotion.

The third chapter focuses on the identification of regional and institutional focal points in scientific and technological activities, supplemented by a presentation of the functional significance of the regional level with regard to Chinese innovation policy and research and technology funding programmes, in which the activities of universities, research institutions and technology companies in China fit in or from which they benefit. This combination of a quantitative, topic-specific identification of central actors on the one hand and a differentiated analysis of the political control system at the regional level on the other hand identifies potential points of contact for future scientific and technological cooperation and at the same time shows the extent to which established impressions about the location of regional science and innovation dynamics in China are currently still true.

The fourth chapter of the report is devoted to the question of international cooperation between central APRA countries (China, Japan, Korea, Singapore), which has already been mentioned in some points in the two previous reports, but has not yet been analysed and presented in detail. In this context, one focus is on a comparative presentation of scientific and technological cooperation, which is supplemented by an examination of current exchanges in the field of science and higher education. This provides a basis for a multi-dimensional classification of the international integration of important Asian science systems.

Across almost all chapters, the report integrates quantitative-empirical contributions with qualitative explanations on the structure of the S&T systems of relevant APRA countries as well as corresponding strategies and measures on the part of policy-makers. From the combination of both, conclusions on the status quo and foreseeable developments in the respective thematic field are derived and analytically evaluated.

Chapter 3: Scientific and technological activities in China from a regional perspective

Compared to its considerable geographical size, China is a nation that is comparably homogeneous politically and institutionally. Nevertheless, due to its size, China shows considerable regional disparities in the area of economic, but also scientific and technological performance. These regional differences are the result of a multitude of parallel developments, some of which go back a long time. The scientific and technological rise of the southern province of Guangdong, which has been underway for about ten years, currently plays the most important role. Although the basic structures of the political control system of the provinces and also of the cities that are directly under government do not differ significantly in formal terms, the differences in the local starting conditions result in projects and policy measures that are very different in practice.

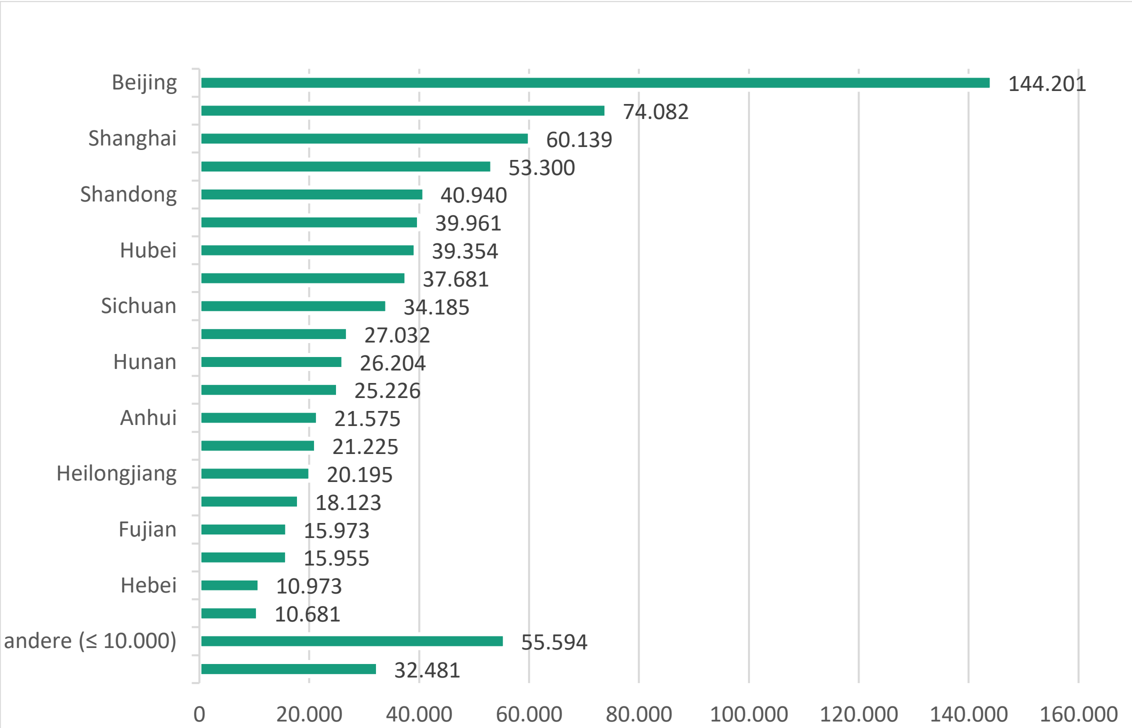
Traditionally, Beijing, and to a lesser extent Shanghai, Hangzhou and Wuhan, have been important academic centres in the country. Economic and technological activities, on the other hand, have been concentrated in the coastal provinces since the 1990s at the latest, with a particular focus on the Yangtze Delta in the hinterland of Shanghai, as well as Shenzhen and the Pearl River Delta in Guangdong. During the 1990s, 2000s and to some extent still the early 2010s, the three metropolitan areas of Beijing, Shanghai (Yangtze Delta) and Shenzhen (Pearl River Delta) formed the undisputed and almost exclusively relevant centres of the country in terms of innovation. Parallel to China's general scientific and technological development, however, not only has the base of relevant activities broadened in the last five to ten years, but so has their geographical distribution. Scientific and technological activities that could play a role in future cooperation activities with Germany, as well as political initiatives from which international partners could also benefit, can now be found in various locations that previously played little role from an international perspective.

With regard to future cooperation, it is therefore important both to identify current focal points of scientific and technological activities and to make clear which political decision-making bodies or implementing agencies of public-private projects could be important as potential contacts in this context. The following chapter addresses both questions in two successive sections that build on each other.

Regional structure of the Chinese science system

The Chinese science system has traditionally been heavily concentrated in Beijing, especially with regard to non-university research (see Figure 41). Although its role has declined somewhat over time, Beijing authors were still involved in around a quarter of all scientific publications in China in 2019. Secondary centres at a considerable distance are Jiangsu with about 13%, Shanghai with about 10%, and Guangdong with about 9.2%. These are followed at a further level by Shandong (7.0%), Shaanxi (6.9%), Hubei (6.8%), Zhejiang (6.5%), and slightly behind Sichuan (5.9%). Other relevant publication locations are the provinces of Liaoning (4.7%), Hunan (4.5%), Tianjin (4.3%), Anhui (3.7%), Henan (3.7%), and Heilongjiang (3.5%), as well as, at an already noticeably lower level, Fujian (2.7%), Jilin (2.7%), Hebei (1.9%) and Jiangxi (1.8%). In all other provinces, the annual publication output was less than 10,000 publications, barely a fifteenth of the level in Beijing.

Figure 1: Publication volume of Chinese provinces, 2019

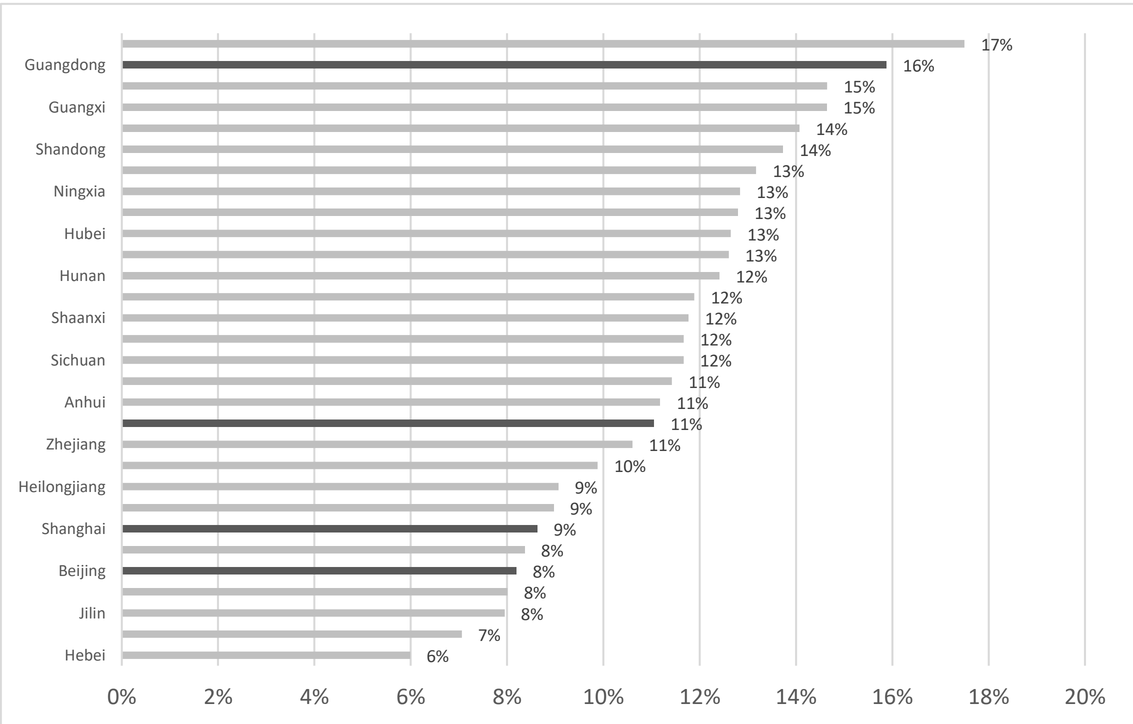


Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

As Figure 42 and Figure 43 shows, the relative importance of the individual provinces for the Chinese innovation system has remained nearly stable over the last fifteen years. The most significant relative changes are a continuous increase in Jiangsu's importance and the increase in Guangdong's importance - due to dedicated expansion activities - from around 2015/16. Shandong and Sichuan have also seen significant relative increases in importance, as have Shaanxi, Zhejiang, Tianjin, Hunan and Henan to a lesser extent in absolute terms. In Hubei, there is a return to the levels of the mid-2000s, after a relative decline in the late 2000s. Chongqing, albeit at a low level, already achieved a significant gain in importance at the end of the 2000s and consequently continued to develop gradually positively, as did many other provinces. In contrast, traditional locations in the northeast such as Liaoning, Heilongjiang and Jilin, but also Hebei since the beginning of the 2010s, have lost relative importance in recent years.

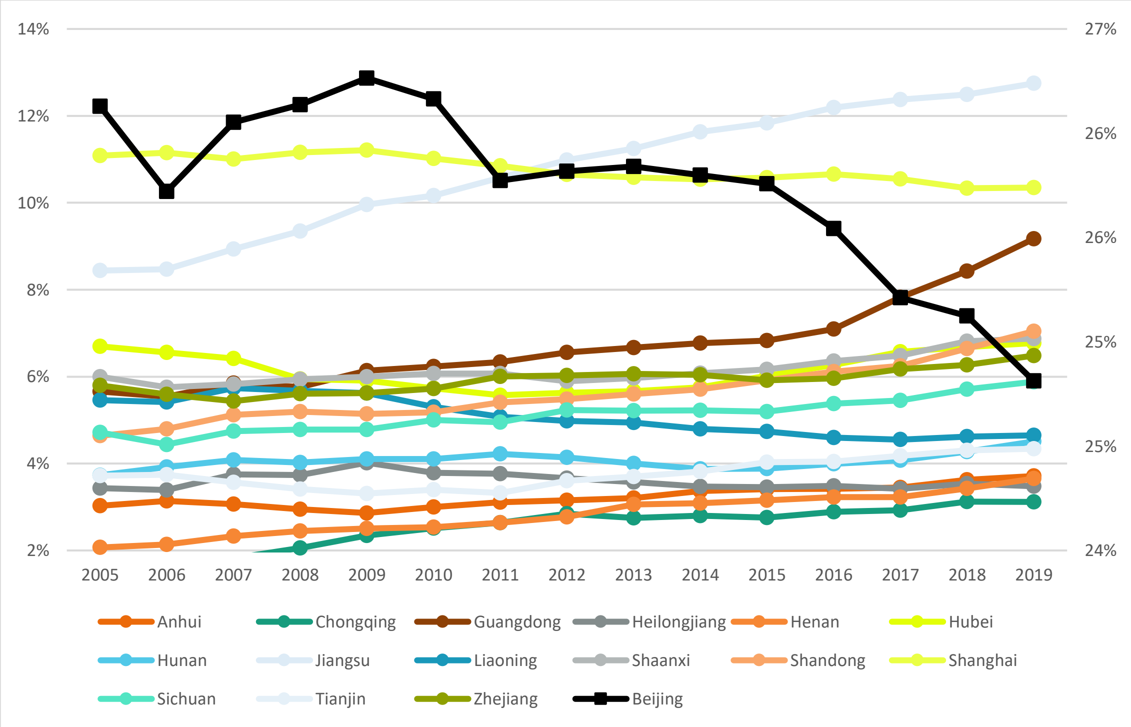
In the overall view, these gradual positive developments in many places lead to a gradual, relative decline in the importance of Beijing and Shanghai. However, authors from Beijing and Shanghai are still involved in many publications by authors from developing locations. Empirical evidence of this can be found in the fact that while the share of Beijing authors in all publications has remained almost stable at 25-26% since 2005, Beijing's share of all authorships has fallen from 23% to 17% since then. This means that, in relative terms, more and more authorships are being added from outside Beijing and Shanghai. But these publications in which no author from Beijing or Shanghai is involved do not have a higher relative weight.This shows that, although the role of the academic centres is unbroken, more and more external authors are becoming involved in the activities there.

Figure 2: Mean annual growth in publication volume of Chinese provinces, 2014-19



Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure 3: Publication volume of Chinese provinces over time



Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Even when differentiated by topic, the ranking of the provinces does not differ significantly. Although there are certainly different degrees of regional concentration of publications in the area of the classic six key technologies[2], there are usually no significant deviations in the ranking of the locations. In all cases, the three leading provinces are Beijing, Jiangsu and Shanghai, followed by the provinces of Guangdong, Shaanxi, Shandong, Hubei, Sichuan and Zhejiang. Large scientific locations thus generally play a comparably central role in all technology areas, while more specific profiles are found primarily in provinces that are less significant overall.

This gradual but not fundamental weakening of the concentration of scientific activities is also reflected in the geographical distribution of China's central scientific publishing organisations. Among the top 25, five, and among the top 100, 17 organisations are based in Beijing. This is followed (among the top 100) by Jiangsu with 16 organisations, Shanghai with eight organisations, Guangdong and Hubei with seven each, Hong Kong and Sichuan with five each, and Shaanxi and Shandong with three leading organisations each.

2 The regional GINI coefficient ranges from 0.499 to 0.586, with three leading provinces accounting for between 31% and 38% of all publications.

Table 1: Top 5 publication locations in the six key technologies

Industrial Biotechnology	**Nano-technology**	**Micro- and Nanoelectro-nics**	**Photonics**	**New Materials**	**Advanced Manufacturing**
Beijing	**Beijing**	**Beijing**	**Beijing**	**Beijing**	**Beijing**
Jiangsu	**Jiangsu**	**Jiangsu**	**Jiangsu**	**Jiangsu**	**Jiangsu**
Shanghai	**Shanghai**	**Shanghai**	**Shanghai**	**Shanghai**	**Shanghai**
Guangdong	**Guangdong**	Shaanxi	**Guangdong**	Shaanxi	Shaanxi
Shandong	Shaanxi	Guangdong	Hubei	**Guangdong**	Zhejiang
Zhejiang	Hubei	Hubei	Shaanxi	Hubei	Liaoning
Hubei	Sichuan	Liaoning	Zhejiang	Sichuan	**Guangdong**
Tianjin	Zhejiang	Sichuan	Sichuan	Shandong	Hubei
Sichuan	Shandong	Zhejiang	Tianjin	Zhejiang	Shandong
Shaanxi	Liaoning	Shandong	Hunan	Liaoning	Tianjin

Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Analysis of key actors and their geographical distribution

A SCOPUS-based ranking of the most scientifically publishing organisations underlines Beijing, Shanghai and Jiangsu's leading position in the science system. Among the institutions with the most publications in absolute terms are the Graduate University of the Chinese Academy of Sciences (UCAS), with nearly 59,000 publications in 2017-19, followed by the CAS Institute of Geology and Geophysics and Tsinghua University, each with about 36,000 publications. Shanghai Jiaotong University is in third place with around 30,000 publications, followed by Harbin Institute of Technology, Peking University (BeiDa), Sun Yat-Sen University, Central South University, Tianjin University, Fudan University, Xi'an Jiaotong University, University of Science and Technology of China, Zhejiang University, Wuhan University and Jilin University with between around 20,000 and around 24,000. A detailed overview of the top 100 publishing organisations can be found in the annex in Figure A9

If we look at the impact or academic visibility instead of the absolute number of publications, (i.e. the extent to which a university's publications are cited by other publications), there are again 17 institutions from Beijing in the top 100, but only three in the top 20 (Beijing University of Chemical Technology, Peking University, Tsinghua University). This means that the top 25 includes more leading organisations from Hong Kong (HK University of Science and Technology, City University of HK, Chinese University of HK, HK Polytechnic University) and now also from Guangdong (Shenzhen University, Guangdong University of Technology, South China University of Technology, Sun Yat-Sen University). Other leading organisations in terms of academic visibility of their publications are Shandong University of Science and Technology, Hunan University, Nankai University (Tianjin), Soochow University (Jiangsu), University of Electronic Science and Technology of China (Sichuan), Nanjing University (Jiangsu), University of Science and Technology of China (Anhui), Wuhan University of Technology (Hubei), Huazhong University of Science and Technology (Hubei), Fuzhou University (Fuzhou), and Fudan University (Shanghai). Almost all of the top 100 universities are above the international reference value of 1.0; almost all of the top 25 universities achieve values above 1.5. Only the Shandong University of Science and Technology and the Hong Kong University of Science and Technology achieve values above 2.0. An overview of the top 100 organisations in terms of the academic visibility of their publications can be found in the annex.

To complement the SCOPUS-based ranking of internationally visible institutions, a supplementary analysis was carried out based on Chinese Wanfang data, differentiated according to selected subject areas.

It is interesting to note that, in terms of absolute numbers, institutions outside Beijing also play a central role. Among the top 10 institutions, only four - Peking University, Tsinghua University, Renmin University and Beijing Normal University - are from Beijing, and Tongji is another from Shanghai, while the others are spread across central academic centres: Wuhan University (Hubei), Sichuan University, Zhejiang University, Jilin University and Nanjing University (Jiangsu). Furthermore, no university from Guangdong is in the top 10 (the first is Sun Yat-Sen University at 33rd place).

The general concentration measures also vary between Gini coefficients[3] of over 0.40 for aerospace, military studies and nuclear energy and those of below or barely above 0.20 for humanities, computer technology, general, industrial engineering, physics, and environmental sciences. Values of 0.25 are also not exceeded in the social sciences, medicine and agricultural sciences.

Another perspective on the regional distribution of centres of scientific productivity is provided by the evaluation of university rankings. Such an analysis was carried out for the QS ranking of 2020, differentiated according to subject disciplines.

[3] The Gini coefficient is a measure of the concentration of activities over sub-elements of an aggregate.
can be mapped. If there is maximum concentration in only one area, it is 1; if there is perfect uniformity, it is 0.

Table 2: Regional distribution of institutions ranked among the world's top 100 or 500 universities for at least one of the five subject groups in the 2020 QS University Rankings

Province	Number of HS in ranking HS 1-500	Number of HS ranked 1-100
Anhui	1	1
Hubei	3	1
Hunan	2	
Beijing	11	2
Fujian	1	
Guangdong	2	
Hong Kong	7	5
Jiangsu	5	1
Macau	1	
Shandong	1	
Shanghai	7	2
Tianjin	2	
Zhejiang	1	1
Heilongjiang	1	
Jilin	1	
Liaoning	3	
Gansu	1	
Shaanxi	1	1
Sichuan	2	

Source: Fraunhofer ISI calculations from available data of the QS World University Rankings by Subject 2020, https://www.topuniversities.com/subject-rankings/2020

The largest number of universities ranked in the world's top 500 for at least one subject group is in Beijing, followed by Shanghai, Hong Kong and Jiangsu, all provinces in the eastern region. Looking only at the institutions that are counted among the top 100 worldwide, Hong Kong clearly leads with five universities, followed by Beijing and Shanghai with two universities each and Jiangsu with one university. The comparatively high publication strength of Guangdong Province is not reflected in this parameter. More differentiated evaluations of rankings of Chinese universities in the individual disciplines can be found in the annex (Annex III: Table A1).

Particularly high-performing institutions that belong to the top 100 for at least three of the five subject groups are mainly found in Hong Kong (three), as well as in Beijing and Shanghai (two each). The only other institution that meets these requirements is also in the eastern region, in Zhejiang province. Outside the eastern region, there are only a few provinces that have at least one university that ranks among the top 500 for at least one of the subject groups. Notable for the central region are the provinces of Hubei with three and Hunan with two institutions, in the north-eastern region the province of Liaoning with three and in the western region the province of Sichuan with two institutions.

Outside the provinces of Beijing, Shanghai, Hong Kong and Jiangsu, there are only a few provinces with universities that are counted among the top 100 for at least one of the subject areas.

Of particular note is the University of Science and Technology of China in Anhui Province, which is very well positioned for natural sciences and for engineering and technology. Two other institutions meet this criterion at least for the subject group engineering and technology: Huazhong University of Science and Technology in Hubei Province and Xi'an Jiaotong University in Shaanxi Province.

Table 3: Central publishing institutions by subject area based on SCOPUS data, 2017-19

	Total	Industrial BioTech	NanoTech	Micro-/Nano-electronics	Photonics	Advanced Materials	Adv Manuf Technologies	Life Sciences	Pandemic
1	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chinese Academy of Sciences	Chin Center for Disease Ctrl & Prev
2	Graduate University of CAS	Graduate University of CAS	Graduate University of CAS	Graduate University of CAS	Huazhong University of S&T	Graduate University of CAS	Shanghai Jiaotong University	Graduate University of CAS	Fudan University (Shanghai)
3	Tsinghua University	Jiangnan University (Jiangsu)	Harbin Institute of Technology	Tsinghua University	Graduate University of CAS	Tsinghua University	Harbin Institute of Technology	Fudan University (Shanghai)	Chinese Academy of Sciences
4	Zhejiang University	Zhejiang University	Tsinghua University	Harbin Institute of Technoogy	Beijing University of Posts and Telec	Harbin Institute of Technology	Zhejiang University	Zhejiang University	Chinese Acad of Agric Sciences
5	Shanghai Jiaotong University	Chinese Acad of Agric Sciences	Shanghai Jiaotong University	Shanghai Jiaotong University	Shenzhen University	Central South Univ (Changsha)	Tsinghua University	Sun Yat-Sen University	Sun Yat-Sen University
6	Sichuan University	Tsinghua University	Xi'an Jiaotong University	Xi'an Jiaotong University	Zhejiang University	University of S&T of China	Huazhong University of S&T	Sichuan University	Zhejiang University
7	Huazhong University of S&T	Nanjing Agric University	Zhejiang University	Huazhong University of S&T	Shanghai Jiaotong University	University of S&T Beijing	Tianjin University	Shanghai Jiaotong University	University of Hong Kong
8	Central South Univ (Changsha)	Shanghai Jiaotong University	Central South Univ (Changsha)	Zhejiang University	Beijing University	Zhejiang University	Northw Polytech University (Xi'an)	Huazhong University of S&T	Yangzhou University
9	Beijing University	China Agric University	Sichuan University	Central South Univ (Changsha)	Univ of Electr S&T of China (Chengdu)	Shanghai Jiaotong University	Chongqing University	Central South Univ (Changsha)	Capital Med University
10	Fudan University (Shanghai)	Northwest A and F University	South China University of Tech	Beijing Inst of Technology	Nanjing University	South China University of Tech	Beijing Univ of Aero and Astro	Capital Med University	Beijing Union Med College
11	Harbin Institute of Technology	East China University of S&T	Huazhong University of S&T	Northeastern University	Tsinghua University	Tianjin University	Graduate University of CAS	Zhengzhou University	Sichuan University
12	University of S&T of China	Sichuan University	Dalian University of Technology	Tianjin University	Sun Yat-Sen University	Huazhong University of S&T	Nanjing University of Aero and Astro	Shandong University	S China Agric Univ (Guangzhou)
13	Wuhan University	Tianjin University	Tianjin University	Chongqing University	Nankai University (Tianjin)	Northw Polytech University (Xi'an)	Dalian University of Technology	Chinese Acad of Agric Sciences	Huazhong Agric University
14	Sun Yat-Sen University	Huazhong Agric University	Jilin University	Dalian University of Technology	University of S&T of China	Sichuan University	Northeastern University	Beijing University	South Med Univ (Guangzhou)
15	Tianjin University	Fudan University (Shanghai)	University of S&T of China	Beijing University of Aero and Astro	Nanjing University of Aero and Astro	Xi'an Jiaotong University	China University of Petroleum	Nanjing Med University	Acad of Military Med Sciences
16	Xi'an Jiaotong University	Jilin University	University of S&T Beijing	University of S&T of China	Tianjin University	Jilin University	South China University of Tech	SH Jiaotong Univ School of Med	Shandong University
17	Jilin University	Sun Yat-Sen University	Shandong University	Nanjing University of Aero and Astro	Yanshan University (Hebei)	Peking University	University of S&T Beijing	Beijing Union Med College	Guangzhou Med College
18	Shandong University	Ministry of Agriculture	Wuhan University of Technology	Shandong University	Nanjing University of Posts and Telec	Southeast Univ (Nanjing)	Central South University	South Med Univ (Guangzhou)	Graduate University of CAS
19	Tongji University	Beijing University	Chongqing University	Sth Ch Univ of Tech (Guangzhou)	Fudan University (Shanghai)	Beijing University of Aero and Astro	Beijing Institute of Technology	Wuhan University	China Agricultural University

Source: Fraunhofer ISI calculations based on Elsevier SCOPUS.

Table 4: Central publishing institutions by subject area based on Wanfang data, 2014-18 (I)

	TOTAL Wanfang	**Aeronautics and Aerospace**	**Agricultural Science**	**Arts and Humanties**	**Astronomy and Geology**	**Atomic Energy Technology**	**Basic chemistry**	**Biology**	**Biotechnology**	**Chemical Engineering**	**Computer Technology**
1	Wuhan University	Nanjing University of Aero & Astro	Northwest A&F University	Beijing Normal University	Chengdu University of Technology	Nuclear Power Inst of China	Jilin University	Northwest A&F University	Jiangnan University	Qingdao University of S&T	Wuhan University
2	Renmin University of China	Beihang University	China Agricultural University	Shaanxi Normal University	China Univ of Geosciences, Beijing	China Inst of Atomic Energy	Sichuan University	Beijing Forestry University	Northwest A&F University	Beijing University of Chem Techn	Nanjing University of Posts & Telec
3	Sichuan University	Northwestern Polytechnical University	Nanjing Agricultural University	Nanjing Normal University	Wuhan University	Tsinghua University	East China University of Science	Northeast Forestry University	Academy of Military Medical Sciences PLA	East China University of Science	Nanjing University of Aero & Astro
4	Peking University	Shanghai Aircraft Design and Res Inst	Hunan Agricultural University	Wuhan University	China University of Geosciences, Wuhan	China Nuclear Power Engineering	Zhejiang University	Southwest University	Sichuan University	South China University of Technology	Sichuan University
5	Tsinghua University	Civil Aviation University of China	South China Agricultural University	Central China Normal University	Nanjing University of Information S&T	China Academy of Engineering Physics	Tianjin University	South China Agricultural University	Guangxi University	Sichuan University	Shanghai University of Technology
6	Zhejiang University	Air Force Engineering University	Northeast Agricultural University	East China Normal University	Jilin University	Nuclear and Radiation Safety Center of the MEE	University of S&T of China	Guizhou University	Jilin Agricultural University	Tianjin University	Tongji University
7	Beijing Normal University	Chinese Flight Test Establishment	Agricultural University of Hebei	He'nan University	Ocean University of China	Shanghai Inst of Applied Physics, CAS	Changchun Inst of Applied Chemistry, CAS	Fujian Agriculture And Forestry University	Fujian Agriculture and Forestry University	Nanjing University of Technology	National University of Defense Technology
8	Jilin University	Harbin Inst of Technology	Gansu Agricultural University	Southwest University	Chang'an University	University of South China	Tsinghua University	Nanjing Agricultural University	Northeast Agricultural University	Jiangnan University	Northwestern Polytechnical University
9	Tongji University	National University of Defense Technology	Shandong Agricultural University	Sichuan University	Information Engineering University	University of S&T of China	South China University of Technology	Agricultural University of The Inner Mongol	Tianjin University of S&T	Liaoning Shihua University	Tsinghua University
10	Nanjing University	China Aerodynamics R&D Center	Xinjiang Agricultural University	Peking University	Chinese Academy of Geological Sciences	Harbin Engineering University	Beijing University of Chemical Technology	Zhejiang University	Hunan Agricultural University	Donghua University	Information Engineering University

Source: Analyses by ISTIC (China), processed by Fraunhofer ISI, based on Wanfang data.

Table 5: Central publishing institutions by subject area based on Wanfang data, 2014-18 (II)

	Crystallography	**Environmental Science and Safety Science**	**Mathematics**	**Medicine and Health Care**	**Military Affairs**	**Organic Chemistry**	**Other Industrial Technology**	**Pharmacy**	**Physics**	**Social Sciences**	**Transportation**
1	Shandong University	Chinese Res Academy of Environmental Sciences	Northwest Normal University	The PLA General Hospital	Academy of Military Sciences PLA	Guizhou University	Tongji University	Zhejiang University of Technology	Tsinghua University	Renmin University of China	Southwest Jiaotong University
2	Hebei University of Technology	Tongji University	Shaanxi Normal University	West China Hospital of Sichuan Univ	National Univ of Defense Technology	Zhejiang University of Technology	Tsinghua University	Harbin Pharmaceutics Group Gene Factory	University of S&T of China	Wuhan University	Chang'an University
3	Shanghai University	Tsinghua University	Anhui Normal University	Beijing University of TCM	Academy of Military Transportation	Sichuan University	Tianjin University	Harbin Sanlian Pharma-ceutical	Beijing Inst of Technology	Peking University	Tongji University
4	Shanghai Institute of Ceramics, CAS	Hohai University	Yan'an University	1st Affiliated Hospital of Zhengzhou University	National Defence University of the PLA	Changzhou University	Chongqing University	China Medicine University	Shanghai Jiao Tong University	Zhongnan University of Economics and Law	Chongqing Jiaotong University
5	Chongqing University	Xi'an University of Architecture & Technology	Southwest University	Tianjin University of TCM	Air Force Engineering University	East China University of Science	Shanghai Jiao Tong University	Jiangnan University	Dalian University of Technology	Nankai University	Wuhan University of Technology
6	Sichuan University	Research Centre for Eco-Environ Sciences, CAS	Xinjiang University	Chengdu University of TCM	Naval University of Engineering	Tianjin University	South China University of Technology	Xian Medical College	Nanjing University of S&T	Chinese Academy of Social Sciences	Beijing Jiaotong University
7	Northwestern Polytechnical University	Beijing Normal University	Northwest University	Shandong TCM University	PLA Nanjing Institute of Politics	He'nan University	University of S&T Beijing	Qingdao University of S&T	Northwestern Polytechnical University	Anhui University of Finance and Economics	China Railway Research Inst Group
8	Harbin Inst of Technology	Liaoning Technical University	Sichuan Normal University	Beijing Union Medical Coll Hospital	PLA Equipment College	Nanjing University of Technology	Central South University	East China University of Science	Peking University	Nanjing University	Changsha University of S&T
9	Ningbo University	Harbin Inst of Technology	Anhui University	Nanjing University of TCM	Xi'an Politics Institute of the PLA	Nankai University	North China Electric Power University	Harbin Pharma Group Sanjing Pharma	Tianjin University	Jilin University	Anhui Jianghuai Automobile
10	Tsinghua University	Nanjing University	Zhejiang Normal University	1st Affiliated Hospital of Xinjiang Medical Univ.	Engineering University of the PAP	Zhejiang University	Zhejiang University	Tianjin University	Xi'an Jiaotong University	East China University of Political Science & Law	China Railway Siyuan Survey & Design Group

Source: Analyses by ISTIC (China), processed by Fraunhofer ISI, based on Wanfang data.

Analysis of the global cooperation patterns of Chinese provinces

Based on Wanfang data[4], the orientation of the international cooperation behaviour of individual provinces can be analytically assessed. These include not only publications from Elsevier SCOPUS, but also other relevant sources of academic publications[5].

Table 6 clearly shows that although Beijing is the central contact point for all of China's partner countries, the degree of concentration varies considerably. For example, only about 21% of all collaborations involve actors from Beijing, while this is the case in 37% of all collaborations with Germany and even 41% of all collaborations with Italy. With the exception of France, the Netherlands, Israel and Norway, cooperation partners from Europe and America usually have a higher degree of concentration on Beijing (32% to 41%) than countries in the APRA region and Russia (25% to 29%). A particularly low degree of concentration is found for Singapore with only about 21%. Beyond Beijing, almost all countries cooperate with Shanghai and Jiangsu in second and third place, in varying order. Only Russia has a completely different profile, with a focus on the regions bordering its own territory, Jilin and Heilongjiang. The profile of cooperation with Israel is also rather different, with focal points beyond Beijing in Heilongjiang (9%), Jilin, Guizhou, Shaanxi and Xinjiang (5% each). India and Singapore also have above-average cooperation with Sichuan, and Mexico with Liaoning, Shaanxi and Yunnan (7% each). The proportionally strongest focus on Shanghai is found in Norway (22%), New Zealand (21%) Brazil (18%), the weakest with Russia, Singapore, Canada, Switzerland and Italy. The strongest focus on Jiangsu is found in Italy (15%), Brazil (14%), as well as the Netherlands and Singapore (13%). Cooperation with the academically still developing province of Guangdong plays the greatest role for France, the Netherlands and Denmark (6%), as well as Singapore. The proportionally strongest cooperation with the traditional science location of Hubei (Wuhan) is found for Denmark and India (9% each) as well as Brazil (8%) and Singapore (7%). Those with the traditional science location of Zhejiang (Hangzhou) are found for the Netherlands (9%), as well as Brazil and Singapore (8% each).

A regional classification of the cooperation between German and Chinese scientists and scholars is also possible using data from the Deutsche Forschungsgemeinschaft (DFG). The regional distribution of collaborations based on formal agreements and referred to in DFG proposals by German applicants was recorded.

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[4] *Wanfang Data* is a fee-based portal for scientific and statistical data affiliated with the Chinese MOST. The analyses cited here were carried out in cooperation with the Institute of Scientific and Technical Information (ISTIC), Beijing.

[5] It provides access to approx. 45 million journal articles, 3.84 million dissertations, 2.98 million conference papers, 77 modules of statistical figures since 1950, experts, institutions, 160 million patents, 1.83 million standards and data on research projects (www.wanfangdata.com).

As with other parameters, the city of Beijing plays a central role in terms of scientific cooperation partners. This is particularly high for the humanities, where a good 79% of cooperation partners come from Beijing. For the other subject groups, the proportion is somewhat lower for Beijing (60.3% to 63.2%), and the differences between natural sciences, engineering sciences and life sciences are small. All other provinces are far less likely to provide cooperation partners for German researchers. The number is above 3% only for a few provinces. For the natural sciences it is Jiangsu (8.9%), Shanghai (6.0%) and Hubei (3.6%). For engineering, it is Shanghai (7.9%), Jiangsu (7.4%), Guangdong (3.9%) Zhejiang (3.4%) and Liaoning (3.0%), for life sciences it is Shanghai (8.8%), Hubei (7.3%) and Jiangsu (3.6%). For the humanities, it is Fujian (6.3%), Hong Kong [6](4.2%) and Jiangsu (4.2%).

In terms of the destinations of German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD) funded conference attendance, the numbers for Shanghai (34) and Beijing (31) are also particularly high, but the dominant conference venue is Hong Kong (51 conferences). A comparatively high number of conferences for which funding was approved took place in the provinces of Shaanxi (11), Zhejiang (10) and Hubei (8). Grantees from the natural sciences and engineering (by far the largest group) overwhelmingly attended conferences in the eastern region (especially Hong Kong and Beijing). A certain concentration on destinations outside the eastern region is only found in the engineering sciences. Just under 16 % of the engineering science grantees attended conferences in Shaanxi Province (see Table 8).

6 When classifying the comparatively low numbers for Hong Kong, it should be taken into account that the majority of collaborations are the result of joint calls for proposals with the NSFC (National Natural Science Foundation of China), for which only applicants from mainland China are eligible to apply.

Table 6 : Share of Chinese provinces in international scientific cooperation activities, 2014-18

	AU	AT	BR	CA	DK	FR	EN	IN	IL	IT	JP	MX	NL	NZ	NO	RU	SG	SE	CH	UK	US	TOT
Beijing	25,8%	39,8%	32,7%	32,0%	34,7%	28,5%	37,0%	28,0%	26,8%	40,7%	23,5%	36,4%	28,8%	25,7%	28,6%	27,2%	20,9%	35,2%	37,4%	35,4%	34,9%	32,3%
Anhui	1,6%	0,0%	0,0%	3,0%	1,2%	3,3%	2,3%	3,7%	3,6%	3,3%	1,3%	2,3%	0,6%	1,1%	0,0%	1,3%	1,5%	1,4%	4,6%	0,7%	1,8%	1,7%
Chongqing	2,9%	0,0%	0,0%	2,5%	1,7%	0,8%	2,6%	1,2%	3,6%	0,8%	2,2%	2,3%	3,9%	3,2%	3,4%	0,0%	3,0%	1,0%	1,5%	2,3%	1,7%	2,0%
Fujian	1,3%	0,0%	0,0%	1,9%	1,7%	1,3%	0,7%	3,7%	0,0%	1,2%	1,2%	2,3%	1,2%	1,6%	0,0%	0,5%	3,3%	2,9%	1,5%	1,1%	1,5%	1,4%
Gansu	1,1%	1,0%	0,0%	1,5%	0,0%	0,0%	0,6%	1,2%	0,0%	0,0%	0,8%	2,3%	1,2%	1,6%	0,7%	3,4%	0,5%	1,0%	0,8%	0,6%	0,9%	0,9%
Guangdong	3,6%	2,0%	2,0%	4,4%	5,8%	6,4%	2,3%	0,0%	0,0%	4,1%	3,2%	2,3%	5,7%	1,1%	2,0%	0,8%	4,8%	3,8%	3,1%	3,9%	4,3%	3,9%
Guangxi	1,0%	0,0%	0,0%	0,2%	0,6%	0,5%	0,2%	0,0%	0,0%	0,0%	0,4%	0,0%	0,3%	1,1%	0,7%	0,0%	0,5%	0,0%	0,8%	0,4%	0,5%	0,4%
Guizhou	1,4%	0,0%	0,0%	0,2%	0,6%	0,2%	0,2%	0,0%	5,4%	2,0%	0,6%	0,0%	0,0%	0,0%	0,7%	0,3%	0,0%	1,4%	0,8%	0,3%	0,3%	0,4%
Hainan	0,0%	0,0%	2,0%	0,0%	0,6%	0,2%	0,1%	0,0%	0,0%	0,4%	0,4%	0,0%	0,0%	0,0%	0,0%	0,0%	0,8%	0,0%	0,0%	0,0%	0,1%	0,1%
Hebei	0,7%	0,0%	0,0%	0,6%	0,0%	0,2%	0,7%	0,0%	1,8%	0,0%	0,7%	0,0%	0,0%	0,5%	0,0%	0,0%	0,3%	0,0%	1,5%	0,5%	0,4%	0,4%
Heilongjiang	1,7%	1,0%	6,1%	2,1%	4,0%	1,4%	1,2%	1,2%	8,9%	1,2%	3,9%	0,0%	0,6%	1,6%	0,0%	10,8%	1,7%	0,5%	1,5%	1,9%	1,6%	2,0%
Henan	1,2%	1,0%	2,0%	1,0%	1,2%	0,3%	1,0%	0,0%	0,0%	0,0%	1,6%	2,3%	0,9%	1,1%	2,0%	1,1%	1,3%	8,1%	1,5%	1,5%	1,2%	1,3%
Hubei	6,3%	5,1%	8,2%	5,7%	8,7%	4,8%	5,0%	8,5%	3,6%	4,1%	4,2%	4,5%	6,3%	2,1%	6,8%	4,7%	7,3%	5,7%	3,8%	5,8%	5,9%	5,7%
Hunan	3,4%	0,0%	2,0%	2,2%	1,2%	2,4%	2,3%	1,2%	0,0%	1,2%	1,5%	0,0%	0,3%	3,7%	0,7%	0,3%	1,8%	2,9%	1,5%	1,9%	1,7%	1,9%
In Mongolia	0,2%	1,0%	0,0%	0,4%	0,0%	0,0%	0,2%	0,0%	0,0%	0,0%	0,5%	0,0%	0,0%	0,0%	0,0%	0,3%	0,2%	0,0%	0,0%	0,0%	0,1%	0,1%
Jiangsu	12,0%	10,2%	14,3%	7,1%	9,8%	11,4%	5,5%	12,2%	3,6%	15,4%	11,4%	2,3%	13,2%	6,4%	11,6%	3,7%	12,9%	9,0%	7,6%	8,9%	9,1%	9,4%
Jiangxi	0,4%	0,0%	0,0%	1,0%	1,2%	0,2%	0,1%	0,0%	0,0%	0,0%	0,1%	0,0%	0,9%	0,5%	0,0%	0,0%	0,5%	0,0%	0,0%	0,5%	0,3%	0,3%
Jilin	1,3%	2,0%	0,0%	2,5%	1,2%	2,4%	1,8%	1,2%	5,4%	0,4%	4,7%	2,3%	1,8%	3,2%	2,0%	17,7%	1,5%	0,5%	1,5%	1,8%	2,3%	2,6%
Liaoning	3,3%	0,0%	0,0%	2,8%	2,3%	1,7%	1,4%	3,7%	0,0%	2,4%	5,5%	6,8%	1,8%	3,7%	0,7%	3,7%	2,7%	1,9%	1,5%	2,9%	2,3%	2,7%
Ningxia	0,1%	0,0%	0,0%	0,2%	0,0%	0,0%	0,0%	0,0%	3,6%	0,0%	0,3%	0,0%	0,0%	1,6%	0,0%	0,3%	0,0%	0,0%	0,0%	0,0%	0,1%	0,1%
Shaanxi	3,7%	12,2%	0,0%	4,8%	1,7%	5,6%	4,6%	2,4%	5,4%	2,4%	4,4%	6,8%	3,3%	2,7%	3,4%	2,4%	5,0%	1,9%	3,8%	2,8%	4,3%	4,1%
Shandong	2,2%	1,0%	2,0%	2,1%	1,2%	1,9%	3,1%	3,7%	3,6%	2,8%	3,0%	0,0%	3,3%	7,5%	4,1%	4,7%	1,5%	1,4%	5,3%	1,9%	2,6%	2,6%
Shanghai	11,0%	12,2%	18,4%	8,9%	12,1%	15,1%	15,9%	9,8%	12,5%	9,3%	13,3%	13,6%	11,1%	21,4%	21,8%	7,9%	8,8%	9,5%	9,2%	11,8%	11,6%	11,9%
Shanxi	1,7%	0,0%	0,0%	1,4%	0,6%	0,2%	0,6%	0,0%	0,0%	0,0%	1,3%	2,3%	1,5%	1,1%	0,0%	0,5%	1,2%	0,5%	0,0%	1,4%	1,0%	1,1%
Sichuan	3,8%	4,1%	2,0%	4,8%	2,3%	3,3%	3,0%	8,5%	3,6%	4,5%	3,4%	4,5%	2,4%	2,7%	2,7%	1,6%	7,5%	3,3%	4,6%	3,5%	3,3%	3,6%
Tianjin	2,1%	4,1%	0,0%	2,4%	2,3%	2,5%	0,7%	1,2%	0,0%	1,6%	2,8%	0,0%	1,5%	0,0%	3,4%	0,3%	2,5%	1,9%	0,8%	2,6%	1,2%	1,7%
Xinjiang	0,3%	0,0%	0,0%	0,2%	0,6%	1,0%	0,8%	1,2%	5,4%	1,2%	0,7%	0,0%	0,0%	1,1%	0,0%	3,2%	0,3%	2,4%	1,5%	0,4%	0,2%	0,5%
Yunnan	0,3%	1,0%	0,0%	0,6%	0,6%	0,8%	0,7%	3,7%	0,0%	0,0%	0,4%	6,8%	0,3%	2,1%	0,0%	0,5%	0,2%	0,0%	0,0%	1,0%	0,6%	0,6%
Zhejiang	5,4%	2,0%	8,2%	3,6%	2,3%	3,8%	5,2%	3,7%	3,6%	0,8%	2,7%	0,0%	9,0%	1,6%	4,8%	2,9%	7,6%	3,8%	3,8%	4,1%	4,1%	4,1%
TOTAL	1429	98	49	1256	173	629	1092	82	56	246	1832	44	333	187	147	379	603	210	131	2308	8791	20075

Note: slight distortions due to double counting of interregional co-publications possible.

Source: Analyses by ISTIC (China), processed by Fraunhofer ISI, based on Wanfang data.

Table 7: Regional distribution of formally agreed collaborations mentioned in DFG proposals by German applicants

	Natural sciences		**Engineering**		**Life Sciences**		**Humanities**	
	(302 cooperations)		**(203 cooperations)**		**(193 cooperations)**		**(48 cooperations)**	
Province	Rank	Share	Rank	Share	Rank	Share	Rank	Share
Anhui	5	2.6%			11	1.0%		
Henan	17	0.3%			14	0.5%		
Hubei	**4**	**3.6%**	9	1.5%	**3**	**7.3%**		
Hunan	17	0.3%	11	1.0%	7	1.6%	5	2.1%
Jiangxi	17	0.3%			14	0.5%		
Shanxi			15	0.5%	14	0.5%	5	2.1%
Beijing	**1**	**60.3%**	**1**	**61.6%**	**1**	**63.2%**	**1**	**79.2%**
Fujian	10	1.7%	15	0.5%	7	1.6%	**2**	**6.3%**
Guangdong	6	2.3%	4	**3.9%**	6	2.1%	5	2.1%
Hong Kong	17	0.3%	11	1.0%			**3**	**4.2%**
Jiangsu	**2**	**8.9%**	**3**	**7.4%**	**4**	**3.6%**	**3**	**4.2%**
Shandong	12	1.0%	11	1.0%	7	1.6%		
Shanghai	**3**	**6.0%**	**2**	**7.9%**	**2**	**8.8%**		
Tianjin	10	1.7%	15	0.5%	14	0.5%		
Zhejiang	14	0.7%	**5**	**3.4%**	5	2.6%		
Heilongjiang	12	1.0%	9	1.5%				
Jilin	14	0.7%	11	1.0%	11	1.0%		
Liaoning	6	2.3%	**6**	**3.0%**	14	0.5%		
Gansu	6	2.3%						
Guangxi					14	0.5%		
Shaanxi	17	0.3%	7	2.5%				
Sichuan	14	0.7%	8	2.0%	11	1.0%		
Xinjiang	17	0.3%						
Yunnan	6	2.3%			7	1.6%		

Note: Identified on the basis of formal agreements based on collaborations referred to in DFG proposals by German applicants. The basis is the projects funded in the period 2015-2019. Each institution is counted only once per project, regardless of the number of persons involved in the institution. The total number of projects (in brackets), the percentage distribution between the provinces and the rank of the respective province for the corresponding subject group are indicated. If the project figures for a province account for more than 3% of the total, the information has been highlighted (in bold).

Source: Evaluations by Fraunhofer ISI of the data provided by the DFG.

Table 8: Regional distribution of DAAD-funded congress attendance (2015-19)

Provinces	Number of congresses	All disciplines	Linguistics and Cultural Studies	Law, Economic and Social Sciences	Mathematics and Natural Sciences	Human Medicine	Veterinary medicine, agricultural, forestry and nutritional sciences, ecology	Engineering-sciences	Art, Music and Sport Sciences
Hubei	8	9	1	5	0	0	0	2	1
Shanxi	1	1	0	0	1	0	0	0	0
Beijing	31	54	5	6	25	0	0	14	4
Fujian	1	2	0	0	2	0	0	0	0
Guangdong	5	12	0	0	8	2	1	0	1
Hong Kong	51	80	18	17	29	4	1	11	0
Jiangsu	6	9	1	0	5	0	1	2	0
Macau	6	11	1	0	10	0	0	0	0
Shandong	4	14	9	1	1	0	2	1	0
Shanghai	34	47	12	11	13	0	1	8	2
Tianjin	1	1	0	0	1	0	0	0	0
Zhejiang	10	18	1	2	13	0	1	1	0
Jilin	2	2	0	0	1	0	0	1	0
Liaoning	5	5	2	1	1	0	0	1	0
Chongqing	5	5	1	0	2	0	0	2	0
Gansu	1	1	0	0	1	0	0	0	0
Guangxi	3	5	0	0	1	0	0	3	1
Inner Mongolia	1	1	1	0	0	0	0	0	0
Ningxia	1	2	0	0	2	0	0	0	0
Shaanxi	11	15	0	1	4	0	0	9	1
Sichuan	5	8	0	2	3	0	0	3	0
Yunnan	2	2	0	0	1	0	1	0	0
Totals	194	304	52	46	124	6	8	58	10

Note: In the "Congress and Lecture Trips" programme, the DAAD supports the participation of German academics and researchers with doctorates in international specialist conferences worldwide. A significant proportion of the applications relate to specialist conferences in China. Although the conferences often do not take place at the universities and research institutions themselves due to the large number of participants, they are usually organised in close cooperation with particularly strong research institutions and take place in close proximity to them. For the specialised conferences attended by persons funded in the programme, the distribution across the different provinces was examined.

Source: Evaluations by Fraunhofer ISI based on DAAD funding data.

Regional focal points in academic cooperation

While the analysis of scientific publications primarily looks retrospectively at what scientific achievements have been made, an analysis of the mobility of students, doctoral candidates and young scientists can provide clues as to which disciplines and regions are of particular interest to future top performers. In the case of China, however, this approach is complicated by the limited range and quality of freely available data. Although the Chinese government has launched extensive programmes worldwide to promote reciprocal student exchanges, the actual mobility figures are mostly not published and the published figures are often so imprecisely defined that their usability is severely limited. Also, the interest of students from Germany in a stay in China is only weak, so the numbers are low.

Target provinces of German DAAD scholarship holders in China

Due to China's great historical, cultural and political importance, it is not surprising that the humanities and social sciences make up the largest group among DAAD funding recipients (39.7%), followed by engineering (19.6%) and the natural sciences (15.2%). The smallest group is made up of the life sciences (6.7%). A subject classification was not possible for 18.8% of the funding recipients.

The choice of location of the funding recipients coincides with the regional distribution for numerous other parameters. Shanghai (24.6%), Beijing (23.2%) and Hong Kong (21.4%) clearly dominate across all disciplines. Here, too, there is a strong concentration on the eastern region, which was chosen by 87.1% of all grantees. Outside this region, only the provinces of Shaanxi and Sichuan were slightly more in demand (3.6% each). For engineering sciences, it is striking that 9.1% of all grantees in this subject group chose Shaanxi province.

Table 9: Share of all DAAD scholarship holders per target province 2017-19 (in percent)

Province	**Natural Sciences**	**Engineering**	**Life Sciences**	**Humanities and Social Sciences**	**n/a**	**Total**
Hubei	0,4	0	0	0,9	0	*1,3*
Beijing	**2,7**	**4,5**	0,4	**9,4**	**6,3**	*23,2*
Fujian	0,4	0,9	0	0,4	0	*1,8*
Guangdong	0	0,4	**1,3**	0,4	0,4	*2,7*
Hong Kong	**4,9**	**1,3**	**1,8**	**9,4**	**4**	*21,4*
Jiangsu	**1,3**	0,4	0,4	**1,8**	0	*4*
Macau	0	**2,2**	0	0,9	**1,8**	*4,9*
Shandong	0	0,4	0	0	0	*0,4*
Shanghai	**2,2**	**4,9**	0,9	**13,4**	**3,1**	*24,6*
Tianjin	0	0,4	0	0	0	*0,4*
Zhejiang	0,4	0,4	0,9	**1,8**	0	*3,6*
Jilin	0,4	0	0	0	0	*0,4*
Liaoning	0,4	0	0,4	0	0	*0,9*
Chongqing	0,4	0,4	0	0	0	*0,9*
Gansu	0,4	0	0	0	0	*0,4*
Guangxi	0	0,9	0	0	0	*0,9*
Qinghai	0	0	0	0,4	0	*0,4*
Shaanxi	0,9	**1,8**	0	0,9	0	*3,6*
Sichuan	0	0,4	0	0	3,1	*3,6*
Yunnan	0	0	0,4	0	0	*0,4*
	15,2	*19,6*	*6,7*	*39,7*	*18,8*	

Note: Regional distribution of DAAD scholarship holders who completed a research or study visit to China in the years 2017 to 2019. The percentage distribution is given in relation to the total number of individually funded scholarship holders (224), broken down as far as possible for the various disciplines. The percentage is given in bold if at least three persons in a subject group have chosen a particular province. In addition, the percentage of scholarship holders who chose a particular province or subject area is indicated (in italics).

Source: Fraunhofer ISI calculations based on DAAD funding data by China, 2017-19

Origin of Chinese Student Applicants in Germany

The data from the Academic Evaluation Centre in Beijing provide a different perspective. Chinese students who apply to study in Germany submit their applications through this office[7]. The table summarises the origin of applicants for partnership and cooperation programmes at German universities for 2019[8]. The following results appear particularly interesting: As far as the origin of applicants is concerned, the eastern region largely dominates, but the differences between the provinces are less pronounced. Most applicants come from Shanghai (21.6%), followed by Beijing (13.2%), Shandong (9.9%), Sichuan (8.1%), Jiangsu (7.9%) and Zhejiang (7.2%). As destinations, universities of applied sciences are more in demand than universities for partnership and cooperation programmes (2,397 and 2,020 applications respectively). Art/music colleges and dual universities hardly play a role as target institutions (0.9% and 1.4% of applications respectively). The comparatively large number of applicants for universities of applied sciences is surprising. It is 19% higher than that of universities, although universities in Germany have greater capacities than universities of applied sciences (approx. 42% higher student numbers)[9]. The origin of applicants for partnership and cooperation programmes also differs between universities and universities of applied sciences. The share of applications from Beijing for universities is significantly higher than that for universities of applied sciences; in other provinces (Anhui, Hebei, Zhejiang, Chongqing, Sichuan) the reverse is true. Applications from the western region make up a significantly larger share of the applicant pool for universities of applied sciences than for universities.

7 In 2019, 12,551 Chinese applicants submitted their applications to the various review procedures of the Academic Review Board (https://www.aps.org.cn/).
The applicants for partnership and cooperation programmes considered here represent a subgroup of all applications received by the APS (approx. 38%). The group of people is clearly defined and since these programmes are based on structured cooperation, they have a particular potential in terms of higher education policy.

8 The applicants for partnership and cooperation programmes considered here represent a subgroup of all applications received by the APS (approx. 38%). The group of people is clearly defined and since these programmes are based on structured cooperation, they have a particular potential in terms of higher education policy.

9 The breakdown of the total number of Chinese students at German universities is more in line with these quantitative ratios; in 2019, 80.8% of them studied at universities and only 16.0% at universities of applied sciences.

Table 10: Number of Chinese applicants by province of origin and target university type in Germany, 2019

	Target university in Germany (by type)			
Province	**University**	**Art / Music College**	**University of Applied Sciences**	**Dual university**
Anhui	19		106	
Henan	70		76	
Hubei	103		73	4
Hunan			36	
Jiangxi	10		13	
Shanxi				
Beijing	497	12	75	12
Fujian	30		30	
Guangdong	93	3	87	4
Hebei			70	
Hong Kong				
Jiangsu	171	3	182	2
Shandong	178		267	
Shanghai	444	11	483	37
Tianjin	26	3	42	
Zhejiang	84	4	237	2
Heilongjiang	9		3	
Jilin	45		12	
Liaoning	35		71	
Chongqing	35		111	
Gansu	12			
Guangxi			9	
Inner Mongolia			1	
Shaanxi	74		109	
Sichuan	70	4	290	
Xinjiang				
Yunnan	15		14	
	2020	40	2397	61
Central	10	0	12,7	6,6
Eastern	75,4	90	61,5	93,4
Northeastern	4,4	0	3,6	0
Western	10,2	10	22,3	0

Note: Origin of applications from Chinese students in the context of partnership and cooperation projects between German and Chinese higher education institutions. The regional distribution (provinces and regions) and the type of German partner institution are indicated. The applications registered via the Academic Evaluation Office were evaluated (4,758 applications, 240 of which were not taken into account because they could not be clearly assigned).

Source: Evaluations by Fraunhofer ISI based on data from the Academic Evaluation Centre, 2019

Strategic planning in higher education development

The "Double First-Class University Plan" of 2015 aims to develop Chinese elite universities by 2050. The funding concerns all regions of China and all disciplines. In terms of the number of projects funded, Beijing clearly dominates (162 projects), followed by the provinces of Shanghai (57 projects), Jiangsu (43 projects) and Hubei (29%). Hubei is thus the most successful province outside the eastern region. In terms of the number of projects, engineering clearly dominates (189 projects), ahead of humanities and social sciences (105 projects), life sciences (102 projects) and natural sciences (69 projects). By far the most projects (70.1%) are in the eastern region, but the dominance of Beijing is only particularly pronounced in the humanities and social sciences. In the life sciences, the western regions follow in second place (13.7% of projects, spread over eight provinces) and the central region (11.8%, of which 8.8% are in Hubei province alone). The projects to promote the natural sciences are particularly broadly distributed across various provinces in the dominant western region; Beijing's dominance is comparatively low. Outside the eastern region, the comparatively high funding shares in Jilin province (northeastern region) and in Anhui (7.2% of projects) and Hubei (5.8% of projects) provinces in the central region are striking. The eastern region also dominates funding in the subject area of engineering sciences. In the western region, the comparatively high funding share of Shaanxi province is striking (6.3%), while in the central region Hubei province (at a low level) receives the highest share (5.3%).

Table 11: Distribution of Double First-Class Discipline Projects by Region

	Total	Humanities and Social Sciences	Life Sciences	Natural Sciences	Engineering
Number of projects	**465**	**105**	**102**	**69**	**189**
Anhui	2,8	1,0	1,0	**7,2**	3,2
Henan	0,9	0,0	2,0	1,4	0,5
Hubei	**6,2**	**5,7**	**8,8**	**5,8**	**5,3**
Hunan	2,6	1,0	0,0	2,9	4,8
Jiangxi	0,2	0,0	0,0	0,0	0,5
Shanxi	0,2	0,0	0,0	0,0	0,5
Beijing	**34,8**	**60,0**	**28,4**	**20,3**	**29,6**
Fujian	1,3	1,0	2,0	4,3	0,0
Guangdong	3,9	1,9	**7,8**	**5,8**	2,1
Hainan	0,2	0,0	1,0	0,0	0,0
Jiangsu	**9,2**	3,8	**7,8**	**10,1**	**12,7**
Shandong	1,3	0,0	0,0	5,8	1,1
Shanghai	**12,3**	**12,4**	**14,7**	**11,6**	**11,1**
Tianjin	2,8	1,9	2,0	4,3	3,2
Zhejiang	4,3	1,0	**7,8**	1,4	**5,3**
Tibet	0,2	0,0	1,0	0,0	0,0
Heilongjiang	2,4	0,0	2,0	0,0	4,8
Jilin	2,6	4,8	0,0	**7,2**	1,1
Liaoning	1,1	1,0	0,0	1,4	1,6
Chongqing	0,9	0,0	1,0	0,0	1,6
Gansu	0,9	0,0	2,0	2,9	0,0
Guangxi	0,2	0,0	0,0	0,0	0,5
Guizhou	0,2	0,0	1,0	0,0	0,0
Inner Mongolia	0,2	0,0	1,0	0,0	0,0
Ningxia	0,2	0,0	0,0	0,0	0,5
Qinghai	0,2	0,0	1,0	0,0	0,0
Shaanxi	3,7	1,9	2,0	1,4	**6,3**
Sichuan	3,0	1,0	4,9	4,3	2,6
Xinjiang	0,9	1,0	0,0	1,4	1,1
Yunnan	0,4	1,0	1,0	0,0	0,0
Central	12,9	7,6	11,8	17,4	14,8
Eastern	70,1	81,9	71,6	63,8	65,1
Northeast	6,0	5,7	2,0	8,7	7,4
Western	10,8	4,8	13,7	10,1	12,7

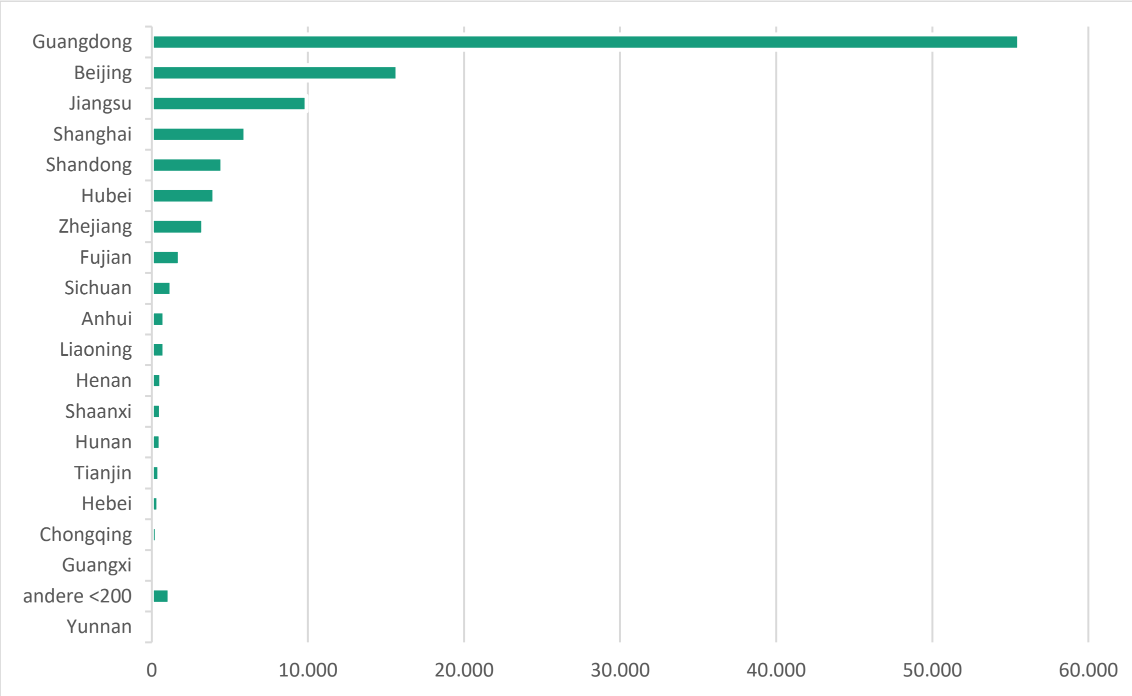
Note: Distribution of funding under the Double Excellence Initiative of the Chinese government. The regional distribution of funded projects is shown overall, as well as broken down by discipline (in each case as a percentage of the total number, values above 5 % are printed in bold).

Source: Evaluations and calculations by Fraunhofer ISI based on data from the Double First-Class Initiative, https://internationaleducation.gov.au/international-network/china/PolicyUpdates-China/Documents/DFC%20initiative%20disciplines%20development%20list%20(Sorted%20by%20discipline).pdf.

Regional distribution of technological activities in China

The regional concentration of technological activities in China that are relevant to the global market is comparable to that of scientific activities[10], albeit with a different geographical focus. Historically grown against the backdrop of the reform and opening-up policy of the 1980s and 1990s, and strengthened once again in the recent past by the dynamic developments in the Shenzhen technology hub, Guangdong province is at the centre of transnational patent applications. In 2017, this province accounted for more than one third of all transnational patent applications, followed by Beijing with 9.5% of all applications, Jiangsu with 6.2% of all applications, Shanghai with 3.7% of all applications, Shandong with 2.8% of all applications, Hubei with 2.4% of all applications and Zhejiang with approx. 2.0% of all applications.

Figure 4: Transnational patent income of Chinese provinces, total 2016-18



Source: Calculations by Fraunhofer ISI on the basis of EPO PATSTAT

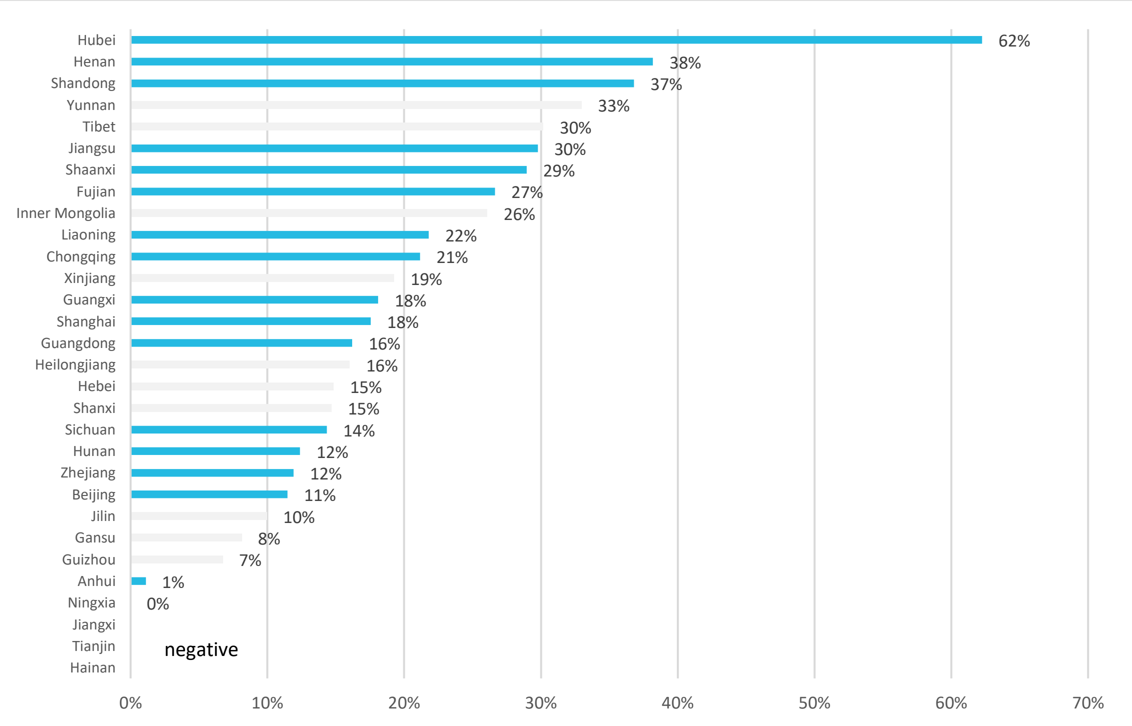
As is common internationally, large corporations also dominate patent activity in China in the area of technological activities relevant to the global market, which, as is also common internationally, are usually registered at the headquarters of the corporation. The regional distribution shown above is thus at the same time a reflection of the regional location of central control centres in the Chinese technology sector. As Table 13shows, this dominance of Guangdong still results from the central role of a few companies in the Chinese innovation system. In 2016-18, for example, Huawei alone accounted for no less than 10% of all Chinese filings. With the exception of BOE

10 In 2017, the concentration measure of the regional Gini coefficient was -approximately 0.64 in both cases.

Technology Group, which is headquartered in Beijing, all of the top five technology companies are based in Guangdong and, excluding BOE, account for just over half of all patent applications in Guangdong. BOE, for its part, contributes about one-third of all patent applications in Beijing.

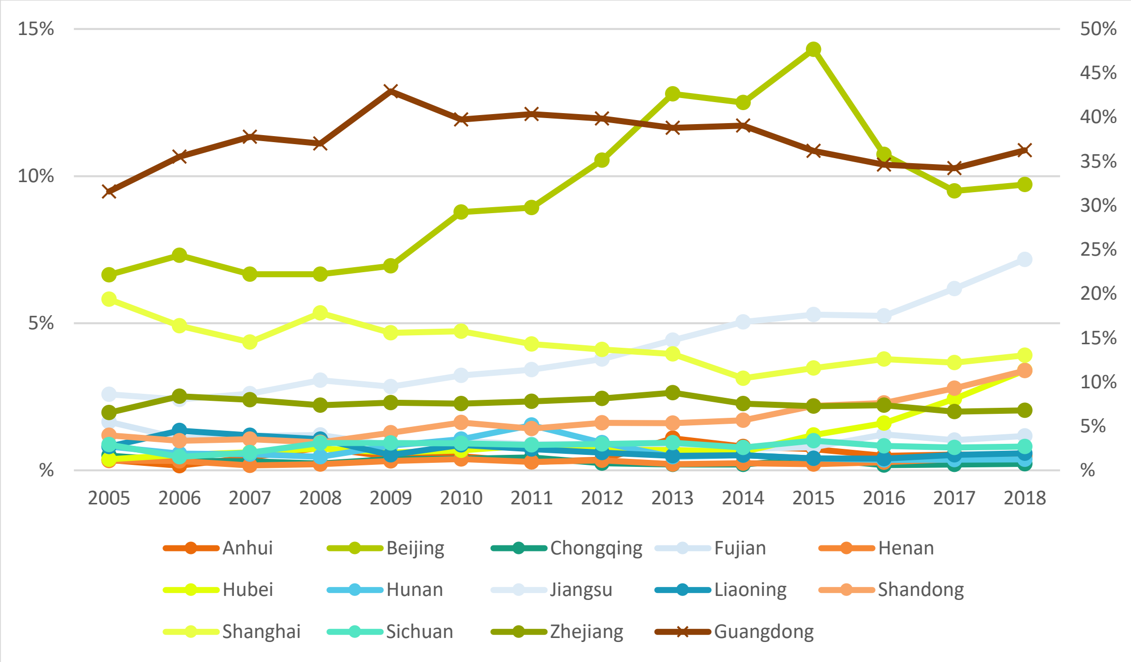
Against this background, it is not surprising that Guangdong's role in national patenting has remained largely stable over the years. It is almost more surprising that its relative share has not increased further. Instead, what can be observed de facto is a relative increase in Beijing's importance over the course of the 2010s from 8-9% to around 14%, although this has declined noticeably again in recent years. Jiangsu, on the other hand, has been able to steadily increase its share from 3-4% to over 6%. On the other hand, Shanghai's importance declined noticeably from about 6% to only 3-4%. Also noteworthy is the dynamic increase in the share of Hubei province from less than one percent in 2014 to probably over 3% today, as well as that of Shandong from 1.6% in 2010 to over 3% today. Further, relatively significant increases can be found in the provinces of Henan, Shaanxi and Fujian.

Figure 5: Mean annual growth of transnational patent output of Chinese provinces, 2013-18



Source: Calculations by Fraunhofer ISI on the basis of EPO PATSTAT

Figure 6: Transnational patent volume of Chinese provinces over time



Source: Calculations by Fraunhofer ISI on the basis of EPO PATSTAT

Unlike in the area of scientific publications, however, the ranking of the provinces can differ significantly depending on the topic. Although Guangdong plays the leading role in most areas, the ranking of the following provinces differs noticeably depending on the topic. While Jiangsu ranks second in industrial biotechnology, new materials, novel production technologies and life sciences, Beijing is second in nanotechnology and photonics. In addition, Beijing is even slightly ahead of Guangdong in the field of micro- and nanoelectronics as defined by KETS (unlike digital communication technology). A similar situation can arise in specific fields such as research on pandemic issues, where Jiangsu, Shanghai and Beijing are all ahead of Guangdong, which only follows in fourth place.

Table 12provides an overview of the regionally specific, relative focal points of the individual provinces. It becomes clear that the above-mentioned differences in rank result from regionally different orientations. For example, Beijing and Hubei specialise in semiconductors and optics, while Guangdong has the well-known specialisation in digital communication technology, telecommunications technology and computer technology. Shanghai, on the other hand, has a focus on pharmaceuticals and biotechnology, Jiangsu on mechanical engineering, and Zhejiang on machine components, furniture/toys and nanotechnology. Finally, in Shandong, as expected, there is a focus on consumer goods (Haier), but also on thermal processes/apparatus and semiconductors. In traditional industrial locations in the northeast or inland, specialisation in materials/metallurgy and various fields of the chemical industry often continues. In rural inland provinces, it is not uncommon to find specialisations in food chemistry. Overall, however, these are all relative focal points.

Table 12: Relative, thematic specialisation of Chinese provinces in transnational patent applications in specific fields

	Rank 1 (according to national RPA)	Rank 2 (according to national RPA)	Rank 3 (according to national RPA)
Anhui	Other consumer goods	Thermal processes/apparatus	Semiconductor
Beijing	**Semiconductor**	**Optics**	**Audiovisual technology**
Chongqing	Simple communication techno-logy	Materials/Metallurgy	Engines/Pumps/Turbines
Fujian	Electrical machines/plants	Microstructure/Nanotechnology	Materials/Metallurgy
Guangdong	**Digital communication techno-logy**	**Telecommunications technology**	**Computer technology**
Guangxi	Food Chemistry	Engines/Pumps/Turbines	Construction
Hebei	Transport	Machine tools	Materials/Metallurgy
Heilongjiang	Plastics/Polymer Chemistry	Food Chemistry	Chemical engineering
Henan	Materials/Metallurgy	Construction	Other special machines
Hubei	**Semiconductor**	**Optics**	**Audiovisual technology**
Hunan	Food Chemistry	Environmental technology	Transport
Jiangsu	**Textile and paper machines**	**Machine tools**	**Conveyor technology**
Jiangxi	Materials/Metallurgy	Other consumer goods	Optics
Jilin	Food Chemistry	Transport	Basic Chemistry
Liaoning	Materials/Metallurgy	Chemical engineering	Microstructure/Nanotechnology
Shaanxi	Materials/Metallurgy	Medical technology	Telecommunications technology
Shandong	**Other consumer goods**	**Thermal processes/apparatus**	**Semiconductor**
Shanghai	**Pharmacy**	**Biotechnology**	**Organic fine chemistry**
Shanxi	Microstructure/Nanotechnology	Conveyor technology	Engines/Pumps/Turbines
Sichuan	Pharmacy	Construction	Organic fine chemistry
Tianjin	Simple communication techno-logy	Engines/Pumps/Turbines	Biotechnology
Yunnan	Food Chemistry	Other consumer goods	Machine elements
Zhejiang	**Machine elements**	**Furniture/Toys**	**Microstructure/Nanotechnology**

Note: due to low numbers, the following areas could not be analysed in a meaningfully differentiated way: Gansu, Guizhou, Hainan, Inner Mongolia, Ningxia, Qinghai, Tibet, Xinjiang.

Source: Calculations by Fraunhofer ISI on the basis of EPO PATSTAT

Table 13: Central patenting institutions in China (with headquarters)

Total	NumberTN Patents	Province
HUAWEI TECHNOLOGIES COMPANY	> 14.500	Guangdong
ZTE CORPORATION	> 5.800	Guangdong
BOE TECHNOLOGY GROUP COMPANY	> 5.300	Beijiing
GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORPORATION	> 5.000	Guangdong
PING AN TECHNOLOGY COMPANY	> 2.600	Guangdong
SZ DJI TECHNOLOGY COMPANY	> 2.200	Guangdong
ALIBABA GROUP	> 1.900	Zhejiang
TENCENT TECHNOLOGY (SHENZHEN) COMPANY	> 1.600	Guangdong
BEIJING XIAOMI MOBILE SOFTWARE COMPANY	> 1.600	Beijing
HKC	> 1.400	Hong Kong Guangdong
CHINESE ACADEMY OF SCIENCES	> 1.300	Beijing
MIDEA	> 1.200	Guangdong
WUHAN CHINA STAR OPTOELECTRONICS TECHNOLOGY COMPANY	> 1.200	Hubei
VIVO MOBILE COMMUNICATION COMPANY	> 1.100	Guangdong
SHENZHEN CHINA STAR OPTOELECTRONICS TECHNOLOGY COMPANY	> 1.100	Guangdong
GREE ELECTRIC APPLIANCES	> 1.100	Guangdong
WUHAN CHINA STAR OPTOELECTRONICS TECHNOLOGY COMPANY	> 1.000	Hubei
QINGDAO HAIER WASHING MACHINE COMPANY	> 900	Shandong
SHENZHEN ROYOLE TECHNOLOGIES COMPANY	> 900	Guangdong
DATANG TELECOM GROUP	> 850	Beijing
SHENZHEN CHINA STAR OPTOELECTRONICS TECHNOLOGY COMPANY	> 800	Guangdong
CHONGQING HKC OPTOELECTRONICS TECHNOLOGY COMPANY	> 750	Chongqing
BYD COMPANY	> 700	Guangdong
TSINGHUA UNIVERSITY	> 700	Beijing
SHENZHEN UNIVERSITY	> 650	Guangdong
CONTEMPORARY AMPEREX TECHNOLOGY	> 650	Fujian
IBM (CHINA) INVESTMENT COMPANY	> 650	Beijing
HEFEI XINSHENG OPTOELECTRONIC TECHNOLOGY COMPANY	> 600	Anhui
LE HOLDINGS (BEIJING) COMPANY	> 550	Beijing
SHENZHEN GOODIX TECHNOLOGY COMPANY	> 550	Guangdong
MEDIATEK	> 550	Hsinchu/TW
GOERTEK	> 550	Shandong
BEIJING BOE OPTOELECTRONICS TECHNOLOGY COMPANY	> 500	Beijing
GUANGZHOU SHIYUAN ELECTRONICS COMPANY	> 500	Guangdong
APPOTRONICS CORPORATION	> 450	Guangdong
QINGDAO HAIER AIR CONDITIONER COMPANY	> 400	Shandong
SHENZHEN TRANSSION COMMUNICATION COMPANY	> 400	Guangdong
SOUTH CHINA UNIVERSITY OF TECHNOLOGY	> 400	Guangdong
BEIJING BYTEDANCE NETWORK TECHNOLOGY COMPANY	> 400	Beijing

Source: Calculations by Fraunhofer ISI on the basis of EPO PATSTAT

Regional science, technology and innovation policy

In China, there is a close connection between the level of economic development of a province and the quality of the regional innovation system as well as national innovation policy strategies. In principle, provinces can achieve an improvement in their national status with suitable initiatives. However, when evaluating innovation policy measures, it must be taken into account that the various regions take on specific functions within the Chinese innovation system - also due to targeted specifications by the central government. In the following, the role of the provinces for national innovation development is examined and illustrated by means of differences and special features in the innovation policy orientation of selected provinces. The focus is on the innovation policy goals and tasks as they emerge from the relevant strategies and plans, and their implementation into concrete innovation projects. The analysis addresses the following questions: How do the science, technology and innovation (STI) policy goals of the central and provincial levels and of the individual provinces differ? What are the differences in the tasks and measures they designate? How do the differences manifest themselves in concrete regional innovation-relevant projects?

Innovation policy decision-making scope of the provinces

China is a centralised state. However, local governments have always played an important steering role, if only because of the size of the country. At the beginning of the reform and opening-up policy, the decentralisation of economic decision-making powers increased the scope for local governments. Decentralisation has contributed significantly to the implementation of market-oriented reforms, such as local support for non-state enterprises, the integration of domestic enterprises and regions into global value chains and the accelerated satisfaction of domestic demand for consumer goods. [11]In terms of technological capacity building, the country made only limited satisfactory progress with the previously less coordinated STI support programmes and the focus on technology cooperation with transnational companies. In the context of a general recentralisation of governance, the Medium to Long-Term Plan for Science and Technology Development (MLP 2006-20) marked a return to "techno-industrial policy", with stronger governance elements for STI again. [12]The "National Strategy of Innovation-Driven Development", demanded by Xi Jinping and published in 2016, finally elevated technological innovation to the core element of economic and social development and the realisation of national strength. This orientation will be reaffirmed in the upcoming 14th Five-Year Plan (2021-25). [13]

[11] Xu, Chenggang (2011) The Fundamental Institutions of China's Reform and Development, Journal of Economic Literature, 49(4): 1076-1151.

[12] Chen, Ling and Barry Naughton (2016) An institutionalised policy-making mechanism: China's return to techno-industrial policy, Research Policy, 45: 2138-2152.

[13] https://merics.org/en/briefing/merics-china-industries-briefing-october-2020.

The strategy of innovation-driven development is to be understood as an overarching long-term policy that relies on the coordination of all measures taken by the different levels of government. It defines the goals of government activities and sets out the basic tasks that must be fulfilled in order to realise the goals. The various plans that governments at all levels draw up at periodic intervals (above all five-year plans) or in ad hoc plans that are added at short notice (e.g. "action plans") serve to concretise the goals and tasks for specific time periods and sectors and to expand or adapt them to new or changed framework conditions. The essential features of the strategy are reflected in all relevant plans, whereby the respective government agencies adapt the plans to their competences, possibilities and priorities. A clear hierarchy of plans as well as the continuous understanding of the central government leadership's guiding ideas (zhidao sixiang) and the guidelines for strategic government action are intended to ensure that the activities of the government agencies are coordinated with each other and with the overarching goals.

For the work of local governments, the national strategies and plans form the relevant environment, on the basis of which they themselves define plan goals, set the essential tasks for the relevant time period and then try to fulfil them by implementing relevant projects. The plans prepared by local governments at the provincial, city and district levels largely replicate the structure of the relevant plans at the higher levels and also retain the basic time periods and innovation indicators in terms of development goals. In particular, milestones represent the end points of the five-year plan periods, the MLP fifteen-year periods (2006-20, 2021-35) and the National Strategy of Innovation-Driven Development. These extend the time horizon with the milestones 2020, 2030 and 2050 mentioned therein by the time the People's Republic plans to celebrate its centenary. Some provinces combine the plans according to their own priorities. Some provinces combine the plans according to their own priorities. Box 19 illustrates this with the planning of Jiangsu Province for the coming 14th Five-Year Plan period.

Projects play a crucial role in the implementation of innovation policy. China's innovation policy has always been particularly focused on direct innovation policy measures, while indirect measures (e.g. tax reductions for R&D activities) tend to have a complementary character.[14] Innovation projects are carried out within the framework of various funding programmes (see 1st APRA Report). The projects include not only R&D projects of various sizes, but also in particular a large number of projects to build innovation-relevant infrastructure. They are implemented by government agencies at all levels. Here, the role of local governments is not only to realise their own projects, but also to carry out the regional integration and complementation of the projects of the different levels. In recent years, cooperative projects between ministries and local governments have become more important.

[14] Kroll, Henning; Conlé, Marcus and Schüller Margot (2010) China: Innovation System and Innovation Policy, in Frietsch, Rainer and Schüller, Margot (eds.) Competing for Global Innovation Leadership: Innovation Systems and Policies in the USA, Europe and Asia, Stuttgart: Fraunhofer, pp. 241-263.

Box 19: Jiangsu's "2+11" STI Plan System

In the context of formulating the relevant plans for the coming years, Jiangsu Province has already presented its "2+11" STI plan system in the first half of 2020. This structures the local plans in terms of a "top-level design" and is intended to support the implementation of the innovation-driven development strategy in the province. The two general plans are the Jiangsu MLP (2021-35) and the Science, Technology and Innovation Plan (hereafter WTI Plan) for the 14th Five-Year Plan period. Both plans are to be prepared by the end of June 2021. These two general plans, which have the same status in all provinces, are supplemented in Jiangsu Province by eleven further specific plans aligned with the province's strategy, which concretise the tasks and procedures in the most important areas. Here, too, the basic STI areas are in line with the plans of the other regions. As in the other provinces, sectoral and spatial aspects play an important role. In addition, one focus of the regional governments' work is to support research activities, especially through the development of scientific and technical infrastructures.

General plans

1. Medium- to Long-term Plan for the Development of Science and Technology
2. 14th Five-Year Plan for Science, Technology and Innovation of Jiangsu Province

Specific plans

1. Development Plan for Basic and Applied Research in Jiangsu Province
2. outline of the development plan for the development of the South Jiangsu Self-reliant Innovation Demonstration Zone (2021-25)
3. special plan of Jiangsu Province for the establishment and development of high-tech zones during the 14th Five-Year Plan period.
4. Special Plan of Jiangsu Province for the Development of High-tech Industries during the 14th Five-Year Plan Period.
5. Special Plan of Jiangsu Province for Science, Technology and Innovation in the Biopharmaceutical Industry during the 14th Five-Year Plan Period
6. Special Plan of Jiangsu Province for Science, Technology and Innovation in the New Materials Industry during the 14th Five-Year Plan Period
7. Special Plan of Jiangsu Province for Science, Technology and Innovation in the Semiconductor Industry during the 14th Five-Year Plan Period
8. Special Plan of Jiangsu Province for Science, Technology and Innovation in the Artificial Intelligence Industry during the 14th Five-Year Plan Period
9. Special Plan of Jiangsu Province for Science, Technology and Innovation in the Field of Modern Agriculture during the 14th Five-Year Plan Period
10. Special Plan of Jiangsu Province for Science, Technology and Innovation in the Field of Social Development during the 14th Five-Year Plan Period
11. Special Plan of Jiangsu Province for the Construction of Scientific and Technical Infrastructure during the 14th Five-Year Plan Period

Source: http://kxjst.jiangsu.gov.cn/module/download/downfile.jsp?classid=0&filename=002051233104457697c112f70051d1d6.pdf

Innovation goals in provincial planning

The setting of quantitative targets is a central element of STI development plans, where across levels not only a mere adjustment to regional baselines takes place, but regional prioritisation and additions are made. However, these reduce the comparability of regional plans, possibly to the advantage of local governments. Table 35 demonstrates the differences in goal-setting using the STI plans of the just completed 13th five-year plan period.[15] The table shows the baseline and target values for the national level and for two relatively comparable developed coastal provinces, Guangdong and Jiangsu, for the five-year period up to and including 2020. The remits of the Ministry of Science and Technology (MOST) and the regions are essentially the same. Since they are primarily oriented towards the economy, the targets listed relate in particular to information on the development of the high-tech industry, the knowledge-intensive service sectors and the economically relevant results of R&D activities. All the plans listed name indicators in these areas; only four indicators are completely identical.

Widely used indicators such as R&D expenditure as a share of GDP are already included in the MLP (2006-20) at the national and provincial levels. At the national level, China had targeted R&D expenditure of 2.5% as a share of GDP for 2020 in the MLP, which it could only achieve with a significant leap given the current level (2.23% in 2019). Guangdong, on the other hand, had already targeted gross R&D expenditure of 2.8% as a share of GDP for 2020 in the provincial-level MLP. While the amount, which is 0.3% higher than the national target, still sounded ambitious at the time the MLP was drafted, the province has already exceeded the target in 2019 (see Table 15). It should be noted here, however, that economic factors favoured the success. For example, the economically particularly dynamic regions in the Pearl River Delta (Guangdong) and Yangtze River Delta (Shanghai, Jiangsu, Zhejiang) have generally been able to increase their R&D expenditure in relation to GDP at an above-average rate, while the northeastern regions struggling with structural problems have consistently made below-average gains. The R&D development of Hunan province is accordingly remarkable, as is the stagnation of the value in Shaanxi province at a higher level. Beijing recorded a development in line with the national increase. Admittedly, the city had set a target of 7% in the MLP. However, in plans during the 13th Five-Year Plan period, the target was scaled down to more realistic 6% (and already reached in 2019). [16]

15 The plans for the next five years (2021-2025) are expected to be published at the beginning of summer 2021. So far, only Jiangsu has presented a concrete roadmap.

16 北京市 "十三五 "时期加强全国科技创新中 心建设规划.

Table 14: Baseline and targets of the STI plans (2015-20)

Indicators	**National**		**Guangdong**		**Jiangsu**	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Share of R&D expenditure in GDP (in %)	2,1	2,5	2,47	2,8	2,55	2,8
Contribution of technical progress to economic growth (in %)	55,3	60	57	60	60	65
Technology autarky rate (in %)			71	75		
Number of R&D personnel (per 10,000 labour force)	48,5	60	46,2	50	110	140
Number of national high-tech companies			11.105	28.000	10.814	15.000
Revenues of high-tech companies (in trillion yuan)	22,2	34				
Share of the gross production value of the high-tech industry in that of all industrial enterprises with a turnover of more than CNY 20 million p. a. (in %)					40,1	45
Share of value added of the high-tech manufacturing industry in all industrial entrepreneurs with a turnover of more than CNY 20 million p. a. (in %)			27	30		
Share of the production value of high-tech products in the total value of industrial production (in %)			40,2	43		
Share of high-tech products in total exports of the province (in %)			36,3	37		
Share of R&D expenditure in operating revenues of companies above designated size (in %)	0,9	1,1				
Number of incubated high-tech SMEs					90.000	150.000
Size of the S&T services industry (in billions of yuan)					501	1.000
Share of value added of knowledge-intensive service sectors in GDP (in %)	15,6	20	16	20		
Number of New R&D Institutes (provincial level)			124	200		
Number of technology incubators			399	800		
Placement in the global innovation ranking	18	15				
Global ranking in citations International scientific articles	4	2				
Number of PCT patent applications (in 1,000)	30,5	61				
Patents granted (per 100,000 inhabitants)	0,63	1,2	1,295	2,0	1,42	2,0
Transaction volume technology markets (billion yuan)	983,5	2.000			72,35	100
Proportion of the population with scientific qualification (in %)	6,2	10	6,91	10,5		

Note: The threshold of more than 20 million CNY turnover p.a. is defined by the NBS ('above designated size').

Source: Fraunhofer ISI compilation from the five-year plans for science, technology and innovation

Table 15: Gross expenditure on R&D per GDP in selected provinces (in %)

Province	2019	Change 2006-19
Beijing	6,31 %	+0,81 %
Shanghai	4,00 %	+1,50 %
Tianjin	3,28 %	+1,10 %
Guangdong	2,88 %	+1,69 %
Jiangsu	2,79 %	+1,19 %
Zhejiang	2,68 %	+1,26 %
Shaanxi	2,27 %	+0,03 %
Shandong	2,10 %	+1,04 %
Liaoning	2,04 %	+0,57 %
Anhui	2,03 %	+1,06 %
Hunan	1,98 %	+1,27 %
Sichuan	1,87 %	+0,62 %
Jilin	1,27 %	+0,31 %
Shanxi	1,12 %	+0,36 %
Heilongjiang	1,08 %	+0,16 %

Source: NBS: 全国科技经费投入统计公报, various years, available at: http://www.stats.gov.cn/tjsj/tjgb/rdpcgb/qgkjjftrtjgb/; http://www.stats.gov.cn/tjsj/zxfb/202008/t20200827_1786198.html

Other indicators relate, for example, to status goals such as placement in international rankings. The reduction of technological dependence on foreign countries under the motto of "independent innovation" (zizhu chuangxin) is also part of this. In the electronics industry, Guangdong Province has long been able to significantly reduce dependency with the increasing localisation of value chains in the Pearl River Delta. In the 13th STI Plan, the province had proclaimed a further reduction as a goal and thus at the same time flaunted the progress already made. In contrast to the MLP, the knowledge-based service sector in particular has gained in importance in recent years as an important link for the commercialisation of technologies. Guangdong has also set additional goals in this area, which relate to concrete initiatives of the province, first and foremost the establishment of so-called New R&D Institutes (xinxing yanfa jigou). With these initiatives, the province sets its own priorities, which are, however, within the framework set by the central government (see below). Jiangsu does not name any concrete intermediary structures in the STI plan, but in the complementary plan for Strategic Emerging Industries during the 13th Five-Year Plan period it sets the goal of establishing 100 innovation platforms at the national level and 1,000 innovation platforms at the provincial level. [17]

[17] http://www.jiangsu.gov.cn/art/2016/12/23/art_46555_3614908.html.

Transfer of national goals into regional task packages

Promoting regional economic development is at the heart of the work of local governments. In many regions, the increasingly visible limitations of an industry focused on labour-intensive production have shifted the focus to the promotion of knowledge-based economic activities. The MLP (2006-20) has already contributed significantly to this reorientation. With the national strategy of innovation-driven development, the central government defines eight overarching task priorities for the systematic promotion of domestic technological innovations. These task priorities have been adapted and concretised by many provincial governments to regional conditions.

Table 16: Task areas in the National Strategy for Innovation-driven development

1) Promote innovation in the ten strategic industry/technology sectors, Creating new development advantages
2) Strengthening original innovations and increasing the upstream supply of research results.
3) Optimising the regional arrangement of innovation activities and creating regional growth poles.
4) Deepening military-civilian innovation cooperation
5) Scaling up the innovation performers and leading innovation development.
6) Implementation of significant S&T projects and engineering works to realise development leaps.
7) Establish teams of high quality talent and build a base for innovation.
8) Promoting innovation and entrepreneurship

Source: Evaluations by Fraunhofer ISI based on the "Draft National Strategy for Innovation-Driven Development

Table 16 names the eight task areas defined at national level. First, promoting better IT penetration of domestic industry and focusing on ten strategic technology fields. Second, strengthening basic and cutting-edge research, which, in line with a linear understanding of the innovation process, should create an upstream supply of commercially exploitable technical knowledge. Optimising the geography of innovation is a third task area, consisting of the measures already mentioned above of establishing demonstration zones for autonomous innovation, reforming and upgrading existing high-tech zones, promoting growth poles for strategic emerging industries and integrating innovation resources across regions. The fourth task area is the deepening of military-civilian innovation cooperation, which should break through the parallel structures that have traditionally existed in China up to now (e.g. in Shaanxi Province). For this purpose, the incubation of technologies for non-military use from military research institutes on the one hand and the procurement of military technologies from civilian (non-governmental) technology companies on the other hand is planned. The development of indigenous world-class innovation actors - be they innovation-oriented firms, universities or research disciplines or research institutes - is a fifth area of activity that has been desired for some time. In addition, however, market-oriented research institutes (see "New R&D institutes" below) and innovation intermediaries are now also increasingly seen as important innovation actors worthy of support. Sixth, with the MLP (2006-20), scientific and engineering megaprojects have regained an important status, which are intended to accelerate the development and technical mastery of large systems in a mission-oriented manner. A seventh task area concerns the training of scientists and engineers, complemented by intensive global recruitment of talent. Finally, eighthly, the promotion of technology start-ups and their support structures has been given considerable importance in recent years.

The regional adaptations of the provincial governments have emerged in feedback with the terms of reference set at the national level. Beijing and Jiangsu, for example, have each published a list of 30 articles, the so-called "30 STI articles" (kechuang 30 tiao) and "30 S&T reform articles" (kegai 30 tiao). These set their own focus and prioritisation, based on the national list, with different categorisations and designations. Beijing divides its 30 S&T articles, published in October 2019, into five areas aimed at improving innovation governance, reforming the scientific 'talent' system, making structural improvements to strategic industry sectors, reforming the science management system, and optimising the innovation and entrepreneurship ecosystem.[18] Jiangsu Province's 30 S&T reform articles of August 2018 are divided into just four areas.[19] Here, the focus is on reforming the science management system, expanding the autonomy of scientific research in universities and research institutes, promoting the integrated development of technology and industry, and creating an entrepreneur-friendly atmosphere characterised by innovation and tolerance of mistakes. Guangdong, for its part, has provided a particularly detailed list with its "12 STI articles" (kechuang 12 tiao) published in January 2019, which further elaborates on each of the 12 areas in a total of 71 sub-items. To illustrate the task at provincial level, Guangdong's 12 articles are described in more detail in the annex.

Regional decision on technology and industrial sectors

One of the most important tasks of regional innovation policy is to promote the development of strategic technologies and industries. In selecting sectors, provincial plans are guided by the national level. With remarkable continuity, China is driving the domestic development of a number of cross-cutting technology sectors. Starting from the National High-Tech R&D Programme (863 Programme) in 1986, through the MLP (2006-20) to the present time, these sectors have been largely maintained and, at most, adapted to newer technological developments, always keeping economic exploitation in mind. The strategy of innovation-driven development identifies ten strategic technologies and industries. These include new generation information technologies, with the focus now shifting to network technologies; smart and green production technologies; modern

18 http://zgcgw.beijing.gov.cn/zgc/zwgk/zcfg18/bjs/620766/index.html.
19 http://kxjst.jiangsu.gov.cn/art/2018/9/13/art_64899_7814977.html.

agricultural technologies; efficient resource and environmental protection technologies; biomedical technologies; and marine and space technologies. Over the years, technologies for digital cities and digital societies have been added, as well as modern service technologies to support business model innovation. Finally, from the perspective of disruptive technologies, the aim is to increase vigilance against new technologies.

The provincial plans contain the strategic technologies and industries mentioned in one form or another, so there is extensive overlap between their plans. Jiangsu and Beijing, for example, name the same six sectors in their current STI plans. However, Beijing has included (satellite) navigation technology as an additional seventh sector, in which research institutions from the capital (e.g. School of Earth and Space Sciences, Peking University) have already built up capabilities. Other provinces are also picking up on emerging local R&D activities in their plans. Anhui Province, for example, has taken the high-profile advances in quantum communications by the team led by returnee Pan Jianwei at the University of Science and Technology of China as an opportunity to select the sector as one of a total of 19 megaprojects at the provincial level (see below). Guangdong, in turn, has named ten megaprojects in addition to the relevant technology sectors, most of which project areas can help to further complete local value chains. For example, there is a focus on capacity building in new semiconductor materials and devices, one of the main weaknesses of the local electronics industry. On the other hand, the promotion of R&D projects in the areas of vehicle batteries and autonomous driving promises to advance the province in fulfilling its ambitions regarding the electric mobility sector.

In the run-up to the preparation of the upcoming MLP, several provinces have announced short-term action plans with further or more concrete technology sectors. The starting point here was primarily the publication of the national strategy on artificial intelligence (AI) in 2017 and the subsequent three-year action plan for *promoting the development of the AI industry (2018-2020). The national action plan has been followed by 13 provinces with similar action plans by the end of 2018.[20] The example of Jiangsu Province shows that the province has also planned an AI special plan for the upcoming 14th Five-Year Plan period. Some provinces have also released complementary action plans. Beijing, one of the country's central locations for information technologies and a pioneer with its own AI action plan (2017-2020, focused on the Zhongguancun high-tech zone), for example, has released further action plans for Industrial Internet of Things technologies (2018-2020), 5G industry development (2019-2022) and blockchain technologies (2020-2022). In conjunction with the previous action plan for Big Data and Cloud Computing (2016-2020), the city is currently (2020-2022) working more on coordinated development of new

[20] Development Solutions Europe (2018) China's '1+N' funding strategy for Artificial Intelligence, Second Ad Hoc Study, Improving EU Access to National and Regional Financial Incentives for Innovation in China.

infrastructures - specifically 5G networks, Gigabit fixed networks, Internet via Satellite, Internet of Vehicles (IoV), Industrial Internet of Things (IIoT) and e-government. [21]

Regional development of innovation infrastructures

The Beijing example points to the essential function of regional governments, namely, the establishment of local infrastructure and support systems for the development of relevant technologies and industrial sectors. This task includes, in particular, the creation of clusters of strategic industries through the establishment and development of zones. As part of the so-called Torch Programme (huoju jihua), 168 national high-tech zones have been established in 30 provinces and non-governmental cities in China to date.[22] In addition, there are a large number of other high-tech zones at the provincial level that can be upgraded to national zones through recognition by the central government. In the previous 13th Five-Year Plan, for example, Jiangsu set itself the goal of upgrading eight provincial-level zones into national high-tech zones. After realising this goal, Jiangsu is now the province with the highest number of national high-tech zones, with 17 zones - ahead of Guangdong (14), Shandong (13) and Hubei (12).

Since many high-tech zones initially led to a concentration of industrial production but produced little innovative activity, the 2000s saw the upgrading of relevant zones into "National Demonstration Zones for Autonomous Innovation" (zizhu chuangxin shifanqu), starting with the Zhongguancun Zone in Beijing, to develop and test appropriate measures to promote technology commercialisation.[23] In many cases, these zones span several high-tech zones. For example, in Guangdong, in addition to the national demonstration zone in Shenzhen, there is another zone, the Pearl River Delta National Demonstration Zone for Standalone Innovation, which includes all eight remaining cities in the Pearl River Delta with their respective high-tech zones. [24]A similar situation applies, for example, to the South Jiangsu Demonstration Zone, which also includes eight high-tech zones in the region (see also the special plan in Table 17), or the He-Wu-Beng Demonstration Zone, an amalgamation of the high-tech zones of the cities of Hefei, Wuhu and Bengbu in Anhui Province.

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[21] 中关村人工智能产业培育行动计划(2017-2020年), 北京工业互联网发展行动计划(2018-2020年), 北京市区块链创新发展行动计划(2020-2022年), 北京市大数据和云计算发展行动计划(2016-2020年), 北京市加快新型基础设施建设行动方案(2020-2022年). All plans retrieved from http://www.beijing.gov.cn/.

[22] http://www.most.gov.cn/gxjscykfq/gxjsgxqml/.

[23] Heilmann, Sebastian; Shih, Lea and Hofem, Andreas (2013) National Planning and Local Technology Zones: Experimental Governance in China's Torch Programme, China Quarterly, No. 216: 896-919.

[24] http://gdstc.gd.gov.cn/zt/zsjgjzzcx/.

Table 17: Guangdong's "1+20" regional clustering system

Views of Guangdong Province on the Development of Clusters for Strategic Key Industries and Strategic Emerging Industries	
Guangdong Province Action Plans for the Development of Key Strategic Industry Clusters (2021-25)	**Guangdong Province Action Plans for Cluster Development (2021-25) for strategic emerging industries**
1. electronics and information technology	1. semiconductors and integrated circuits
2. green petrochemistry	2. high-end machines
3. intelligent household appliances	3. intelligent robotics
4. automotive industry	4 Blockchain and quantum information
5. advanced materials	5. latest materials
6. modern light and textile industry	6. new energies
7. software and information services	7. lasers and additive manufacturing
8. ultra HD screens (incl. acceleration of the establishment of a corresponding experimental zone).	8 Digital Creative Industries
9. biopharmaceutical and healthcare industry	9. safety and emergency technology and environmental protection
10 Modern Agriculture and Food	10. precision instruments and equipment

Source: People's Government of Guangdong Province [25]

In addition to the promotion of individual zones, the local and regional connection of clusters is an important thrust of regional innovation policy. In cities like Beijing, this concerns not least the linking of parks and zones within the city. While the original Zhongguancun zone was limited to parts of the Haidian city district, the zone's administrative area was expanded to include parks in Changping, Fengtai, Daxing and the Beijing Economic-Technological Development Area (BDA), among others, by the end of the 2000s when it was upgraded to a national demonstration zone for independent innovation. According to the 13th STI Plan, the demonstration zone will be further developed under the slogan "three cities and one zone" (san cheng yi qu). The three science cities comprise the original "science city" Zhongguancun, the new "science city" Huairou near the Great Wall of China, which has been designated as the site of one of the (so far) three national Comprehensive Science Centres (see 1st APRA report), and the Beijing Future Science Park, an original office park in Changping District, which is to be massively expanded and extended in the coming years. Finally, the high-tech zone refers to the Yizhuang BDA. Supra-regionally, Beijing is to strengthen the "innovation community" (chuangxin gongti) with the surrounding provinces of Hebei and Tianjin, according to the plan.

The introduction of coordinative structures within and across high-tech parks and zones is necessary, not least because of the many cooperation problems. Since state projects play an important role in the Chinese innovation system, administrative boundaries are of essential importance. For example, in its regional MLP (2006-20), the city of Beijing set as a task to establish

25 http://www.gd.gov.cn/zwgk/wjk/qbwj/yfh/content/post_2997541.html.

a cooperation mechanism between the city and the national ministerial level in order to better use central government resources for the city's development. On the one hand, the city opened up its S&T research programmes to Beijing-based national research institutions, giving them easier access to city funding and city-owned land. On the other hand, the primarily national research institutions are supposed to seek exchange with local firms in projects, even if these firms are not affiliated with the national level.

The same problem also applies across regions. Here, supra-regional zones are meant to create proximity, enabling cooperative projects, regional forms of division of labour and knowledge diffusion. The aforementioned integration of the "Jing-Jin-Ji" region (i.e. Beijing, Tianjin, Hebei) follows this logic. In the above-mentioned region and in the Yangtze Delta region, coordination is difficult because several provinces are involved, each with its own objectives that often run counter to a better division of labour. The inclusion of both regions in central government plans should help break down the administrative barriers. Within a single province, corresponding adjustment measures are usually (but by no means always) easier to implement. Most recently, for example, Guangdong province published a package of measures that provides for detailed planning of the regional division of labour.

Box 20: Regional innovation policy cooperation using the example of Guangdong

Guangdong Province has presented a package of measures with the help of which the provincial government wants to strengthen the regional division of labour and realise technological spillover effects between the two central knowledge centres Guangzhou and Shenzhen and the surrounding cities. First, the province published the "Views of Guangdong Province on the Development of Clusters for Key Strategic Industries and Strategic Emerging Industries" in May 2020. The document identifies the ten key strategic industries shown in Table 17and ten other strategic emerging industries to be prioritised for development in the province. For each of these industries, the province presented independent action plans for the period 2021-2025 at the end of September 2020, which complete the so-called "1+20" system of measures.

Based on an inventory of past industrial development within the province, the documents determine future regional development priorities and interregional cooperation. In the electronics industry, for example, clusters for smart terminals are to be established in Guangzhou, Shenzhen, Huizhou, Dongguan and Heyuan, for new electronic components in Shenzhen, Shantou, Meizhou, Zhaoqing and Chaozhou, and IT security in Guangzhou and Shenzhen, while the other regions are to support companies that can complete the value chains. In smart robotics, as an example of an emerging industry, the focus is on five cities: Guangzhou is to build further R&D capabilities in key technologies and focus on system integration for automotive, shipbuilding, and aerospace industries. Shenzhen is to develop service robots, specialised robots and drones, and advance systems integration for the 3C industry (i.e. computers, communications and consumer electronics). Zhuhai is to make advances in robot bodies and core components with the help of the Zhuhai Gree Intelligent Equipment company and the Sinomach Robotics Science Park. Foshan is to complete the Kuka manufacturing base (Midea) and the Country Garden Robot Valley, and intensify system integration for traditional industries including home appliances, ceramics, textiles and furniture. Finally, Dongguan is to focus on the incubation of core component companies and system integrators as well as system integration for electronics and information technology industries on the one hand and electrical machinery and equipment on the other.

Source: People's Government of Guangdong Province [26]

[26] http://www.gd.gov.cn/zwgk/wjk/qbwj/yfh/content/post_2997541.html, A similar document concerning investment in strategic emerging industries and development of new growth poles has been issued at the central government level by NRDC, MOST, MIIT and MOF in September 2020. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202009/t20200925_1239582.html.

Innovation projects at regional level

Regional innovation policy is oriented towards the areas of responsibility of central government. Therefore, there are large regional overlaps. Differences result primarily from the different initial endowments, such as the number of excellent universities and research institutions or the general attractiveness of the cities for companies and researchers, which give the provinces different scope for action. [27]Another important reason for differences in innovation policy is local financial leeway.

Infrastructure projects

The implementation of the goals and tasks is achieved in China primarily through the realisation of projects relevant to innovation policy. Indirectly, this also includes the various infrastructure projects that drive China's urbanisation and at the same time seek to increase the mobility of skilled workers. In connection with the 2015 plan for the integrated development of the Beijing-Tianjin-Hebei (Jing-Jin-Ji) region, for example, nine additional express train lines totalling 1,100 line kilometres were to be built by 2020, bringing the total line length in the region to 9,500 km. In addition, there will be another 9,000 km of motorways. [28]The "new area" Xiong'an in Hebei province - planned with a comparable high status to Pudong in Shanghai or the Shenzhen Special Economic Zone - is to grow into a hub in the region. At the end of 2020, Xiong'an was connected to Beijing, about 90 km away, and to the newly built Beijing Daxing International Airport by a high-speed train.[29] In the Pearl River Delta, the innovation centres of Guangzhou and Shenzhen, which are about 100 km apart by air, can now be reached by fast train in less than 30 minutes. A metro line exists between Guangzhou and Foshan, while Dongguan plans to link its metro line 1 with the metro networks of Guangzhou and Shenzhen by 2023. [30]This route planning will especially increase the accessibility of Dongguan's high-tech Songshan Lake zone. In the Yangtze River Delta Region, the third region that, along with the Jing-Jin-Ji Region and the Pearl River Delta Region, occupies a prominent position among the total of 19 mega-regions (chengshiqun) named in the national 13th Five-Year Plan, a plan for the integrated development of the region was adopted at the end of 2019, which also envisages the expansion of regional high-speed train lines by more than 1,000 km. [31]

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27 Thus, the establishment of new universities in Beijing is a less pressing problem due to the already considerable density of higher education institutions, just as Shanghai's attraction for foreign companies, skilled workers and returnees has only been strengthened by regional policy measures, but not primarily triggered.

28 https://www.china-briefing.com/news/the-beijing-tianjin-hebei-integration-plan/.

29 http://english.xiongan.gov.cn/2018-04/21/c_129855751.htm; http://www.xinhuanet.com/english/2020-12/27/c_139621999.htm.

30 http://www.newsgd.com/news/2017-07/17/content_174499733.htm.

31 http://www.bjreview.com/Business/202006/t20200615_800209939.html.

Regional STI programmes

Integrated development plans have been elevated to national strategies, so that infrastructure projects are financed through allocations from the central government budget. Against this backdrop, local governments seek to attract central government resources. Guangdong's above-mentioned intention to also build a national Comprehensive Science Centre is only one of many examples of this policy. Local governments also benefit from central government financial resources when national innovation projects are implemented in their regions. These projects are generally implemented through one or more national STI programmes. Since the latest reforms in 2014/15, the programmes are divided into five categories (see 1st APRA Report, p. 55): research projects of the National Natural Science Foundation of China (NSFC); priority projects under the science and engineering "megaprojects"; projects under the National Key R&D Programme; projects supported by steering funds; and projects to build innovation infrastructure and to train and recruit scientists and high-tech entrepreneurs. Local governments play a role in this by providing funding to enable regional innovation actors to successfully apply for central government programmes. [32]

With the exception of the NSFC, counterparts of these programmes exist at the provincial level and partly below, at the city and district level. The megaprojects mentioned above are defined by each province based on a mix of national targets and regional priorities. Table A2compares the megaprojects of different provinces (cf. Annex).

Innovation platforms

Megaprojects are platforms through which different innovation actors interact to carry out a specific mission (see efficiency chapter). In addition, the establishment of innovation platforms in the narrower sense plays a weighty role in the work of local governments. Innovation platforms are the essential elements of regional innovation infrastructures, the development of which is supported through various programmes. In its 2010 "Guiding Principles for Intensifying the Development of a Regional Basic Capacity for Regional Industrial Innovation", the NRDC subsumes national and local engineering research centres, engineering laboratories, corporate R&D centres [33]and public technology service platforms under innovation platforms.[34] With the consolidation of

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[32] This includes, for example, promotion that concerns the fulfilment of one of the above-mentioned essential quantitative goals: the number of national high-tech enterprises. To increase the number, many provinces (as determined by the central government) draw up lists of technology-intensive enterprises that are to achieve the requirements to be fulfilled for the status of a national high-tech enterprise through targeted promotion (gaoxin jishu qiye peiyu ruku qiye).

[33] This is a programme that supports the development of R&D centres by (high-tech) companies corresponding to the conditions.

[34] http://www.gov.cn/gongbao/content/2011/content_1803164.htm. The engineering research centres and laboratories were originally two concurrent programmes established independently by MOST and NRDC. With the reform, the two programmes have been merged.

the innovation infrastructure programmes under the Industry Base and Human Capital Programme as a result of the reform of the research funding programmes, the term innovation platforms also includes the state-funded laboratories.

In the provinces, the establishment of innovation platforms results in a structure that can be divided into three groups, in line with Guangdong's plan[35]:

1. Laboratories and focal point laboratories at national and provincial level, possibly also at city level.
2. Innovation Centres for Technology (jishu chuangxin zhongxin) as well as the aforementioned engineering science centres at national and provincial level respectively.
3. Technology service platforms such as technology transfer platforms, technology transaction platforms, and public S&T service platforms. These include the University Science Parks (daxue kejiyuan), Technology Business Incubators (keji qiye fuhuaqi), Makerspaces (zhongchuang kongjian) and Productivity Promotion Centres (shengchanli zujin zhongxin), known from the National Torch Programme, which was the main overarching programme for innovation infrastructure building until the reform of the funding programmes. In addition, there are a number of other platforms at regional level to promote intermediary functions, especially for specific technology services geared to local industry.

For local governments, innovation platforms offer a way to target specific activities and functions in the innovation process - be it R&D, automation of production processes, technology transfer, technical training, quality assurance applications and support services for start-ups and growth companies. National and local platforms coexist and increase the total number of respective platforms. As Table 18shows, using the example of science focus labs, the number of regional platforms tends to be higher than that of national platforms, including in Beijing and the country's other knowledge centres.

[35] Construction plan for the system of STI platforms in Guangdong (广东省科技创新平台体系建设方案) from 2016. See: http://stic.sz.gov.cn/xxgk/zcfg/gdkjcxzcfg/201710/P020171030684153619623.pdf.

Table 18: Focus laboratories in selected provinces

	National level (2016)	Provincial level (2019)
Beijing	79	457
Tianjin	6	161
Jiangsu	20	73
Zhejiang	9	323
Guangdong	11	240
Liaoning	8	441
Jilin	10	97
Heilongjiang	4	269
Chongqing	5	172
Hunan	5	307

Source: Compilation of the Fraunhofer ISI

Contrary to what might be assumed, innovation platforms, including e.g. engineering research centres, are only in the rarest cases independent institutions. Instead, the platforms are usually embedded in their "supporting units" (yituo danwei) or in "innovation carriers" (chuangxin zaiti). These units mainly include universities, research institutions and companies. In recent years, the diversity of these units has increased considerably, especially at the regional level. Non-governmental science and technology parks (kejiyuan) and research institutes, for example, are now ubiquitous in many provinces.[36] Platform projects play a particularly important role in the development of the regional innovation system.[37] This refers to projects that drive the development of such units, which can be carriers of various innovation platforms and thus contribute to the successful accomplishment of several of the tasks defined by the local governments. Universities, research institutes, companies and non-profit organisations can potentially integrate focal laboratories, research centres, incubators and other platforms and target them to the relevant strategic sectors. In addition to the existing regional research infrastructure, differences between provinces in terms of their regional development are evident precisely in the quality of the platform projects that a particular province or region implements or can implement.

36 Reliable numbers on non-governmental institutions as part of regional innovation infrastructures are scarce. One indicator of the relative importance of such institutions within a province could be the number of registered non-governmental non-profit research institutes (yanjiuyuan and yanjiusuo) in the Ministry of Civil Affairs database (http://www.chinanpo.gov.cn/search/orgindex.html). Judging purely by numbers, such non-profit institutes play the largest role in Shandong, Guangdong and Zhejiang. Henan and Heilongjiang also stand out from the midfield, which includes Jiangsu, Anhui, Hebei, Shanxi, Shaanxi, Beijing and Sichuan.

37 Zhao, Wei and Conlé, Marcus (2020) Constructing advantage using innovation platforms: Regional Innovation Policy in Guangdong, China, Paper presented at the Online Workshop "Governance and Emerging Technological Change in China", IN-EAST, University of Duisburg-Essen, November 19, 2020.

Regional university foundations

The establishment of universities is a key instrument of regional development. Universities and other higher education institutions have been experiencing dynamic development in China for quite some time; in the period from 2002 to 2017, tertiary education institutions almost doubled. Even in the country's educational strongholds, the dynamics are remarkable, with growth in the number of higher education institutions ranging from nearly 30% (Shanghai) to almost 50% (Beijing). Guangdong's development is particularly impressive. The province has been able to expand its higher education sector at an above-average rate in terms of numbers over the last two decades. Table 19 shows the number of HEIs in the fifteen provinces with the highest total numbers in 2017, with Jiangsu (still) in first place, now followed by Guangdong, which has moved from fifth place in 2002 to second position between Jiangsu and Shandong. But provinces such as Henan, Hunan and Jiangxi are also recording high growth rates. From a low base, Fujian has passed provinces like Shanxi, Jilin and Heilongjiang. Virtually all of the new universities added are either state schools established at the provincial level or below, or private educational institutions.

Table 19: Size and growth of the tertiary education sector, top 15 provinces

	2017	Growth (2002-2017)
Jiangsu	167	79,6%
Guangdong	151	112,7%
Shandong	145	93,3%
Henan	134	106,2%
Hubei	129	76,7%
Hunan	124	106,7%
Hebei	121	61,3%
Anhui	119	95,1%
Liaoning	115	71,6%
Sichuan	109	91,2%
Zhejiang	107	75,4%
Jiangxi	100	112,8%
Shaanxi	93	78,9%
Beijing	92	48,4%
Fujian	89	169,7%

Source: China Statistical Yearbook on Science and Technology, various years

For all the dynamism, it should be noted that most of the new universities are located in the broad field between technical colleges and universities of applied sciences.[38] In fact, the outstanding new university establishment in the period took place exclusively in four provinces of the Yangtze and Pearl River Delta: in Shanghai, Jiangsu, Zhejiang and Guangdong. Table 20provides an overview of the relevant new university establishments. These include ShanghaiTech University,

38 The discussion is based on the analysis of the MOE list of all universities existing in 2019. It is available at http://www.moe.gov.cn/jyb_xxgk/s5743/s5744/A03/201906/t20190617_386200.html.

founded in 2013 by the Shanghai government together with CAS, Westlake University in Hangzhou (Zhejiang), which was recently initiated as a private university on the initiative of some renowned Chinese academics, and SUSTech, which has attracted attention through its rapid upward movement in international rankings and the recruitment of top international researchers (see 1st APRA Report, p. 64). In the same city as SUSTech, Shenzhen Technology University was also founded in 2018, which, like a few other less sensational new university establishments, [39]aims to emulate the German University of Applied Sciences system. In the context of the Sino-German College of Intelligent Manufacturing, Shenzhen Technology University has, according to its own brochure, entered into cooperation with OTH Regensburg, Aalen University of Applied Sciences and Munich University of Applied Sciences.

Many newer universities in the above provinces were established as joint ventures with foreign participation. British universities were the pioneers here with the Ningbo (Zhejiang) campus of the University of Nottingham and the joint venture established in 2006 in Suzhou (Jiangsu) between Xi'an Jiaotong University from Shaanxi Province and the University of Liverpool. US universities are now also represented with New York University Shanghai and Duke Kunshan University, initiated in 2012 and 2013 respectively. These universities represent the most significant participations in the extensive education and research cooperation between China and the USA. Recent research identifies a total of 42 international university research ventures by US universities in China, more than four times the number of collaborations with the countries with the next most US research collaborations (i.e. Singapore, Qatar and South Korea).[40] Many collaborations, initiated either directly by universities or with the help of local governments, are now formalised. [41]They are also mainly concentrated in the advanced regions, especially in the most prestigious universities in Beijing (15), Shanghai (9) and Guangzhou (5), although the University of Science and Technology of China in Hefei (Anhui) and Northwestern Polytechnical University in Xi'an (Shaanxi) are also sought-after cooperation partners.

In addition to research cooperations with foreign participation, the influence of Hong Kong universities is particularly pronounced in the Pearl River Delta - and is expected to increase even more in the coming years, according to the 12 STI articles. The importance of Hong Kong universities should not be underestimated, especially in the development of innovation infrastructure in Shenzhen. This applies not only to the establishment of new universities, but also in relation to the establishment of the branch institutes already mentioned above, which are managed locally as so-called New R&D Institutes. The Chinese University Hong Kong represents a particularly good

[39] One of the few examples of start-ups is, for example, the West Yunnan University of Applied Sciences (滇西应用技术大学), which was launched in Dali (Yunnan) in 2017.

[40] Kolesnikov, S., Woo, S., Li, Y., Shapira, P. and Youtie, J. (2019) Mapping the emergence of international university research ventures, Journal of Technology Transfer, 44: 1134-1162.

[41] "IURVs in China are more decentralized, initiated either through an individual university or a local government initiatives. "See: Youtie, J., Li, Y., Rogers, J. and Shapira, P. (2017) Institutionalization of international university research ventures, Research Policy, 46: 1692-1705. (Citation: p. 1697).

example of the extensive activities of Hong Kong universities, especially in Shenzhen. But Hong Kong universities are also present in other cities in the Pearl River Delta.

Table 20: China's main newly founded universities

National start-ups			
ShanghaiTech University	Shanghai	2013	by Shanghai Government and CAS
Westlake University	Hangzhou	2018	Private University
Southern University of Science and Technology (SUSTech)	Shenzhen	2011	by Guangdong Provincial Government
Shenzhen Technology University (University of Applied Sciences)	Shenzhen	2018	by Guangdong Provincial Government and Shenzhen Municipal Government
Newly founded universities with an international partner			
New York University Shanghai	Shanghai	2012	New York University, East China Normal University
University of Nottingham Ningbo China	Ningbo	2004	University of Nottingham, Zhejiang Wanli Education Group
Wenzhou Kean University	Wenzhou	2014	Kean University (New Jersey)
Duke Kunshan University	Kunshan	2013	Duke University, Wuhan University
Xi'an Jiaotong-Liverpool University	Suzhou	2006	University of Liverpool, Xi'an Jiaotong University
Guangdong Technion-Israel Institute of Technology	Shantou	2015	Technion-Israel Institute of Technology, Shantou University, Li Ka Shing Foundation
Shenzhen MSU-BIT University	Shenzhen	2016	Lomonosov Moscow State University, Beijing Institute of Technology, Shenzhen Government
Newly founded universities with Hong Kong partner			
Beijing Normal University-Hong Kong Baptist University United International College	Zhuhai	2005	Beijing Normal University, Hong Kong Baptist University
Chinese University Hong Kong, Shenzhen	Shenzhen	2012	Chinese University of Hong Kong, Shenzhen University

Source: Compilation of the Fraunhofer ISI

New R&D institutes

Besides universities, the establishment of research institutes is the most important form of platform projects for promoting regional innovation-driven development. In recent years, market-oriented research institutes in particular have become the focus of attention.[42] At the national level, the promotion of such institutes is already mentioned as a sub-task in the strategy of innovation-driven development (see above). Most recently, the MOST published the "Guiding Principles for

[42] The New R&D Institutes are compared to several models in China, such as the Federally Funded Research and Development Centers in the US, the Fraunhofer Institutes in Germany, the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, the Korea Institute of Science and Technology (KIST) and the Industrial Technology Research Institute (ITRI) in Taiwan. See: Xu, Wanqiang and Qiao, Nana (2018) Review and Propsect on New Type R&D Institutions in China Based on Domestic Researches from 2001 to 2016 (in Chinese), Science and Technology Management Research, 2018 No. 12, pp. 1-8.

Promoting the Development of New R&D Institutes" (xinxing yanfa jigou) in September 2019.[43]However, the development of these institutes has started at the regional level. New R&D institutes as an umbrella term for various applied research institutes already exist in various provinces; again, Guangdong and Jiangsu are among the pioneers. For example, the "Plan of Liaoning Province for Establishing Innovation Platforms for Production Technologies during the 13th Five-Year Plan Period" [44]takes the two provinces and their best-known institutes as its model.

In 2015, Guangdong consolidated its previous efforts in the establishment of local non-university platform projects in a separate programme and issued trial regulations regarding the support of New R&D Institutes. Based on these and further regulations from 2017, a total of 297 such new R&D institutes were recognised at provincial level by the end of November 2020.[45][46] The Research Institute of Tsinghua University in Shenzhen, which has been operating since 1999, is not only the oldest of the institutes in the programme, but is also widely regarded as the first institute of this new type in China. From Shenzhen, the institutes have gradually spread throughout the province, with most institutes located in the core region in Shenzhen, Dongguan, Foshan and Guangzhou.

According to recent research on this phenomenon, there is a relatively high diversity among the institutes.[47] About half of the institutes are housed in key enterprises in the province (e.g. Midea), where they are intended to serve as a platform for R&D collaboration with other enterprises and academic institutions. A particularly interesting subset of these institutes are those set up by recruited teams to commercialise their own research results or bring them to market with other innovation actors. One example is BGI Shenzhen, which was founded as a non-profit organisation and is now a public institution (without a permanent funding commitment) that has incubated companies such as the listed BGI Genomics based on the public platform. Kuang-Chi Institute of Advanced Technology, an institute founded by Chinese graduates of Duke University in the US and Oxford University in the UK, with commercial offshoots on the Hong Kong and Shenzhen stock exchanges, is also among them. A large number of new R&D institutes, like the aforementioned Tsinghua University institute, have been set up by the local government together with universities, often from outside the province. In the early 2000s, the city of Shenzhen in particular benefited from this, as its institutes at the time were almost exclusively established by universities from Beijing and Hong Kong. Apart from this, Shenzhen has established the Shenzhen Institutes of Advanced Technology (SIAT), CAS, in local-national cooperation with CAS (and the Chinese University Hong Kong), which has the best performance of all CAS institutes in terms of PCT

43 http://www.gov.cn/gongbao/content/2020/content_5469722.htm.
44 http://kjt.ln.gov.cn/xxgk/kjgh/201805/W020180508563410057009.pdf.
45 http://gdstc.gd.gov.cn/HTML/zwgk/zcfg/bmgfwj/1443085303979-1517612351401000 29.html.
46 http://sjfb.gdstc.gd.gov.cn/app/sjkf/index.jsp.
47 Conlé, Marcus; Zhao, Wei and ten Brink, Tobias (2020) Technology Transfer Models for Knowledge-Based Regional Development: New R&D Institutes in Guangdong, China, Science and Public Policy, https://doi.org/10.1093/scipol/scaa063.

patent applications. Finally, there are institutes such as the National Supercomputer Center in Guangzhou, which provides Tianhe-2, one of the fastest supercomputers in the world, for research.

As platform projects, each of these institutes brings together a range of innovation platforms, with a focus on combining applied research, supported by key laboratories and engineering science centres at various levels of government, and incubation, supported by makerspaces and incubator programmes. All institutes are explicitly designed as a drop-in centre for experts and talents from other regions of China and abroad, with access to all existing government recruitment programmes.

Although too little research has been done on this so far, new R&D institutes in other provinces are likely to follow similar development directions. As one of the other pioneers, Jiangsu Province is mainly trying to learn from the experience of the Industrial Technology Research Institute (ITRI) in Taiwan. Among the nationally best-known new R&D institutes from the province is, for example, the Kunshan Industrial Technology Research Institute (KSITRI), founded in 2008. With the Jiangsu Industrial Technology Research Institute (JITRI) initiated in 2013, however, the province has taken a new path that differs structurally from that in Guangdong. JITRI was established on the basis of a merger of 23 existing CAS institutes and universities from the province to promote the commercialisation of new technologies in the strategic sectors of advanced materials, energy and environmental protection, information and communication technology, and biology and medicine.

Summary and conclusions

Summary

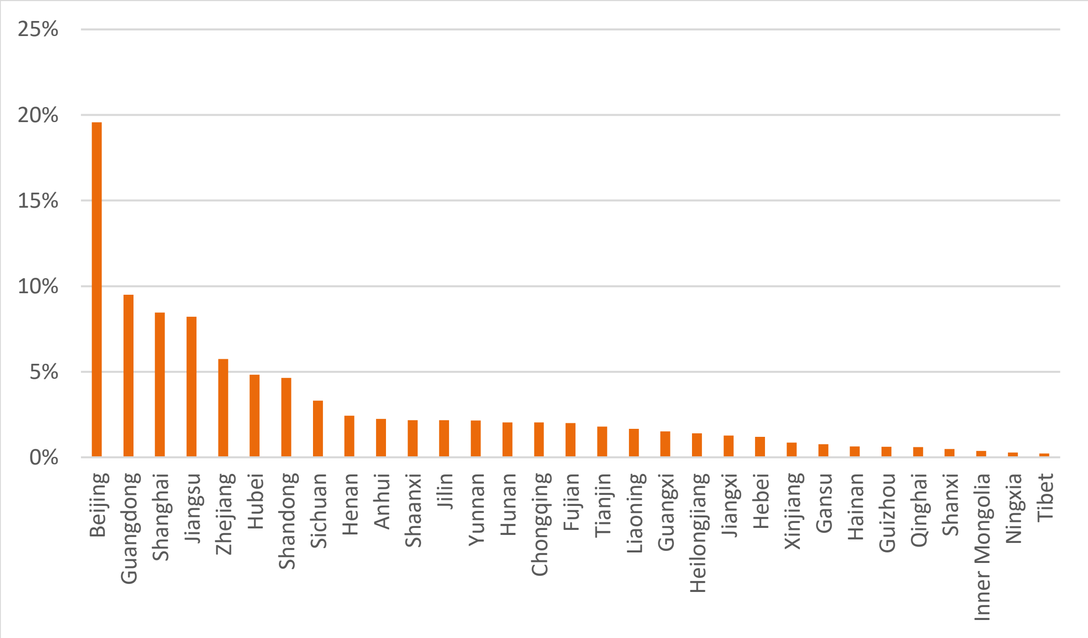
- China's scientific system shows a substantial centralisation on the capital Beijing, China's technological system an almost equally pronounced focus on Guangdong province.
- Through the establishment of new universities and research institutes, Jiangsu, Zhejiang and especially Guangdong and Shanghai have significantly influenced and increased their scientific and technological capacities.
- While regional concentration in the scientific system has gradually decreased in recent years, this is only partly the case in the technological system; growth remains too great even in the leading regions.
- Beijing, Jiangsu, Shanghai and Guangdong are the absolutely decisive locations in almost all subject areas. However, the provinces have very different specialisations, so that important individual players can also be found outside the centres.
- The importance of different provinces for China's scientific cooperation with individual partner countries varies considerably. However, Beijing, Shanghai and Jiangsu are always key partners.
- The ranking of individual institutions differs considerably depending on whether all Chinese or only internationally relevant publications are listed.
- The high-performing universities according to the QS ranking are concentrated in Beijing, Hong Kong and Shanghai, and - to a lesser extent - in Jiangsu. Zhejiang has at least one particularly high-performing university, Zhejiang University.
- The regional distribution of collaborations with Chinese researchers listed in DFG proposals shows a very strong concentration in Beijing; the provinces of Jiangsu and Shanghai are much less well represented, followed at some distance by Hubei and Guangdong.
- Shanghai, Beijing and Hong Kong also dominate by a wide margin in the choice of location for German DAAD scholarship holders, although there are differences between the disciplines.
- The origin of Chinese applicants for cooperation agreements with German universities shows a much more balanced picture. The provinces of Shandong, Sichuan and Zhejiang are also comparatively well represented here. The regional distribution differs for the different types of institutions in Germany, and universities of applied sciences play a greater role than universities in terms of size.
- In the strategic project of the Double First-Class University Plan, the focus on Beijing also remains, and the other provinces of Shanghai, Jiangsu and Hubei, which are comparatively more strongly considered, do not suggest any fundamental changes to the current distribution.
- Regional STI policy is closely integrated into the long-term, innovation-driven economic policy of the central government through objectives, plans and allocation of specific tasks. Within the general policy framework, local governments can develop their own STI priorities according to their resources.
- Local governments play a central role in building local infrastructure and promoting strategic technologies and industries. The most important instruments are regional clustering, based on the implementation of a variety of different innovation projects, especially projects to build innovation platforms (e.g. focal point labs, innovation centres, technology service platforms).

Conclusions

- The leading regions of Beijing, Shanghai, Jiangsu and Guangdong continue to be the centre of many activities relevant to international cooperation.
- Notwithstanding this, relevant activities in many other regions have also reached a sufficient level in absolute and qualitative terms to warrant international attention.
- In addition to Germany's cooperation activities, which have so far focused primarily on Beijing and Shanghai, there are additional opportunities for scientific cooperation, especially in southern China.
- In addition, specialised research institutions or companies are also relevant for establishing contacts outside the centres; this requires thematically specific individual case studies.
- The establishment of additional scientific centres and institutions also offers international partners new points of contact for scientific or, in a broader sense, academic cooperation.
- Many regional governments are closely integrated into the central government's science and innovation policy in the area of planning and - even more so - in the area of implementation and funding, and are thus important contacts in scientific and technological cooperation.
- The local STI policy focuses primarily on cluster formation and integration of high-tech zones. The emerging innovation infrastructure with its diverse range of scientific facilities, equipment and innovation services also offers foreign actors interesting starting points for cooperation.
- With regard to a long-term broad impact on the entire spectrum of Chinese provinces, the expansion of cooperation and partnership programmes of universities appears to be an interesting strategy. Universities of applied sciences can make an important contribution here.
- Several of the parameters examined (Double First-Class University Plan, conferences with DAAD-funded participants, university rankings for the individual disciplines) indicate that the western region of Shaanxi could offer interesting points of contact in the field of engineering.

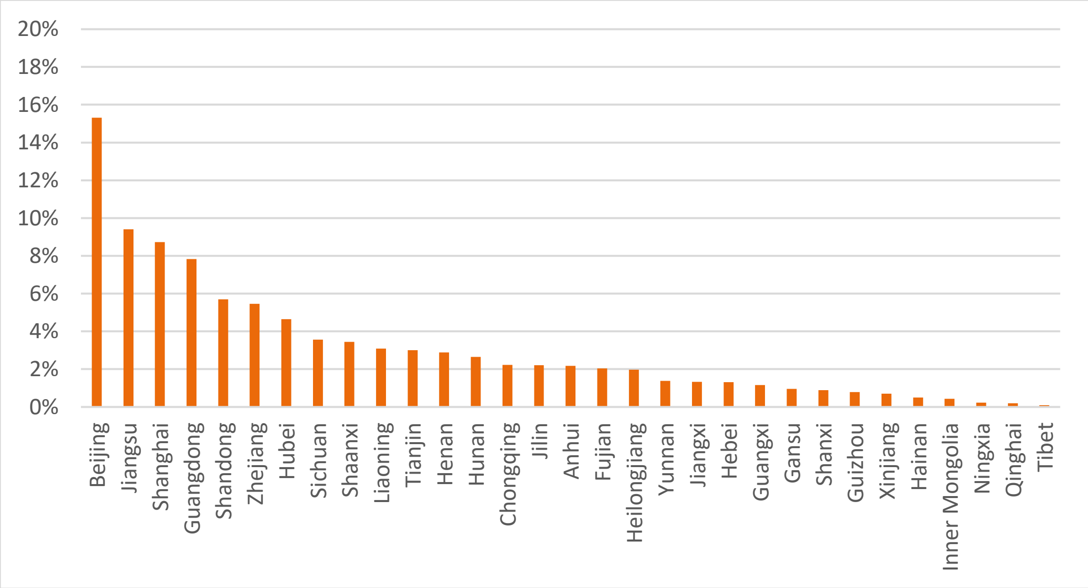
Annex II: Subject-related detailed analyzes for Chapter 3

Figure A1: Share of Chinese provinces in the number of publications in the field of pandemics



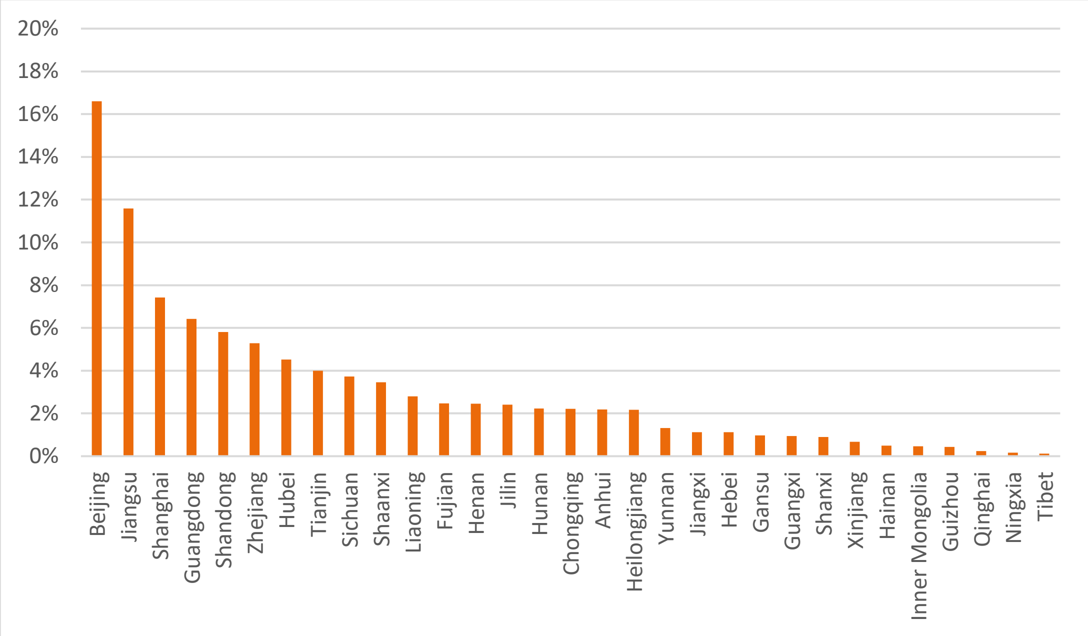
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A2: Share of Chinese provinces in the number of publications in the life sciences



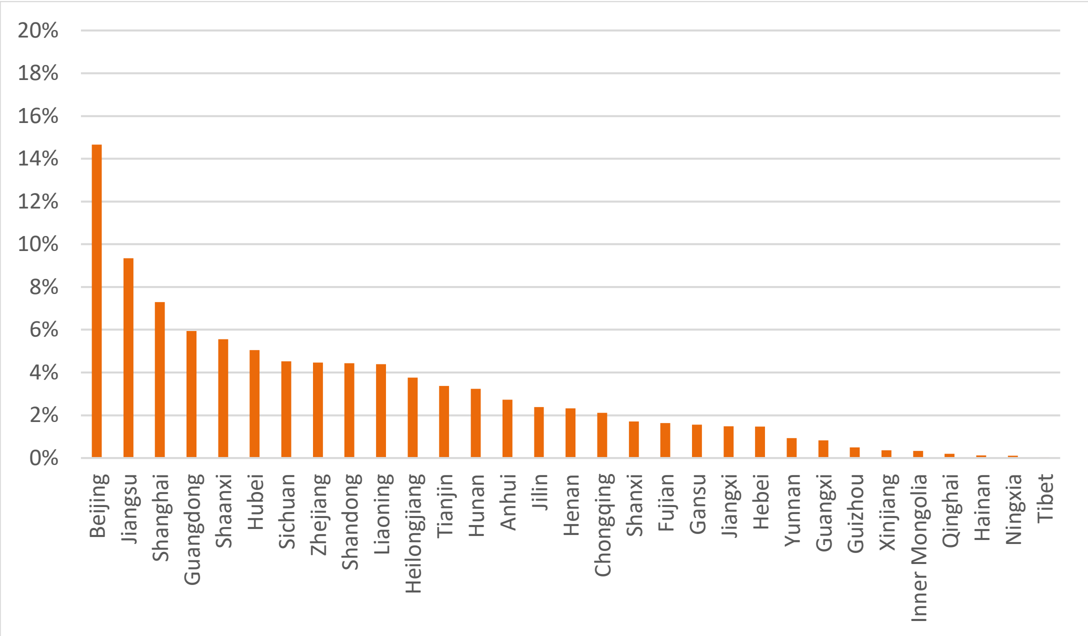
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A3: Share of Chinese provinces in the number of publications in the field of industrial biotechnology



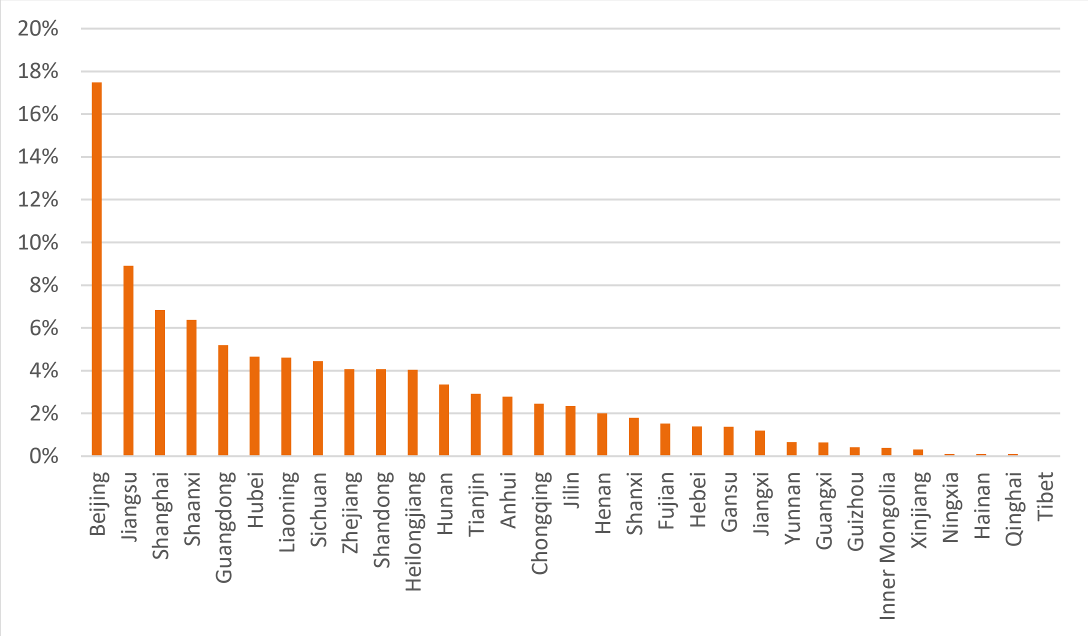
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A4: Share of Chinese provinces in the number of publications in the field of nanotechnology



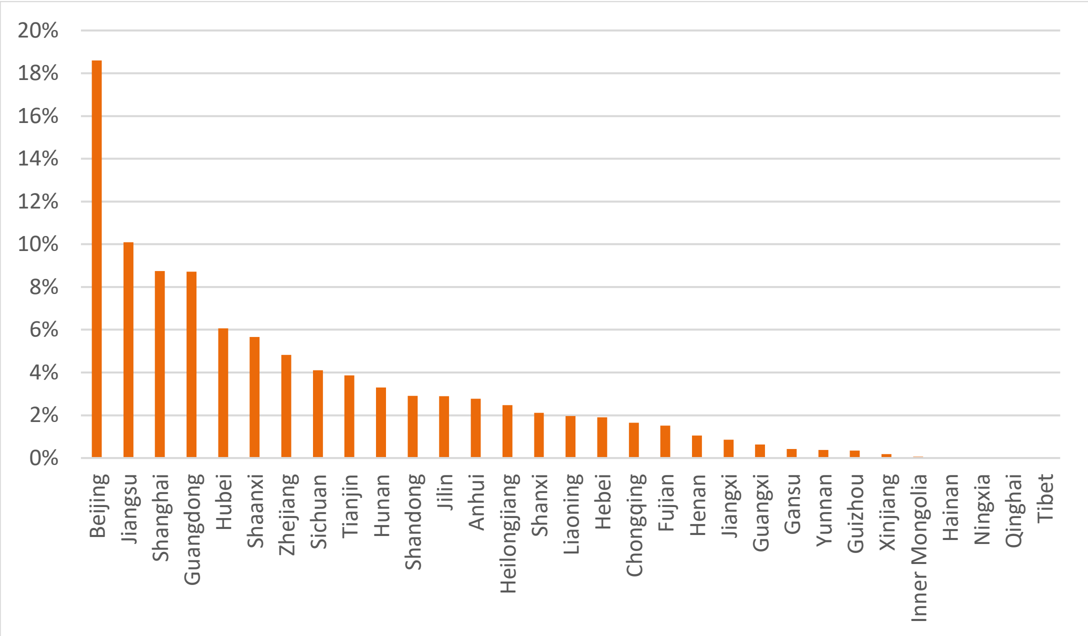
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A5: Share of Chinese provinces in the number of publications in the field of micro- and nanoelectronics



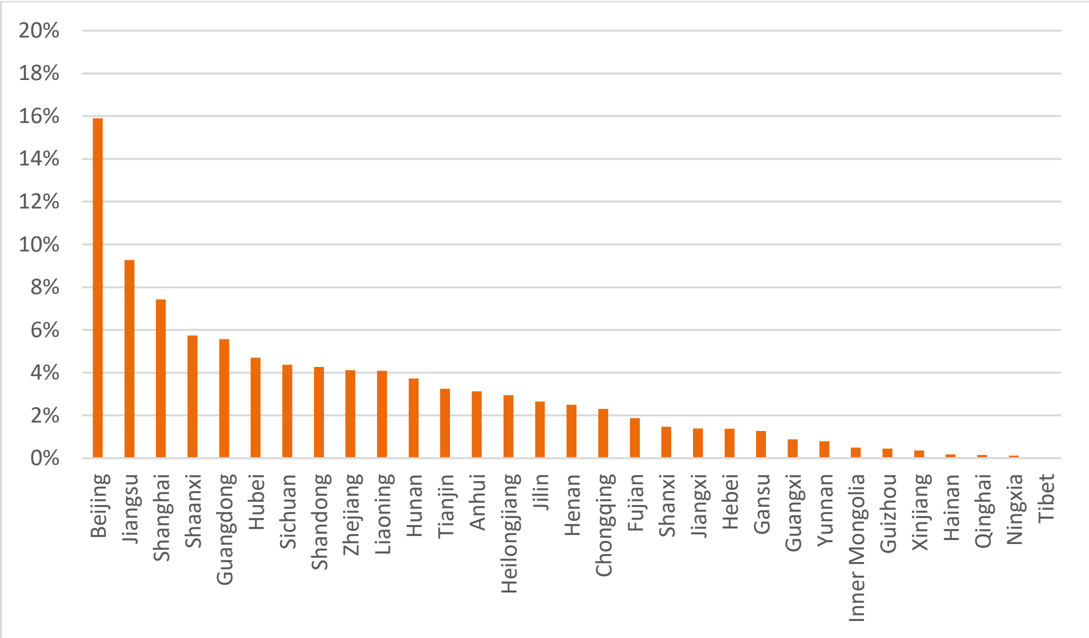
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A6: Share of Chinese provinces in the number of publications in the field of photonics



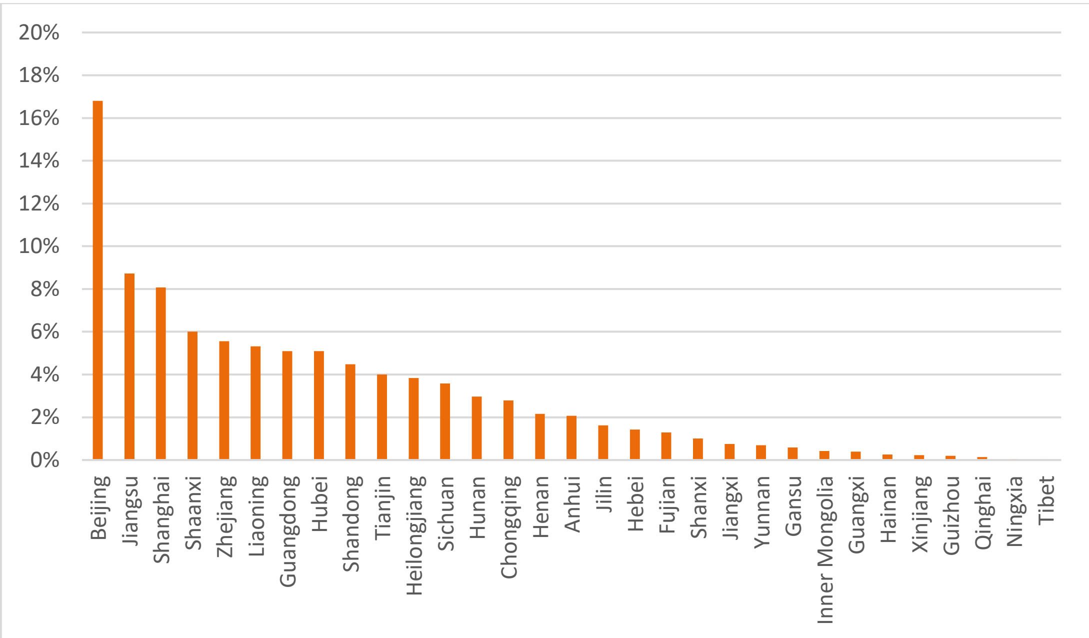
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A7: Share of Chinese provinces in the number of publications in the field of new materials



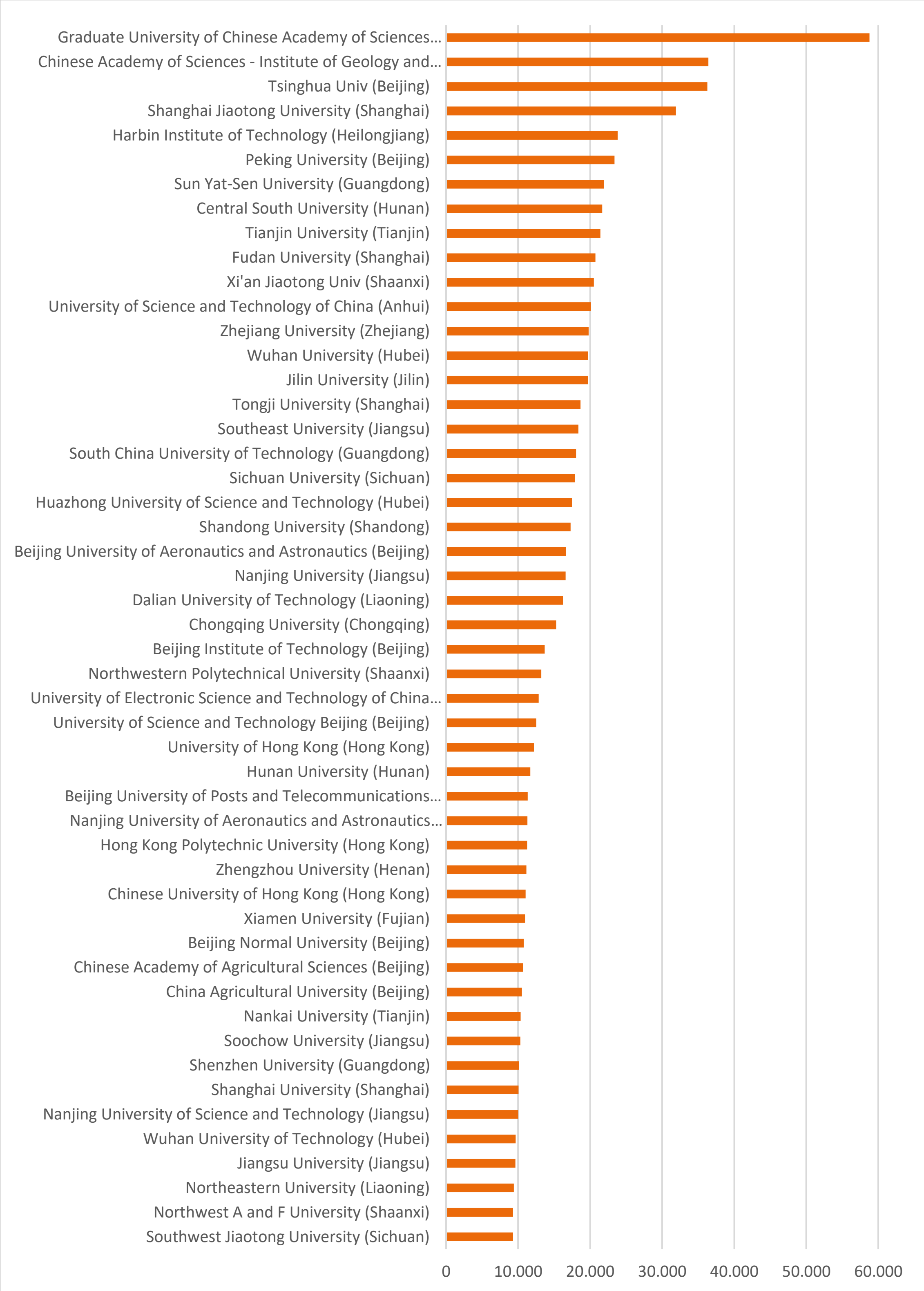
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A8: Share of Chinese provinces in the number of publications in the field of novel manufacturing technologies



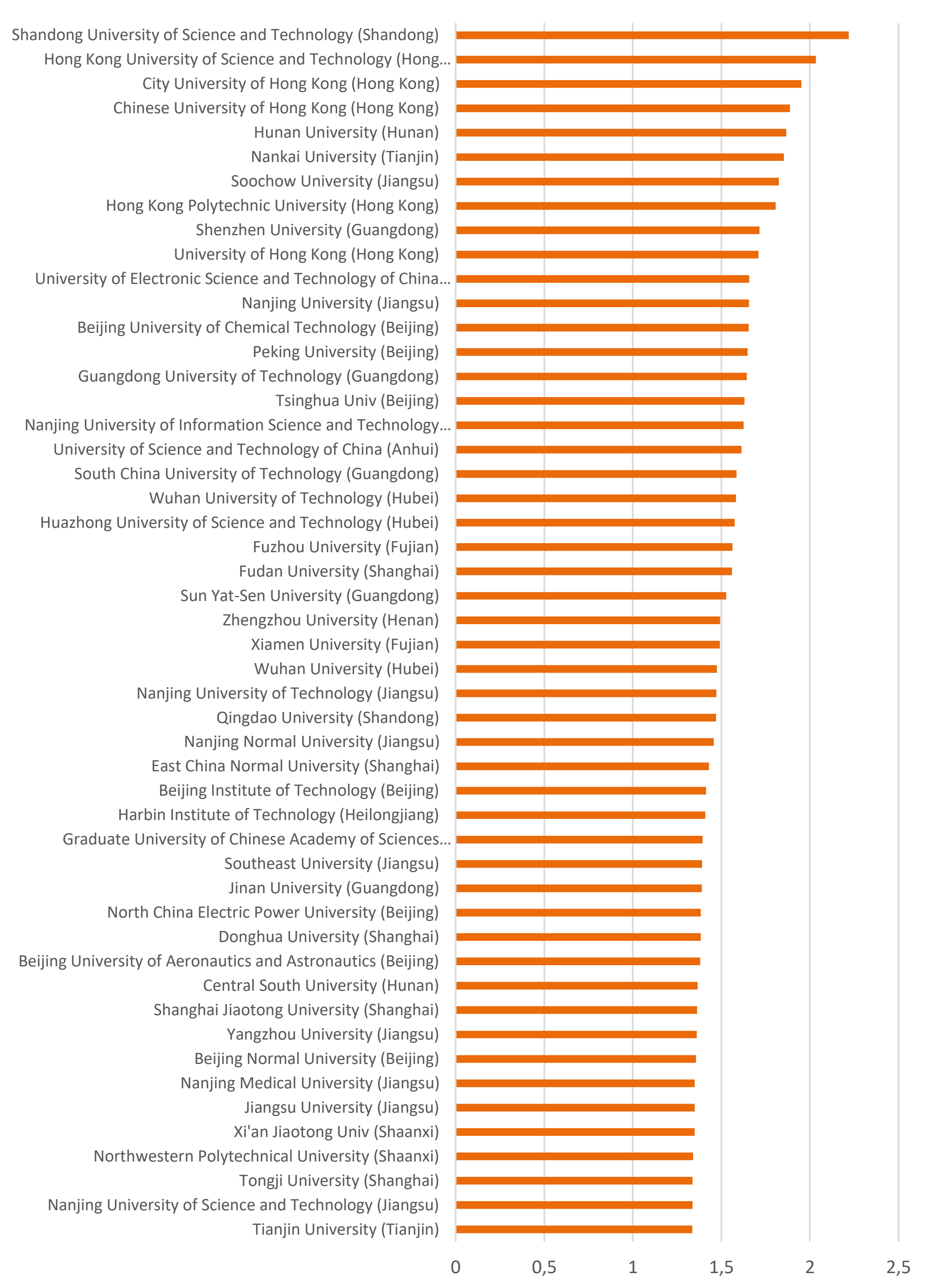
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A9: Publications from central Chinese institutions, total 2017-19



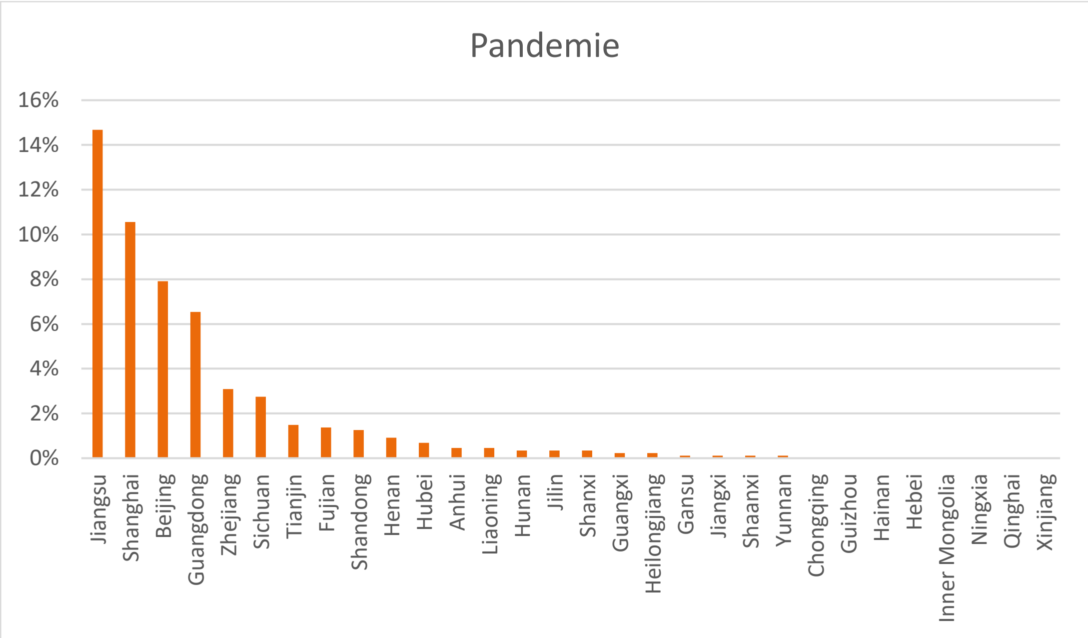
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A10: Crown indicator of central Chinese institutions, total 2017-19



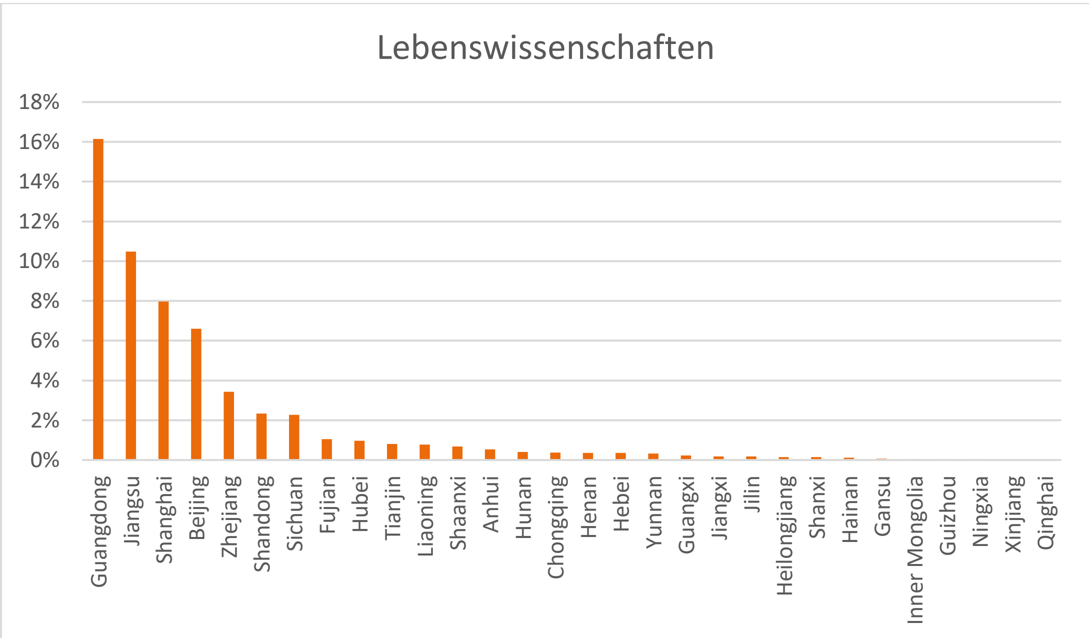
Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Figure A11: Shares of Chinese provinces in transnational patents in the pandemic subject area



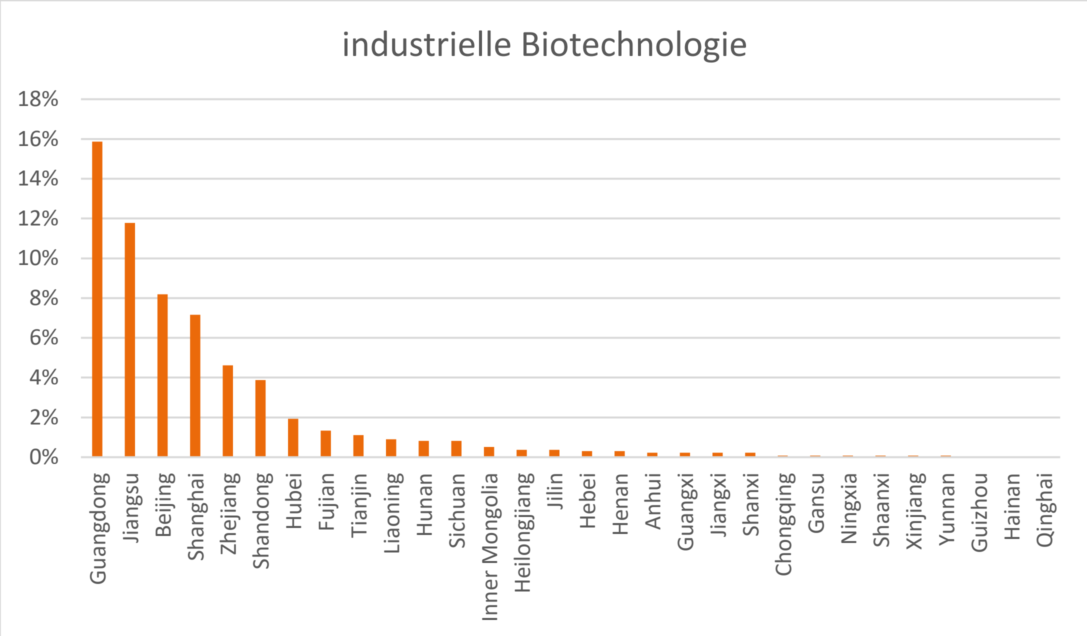
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A12: Shares of Chinese provinces in transnational patents in the life sciences



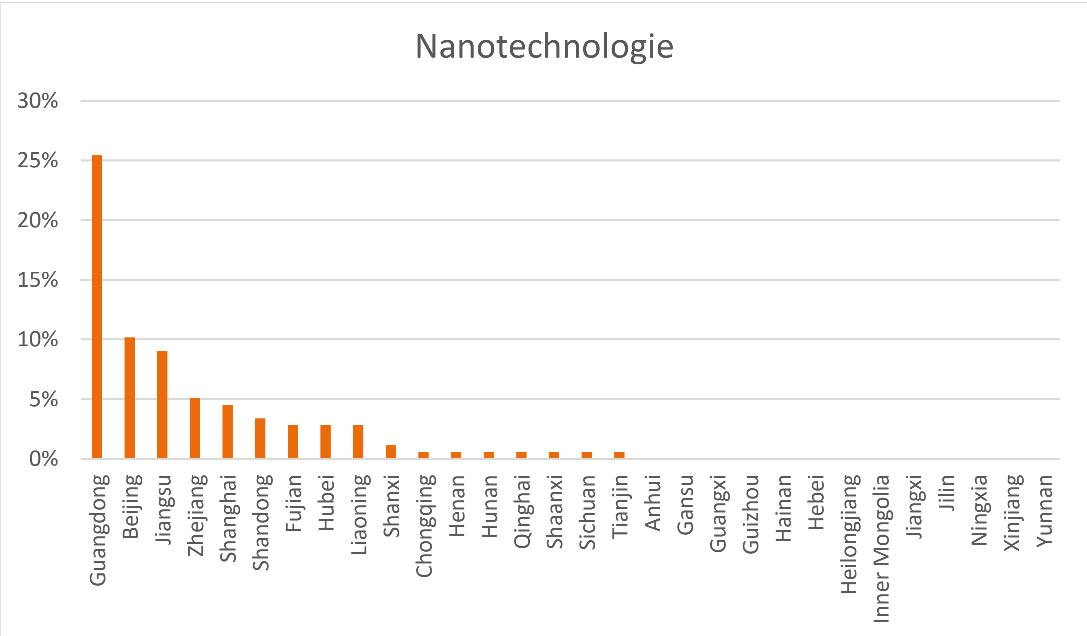
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A13: Shares of Chinese provinces in transnational patents in the field of industrial biotechnology



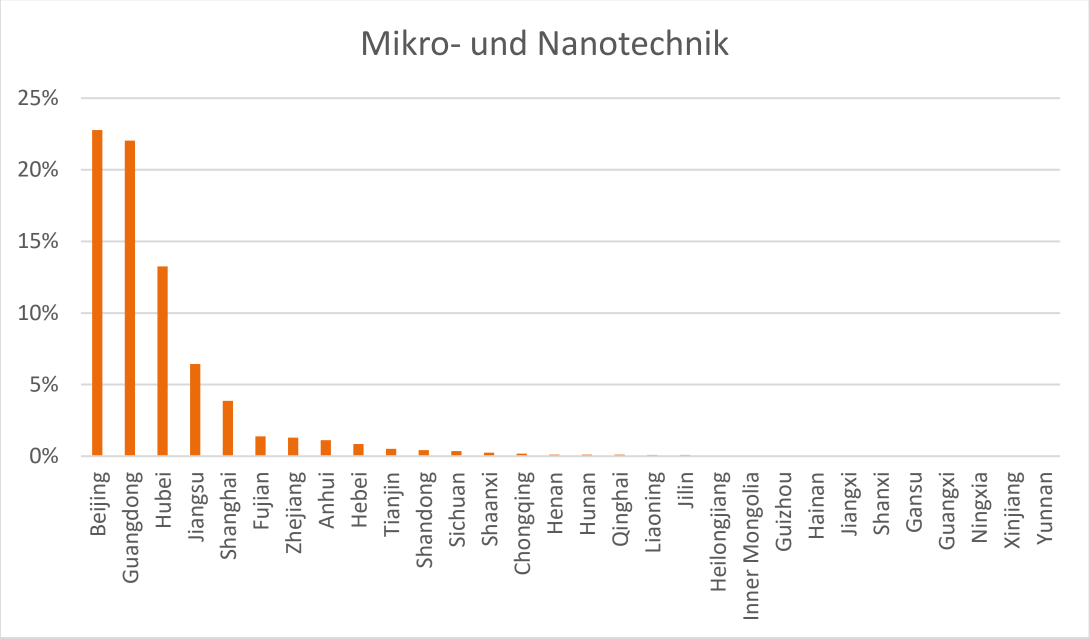
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A14: Shares of Chinese provinces in transnational patents in the field of nanotechnology



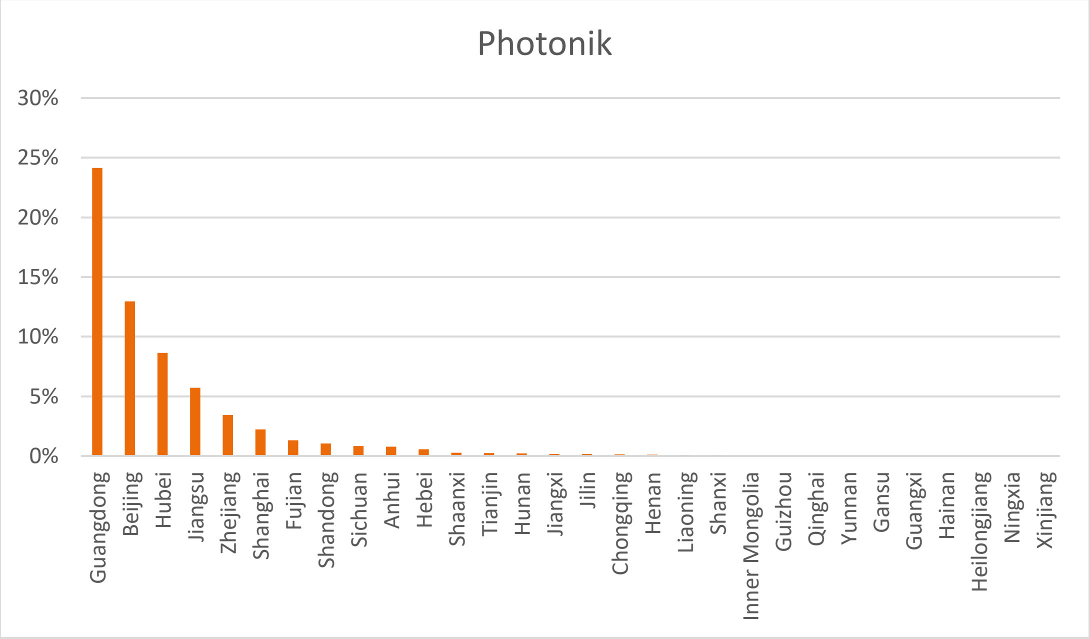
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A15: Shares of Chinese provinces in transnational patents in the field of micro- and nanoelectronics



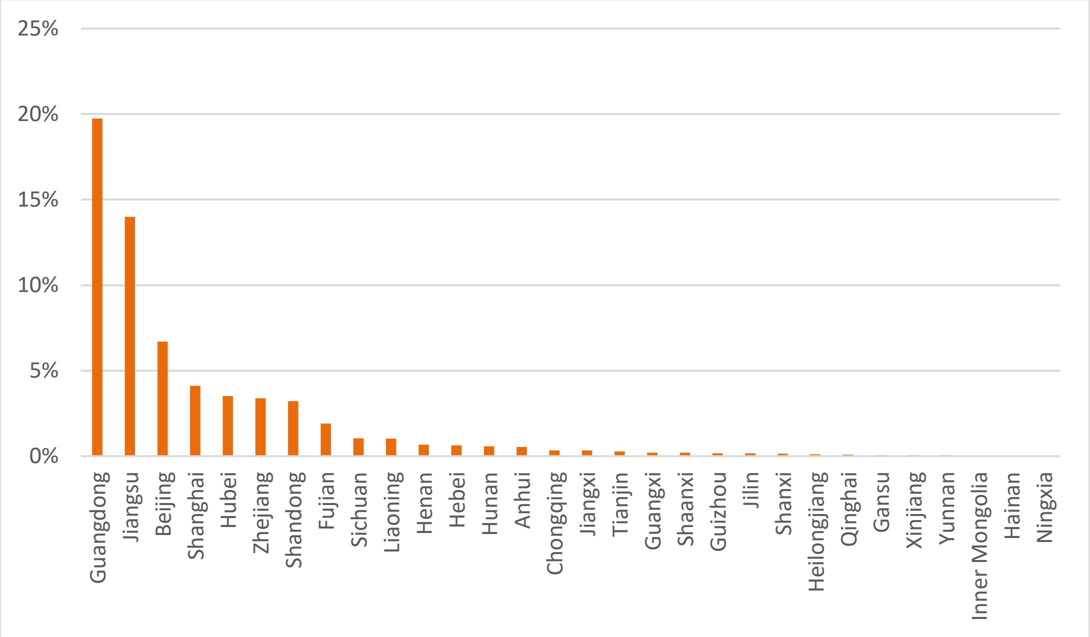
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A16: Shares of Chinese provinces in transnational patents in the field of photonics



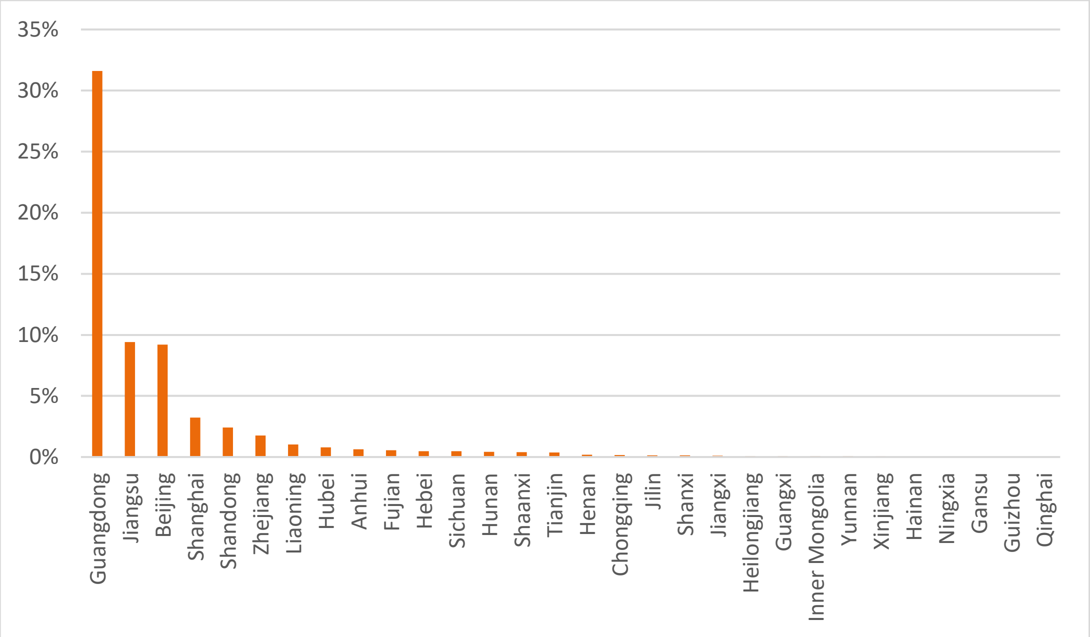
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A17: Shares of Chinese provinces in transnational patents in the field of novel materials



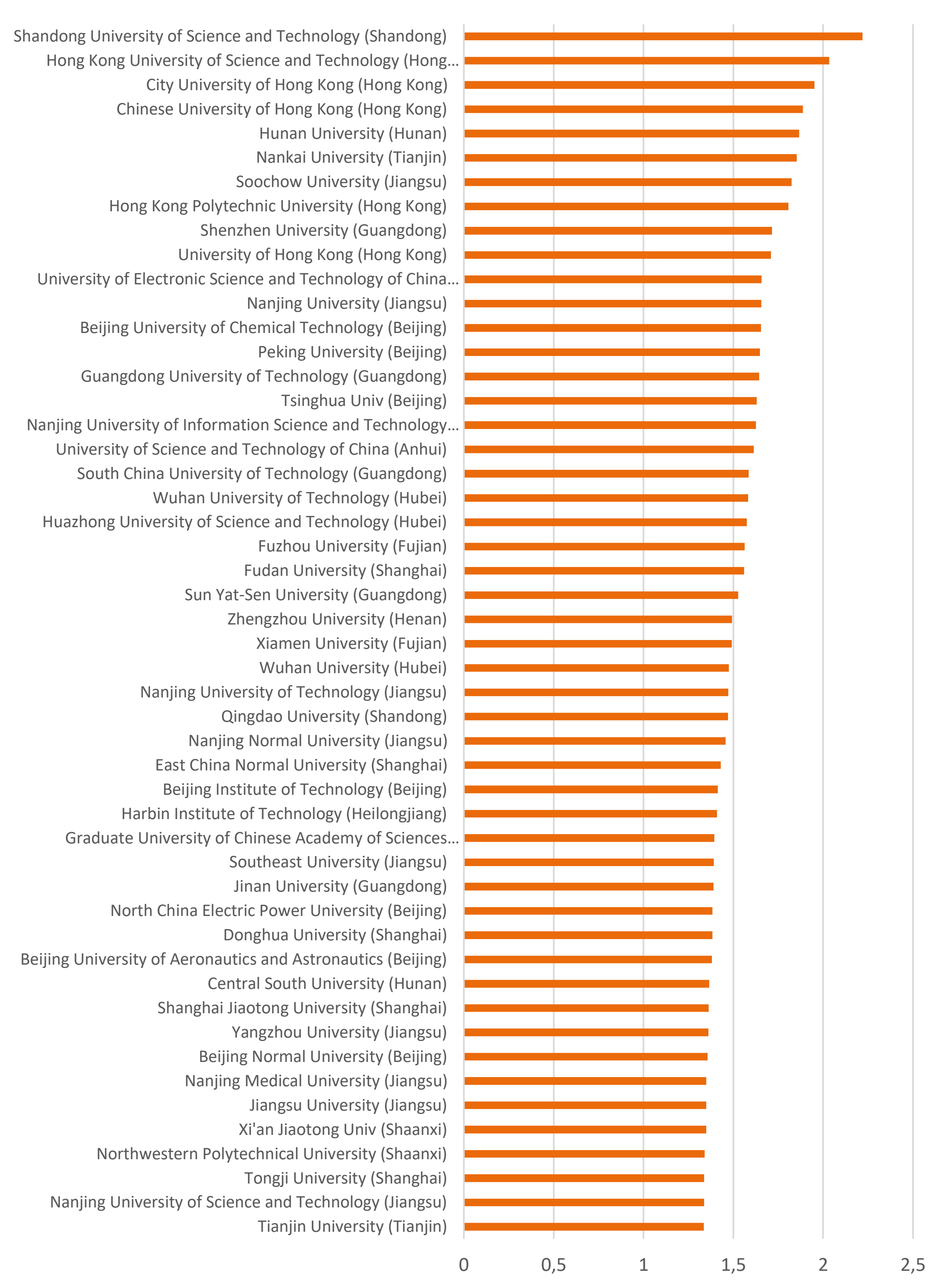
Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A18: Share of Chinese provinces in transnational patents in the field of novel manufacturing technologies



Source: Calculations by Fraunhofer ISI based on EPA PATSTAT

Figure A19: Crown indicator of central Chinese institutions, total 2017-19



Source: Calculations by Fraunhofer ISI based on Elsevier SCOPUS

Annex III: Central University Actors in China

Table A1: Regional distribution of the Chinese institutions listed among the best 500 universities in the QS University Ranking of 2021

		Natural Sciences	Life Sciences and Medicine	Engineering and Technology	Humanities and Arts	Social Sciences and Management
Anzahl		**41**	**28**	**40**	**24**	**26**
Provinz		Rang	Rang	Rang	Rang	Rang
Anhui	**University of S&T of China**	35	286	67		305
Hubei	China University of Geosciences	451-500				
Hubei	**Huazhong University of S&T**	242	292	100		401-450
Hubei	**Wuhan University**	146	247	156	224	168
Hunan	Central South University		386			
Hunan	Hunan University	451-500				
Beijing	**Beihang University**	302		221		
Beijing	**Beijing Institute of Technology**	295		167		
Beijing	**Beijing Jiaotong University**			401-450		
Beijing	**Beijing Normal University**	202	401-450	327	150	151
Beijing	**Beijing University of Chemical Technology**	451-500		451-500		
Beijing	**Beijing University of Technology**	451-500		383		
Beijing	China Agricultural University		310			
Beijing	**Peking University**	17	53	22	38	20
Beijing	**Renmin University of China**			451-500	110	89
Beijing	**Tsinghua University**	16	129	9	56	32
Beijing	**University of S&T Beijing**	302		314		
Fujian	**Xiamen University**	275	401-450	359	451-500	401-450
Guangdong	**South China University of Technology**	364		277		
Guangdong	**Sun Yat-Sen University**	153	165	208	231	199
Hongkong	**City University of Hong Kong**	197		90	113	69
Hongkong	**Hong Kong Baptist University**	451-500		451-500	250	344
Hongkong	Lingnan University				357	

Hongkong	**The Chinese University of Hong Kong**	104	83	72	39	41
Hongkong	**The Hong Kong Polytechnic University**	201	390	82		72
Hongkong	**The Hong Kong University of S&T**	40	355	18	250	33
Hongkong	**The University of Hong Kong**	49	50	39	27	21
Jiangsu	Nanjing Agricultural University		401-450			
Jiangsu	Nanjing Medical University		451-500			
Jiangsu	**Nanjing University**	60	208	117	160	196
Jiangsu	**Soochow University**	451-500	451-500			
Jiangsu	**Southeast University**	401-450	451-500	318		
Macao	University of Macao					451-500
Shandong	**Shandong University**	282	365	301	401-450	451-500
Shanghai	East China Normal University	401-450				
Shanghai	**East China University of S&T**	401-450		401-450	348	
Shanghai	**Fudan University**	39	82	50	68	47
Shanghai	**Shanghai Jiao Tong University**	55	102	26	164	58
Shanghai	**Shanghai University**	331		337		401-450
Shanghai	Shanghai University of Finance and Economics					401-450
Shanghai	**Tongji University**	362	364	164	219	401-450
Tianjin	**Nankai University**	202	451-500	383	451-500	401-450
Tianjin	**Tianjin University**	329		247		
Zhejiang	**Zhejiang University**	63	146	32	164	89
Heilongjiang	**Harbin Institute of Technology**	246		119		
Jilin	**Jilin University**	242	401-450	277		
Liaoning	**Dalian University of Technology**	390		323		
Liaoning	Northwestern Polytechnical U			451-500		
Liaoning	**Xi'an Jiaotong University**	195	328			
Gansu	Lanzhou University	401-450				
Shaanxi	Xi'an Jiaotong University			93		308
Sichuan	**Sichuan University**	401-450	286	401-450	451-500	
Sichuan	University of Electronic S&T of China			401-450		

Note: The classifications for the subject-specific rankings are given and the universities have been assigned to the respective provinces. Institutions that are among the top 500 universities for more than one subject category are shown in bold letters.

Source: Calculations by Fraunhofer ISI from available data from the QS World University Rankings by Subject 2020, https://www.topuniversities.com/subject-rankings/2020

Annex V: Regional focus in China

Table A2: Megaprojects of selected provinces during the 13th Five-Year Plan period (2016-2020)

Guangdong	Anhui	Hubei	Hunan
Computing and communication integrated chips	New electronic display	Advanced memory, optical communications and 5G networks	Key technology research and application of intelligent complete sets of equipment for super underground projects
Key technologies and devices for mobile Internet	Intelligent linguistic system	Efficient processing and intelligent analysis of big data from mapping and remote sensing	
Cloud computing and big data management techniques	High-performance special-purpose integrated circuits	Laser precision manufacturing	Hunan Province birth defects collaborative prevention and treatment science and technology major special project
Intelligent Robotics	Robots	Smart and Internet connected vehicles	
New Energy Vehicle Batteries and Power Systems	High-end numerical control equipment	Intelligent construction	
Additive manufacturing (3D printing) technology	Rail transportation equipment	Hubei traditional Chinese medicine quality control standard material research	
New (OLED) display printing technology and materials	Aviation equipment	Next generation artificial intelligence technology	
Third generation semiconductor materials and devices	New energy vehicles		
Precision Medicine and Stem Cells	New materials		
Automated Intelligence Technology	Quantum communication		
	Big data-based technology services		
	Biomedicine		
	Environmental monitoring and governance		
	High-end medical devices		
	Biological breeding		
	Agriculture product refinement		
	Intelligent agriculture		
	Modern agricultural equipment		
	Agroecology and environmental protection		

Source: Fraunhofer ISI calculations

Table A3: Guangdong's "12 STI Articles"

1) Support the development of a Greater Bay Area Innovation Centre.

In the context of strengthening the cross-regional concentration of innovation resources, the province is working to build an international innovation centre to better integrate the entire Greater Bay Area (Yue-Gang-Ao Dawanqu) with Guangdong, Hong Kong and Macao, ensuring better use of the diversity of regional resources and institutional systems. Following the joint agreement of the regions concerned and the NRDC in July 2017 and the Greater Bay Area Development Plan in February 2019, which was released almost simultaneously, the 12 STI articles envisage the establishment of a more dynamic scientific cooperation system, including the promotion of branch institutions established in Guangdong by Hong Kong and Macao universities, research institutes and enterprises. This is also to be done against the background of the Guangdong provincial government's efforts to establish another Comprehensive National Science Centre in addition to the three existing centres in Zhangjiang (Shanghai), Hefei and Huairou (Beijing). Further large-scale research facilities are to be established for this purpose, while the existing large-scale facility China Spallation Neutron Source (CSNS) in Dongguan is to be opened to scientists from Hong Kong and Macao.

2) Encourage Hong Kong and Macao universities and research institutes to take up provincial-level S&T projects.

Universities and research institutes from Hong Kong and Macau have so far been able to access the megaprojects at provincial and local level by establishing branch institutes in Guangdong. The 12 STI Articles provide that universities and research institutes can now apply for megaproject funding from Hong Kong and Macau. If successful, the institutions are to receive ownership rights for the research results. In return, efforts are to be made to commercialise the technologies in Guangdong.

3) Promoting the formation of a "highland" for innovative talent

The province wants to become a stronger magnet for innovation talent from all over the world. To this end, it is trying to realise synergy effects between the talent acquisition programmes and the regional research funding programmes, especially the megaprojects. The environment for recruited scientists and engineers is to be improved by adjusting the rules for residence permits, visa issuance and other relevant rules on the one hand, and by offering advantages in terms of housing and work-life balance on the other.

4) Accelerate the establishment of Provincial Laboratories and New R&D Institutes.

Guangdong has set out to massively advance the establishment of innovation platforms (see below). On the one hand, Guangdong wants to establish ten provincial laboratories analogous to the national laboratories and large-scale research institutions at the national level (see 1st APRA Report, p. 69). In addition, the province is continuing its policy of promoting New R&D Institutes. In establishing the institutes, the province mainly seeks cooperation with domestic and foreign renowned universities and research institutions, global top 500 companies and central state-owned enterprises. New R&D institutes are to be granted a decision-making right on (state) investment of 30 million Yuan RMB.

5) Accelerate reform and innovative development of high-tech zones.

Guangdong has the second most national high-tech zones after Jiangsu (see above). By the end of 2022, more than 40 new high-tech zones are to be added at the provincial level. A development fund is to be established to enhance the promotion of the high-tech zones and high-tech enterprises within the zones. Furthermore, the administrative bodies of the zone are to be reformed and equipped with more economic competences.

6) Increasing support for business innovation

State support for innovation processes in firms is to be further expanded. This includes financial support measures and comprehensive tax benefits for firm R&D, support for growth firms in raising funds via an IPO at home and abroad, issuing innovation vouchers for the purchase of innovation services by technology-based small and medium-sized enterprises and entrepreneurs, encouraging the establishment of provincially-affiliated innovation centres for technology, industry or production (see efficiency chapter) to strengthen cooperation between firms, universities and research institutions, and establishing a procurement system (in line with international principles) for innovative products.

7) Completing the "last mile" in the commercialisation of research results.

In order to achieve greater commercialisation of research results, Guangdong is focusing on improving support for the final stages of the commercialisation process. For example, a mechanism for continued support of national priority projects will be established. National projects are to be specifically solicited in order to commercialise them locally in Guangdong. Furthermore, better incentives for universities and research institutions for technology transfer, for example through more favourable revenue regulations and more advantageous property rights, are to be created and specialised service providers are to be promoted.

8) Promoting S&T merger and funding

The financing of innovation processes is an important problem that has the highest priority at all levels in China. State steering funds (yindao jijin) have played a particularly large role in this regard in recent years. [48]In addition to capital from the government at the relevant level, the funds collect capital from other investors, such as state-owned banks and firms, non-state firms and venture capitalists, and also foreign investors. The government thus uses its deployed capital as leverage to generate additional investment funds, which are channelled into the local government's preferred strategic sectors. According to the 12 articles of the STI, the investment fund is to fulfil its steering function by investing more in high-tech start-ups. In order to attract additional capital providers, banks are to be encouraged to create special services for technology loans and a reserve from public finances is to be created to partially absorb losses from loans to local growth-oriented technology companies. Venture capitalists who lend to local high-tech start-ups are to be rewarded. In addition, a fintech industry is to be established in cities that meet the necessary requirements.

9) Strengthening the guarantee of land for R&D activities

The shortage of building land in many provinces, including Guangdong, calls for better land use planning. Guangdong wants to ensure that sufficient land is available for priority projects. At the same time, brownfield projects, especially the establishment of science and technology parks and business incubators that contribute to the redevelopment of old towns, villages and factories (the "three old ones", san jiu), will be supported with simplified rules and various benefits. Incubators that increase their building density and floor area, as well as universities and research institutions that use previously unused space and real property to set up makerspaces, incubators and accelerators, will also draw financial benefits.

10) Improving the balance and coordination between regional innovation development

While the national plan for innovation-driven development focuses on reducing the significant disparities between the east coast and inland provinces, provinces such as Guangdong have to cope with significant disparities within the province. In line with the national strategy, Guangdong aims to provide regionally differentiated policy support. This specifically means special support for projects carried out in the areas outside the Pearl River Delta and the Special Economic Zones. The establishment of new R&D institutes, branches of universities, research institutions, renowned hospitals and national key laboratories are mentioned here. High-tech companies that move their headquarters to these regions are to be rewarded with special tax

[48] http://chinainnovationfunding.eu/technology-innovation-guiding-fund/ (no longer accessible!); https://web.archive.org/web/20200927075929/http://chinainnovationfunding.eu/technology-innovation-guiding-fund/.

benefits. The "sailing plan" (yangfan jihua), a provincial fund for attracting talent and innovation projects, is also to be used for the development of the outer region of the province.

11) Strengthening research integrity and research ethics

The 12 STI Articles coincide with the high-profile case of biophysicist He Jiankui, who lost his job at the Southern University of Science and Technology (SUSTech) in Shenzhen after a lecture in November 2018 in which he presented his research on altering the genetic make-up of a pair of twins conceived through artificial insemination using the CRSIPR/Cas method, and has since been sentenced to three years in prison and a hefty fine. Also in response to this incident, the 12 STI Articles provide for the establishment of ethics committees in all institutions involved in biomedical research on humans and the production and use of laboratory animals. In addition, research activities on the hazard potential of biology, medicine, artificial intelligence and other new fields for society and the environment are to be promoted.

12) Intensify the reform of decentralisation of management in the S&T sector.

Finally, the reform and simplification of administrative processes is to be intensified by, on the one hand, transferring more STI competencies from the provincial level to the cities, starting with Guangzhou and Shenzhen, and, on the other hand, leaving project fund management to the universities and research institutions.

Source: People's Government of Guangdong Province, own translation [49]

[49] http://www.gd.gov.cn/zwgk/wjk/qbwj/yf/content/post_1054700.html.

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