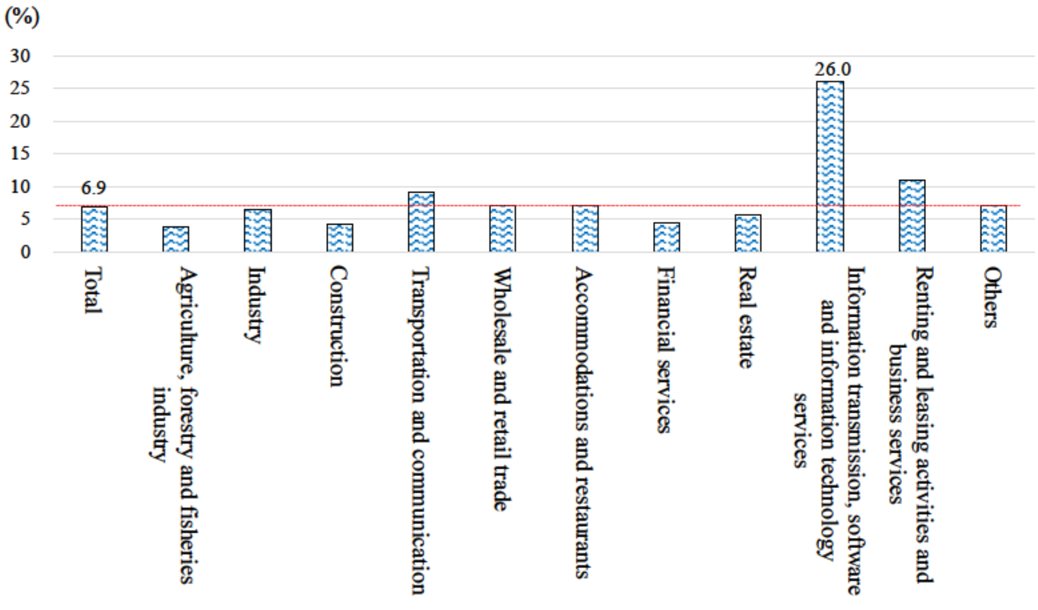
Section 2　Advance of new industries

1. New industries

In the previous section, it was noted that in China, there is an ongoing shift in the industrial structure to the tertiary industry and in the demand structure from investment to consumption. Here, we will look at how businesses that provide new services connected with the internet are developing in the tertiary industry and how they are promoting the expansion of consumption.[95] First, we will examine the growth in information transmission, software and information technology services in terms of share in China's GDP and the development of emerging companies, mainly those providing internet-based services. Next, we will provide an overview of the usage of the internet and the expansion of the scale of the e-commerce market. In addition, with a focus on internet-based services for consumers, we will look at what the user profile is and what kinds of services are used. We will also provide an overview of trends in the so-called sharing economy. While looking at these matters, we will consider the impact on employment in addition to the scale of the economy.

One distinctive feature of new industries in recent China is that companies providing services that form business infrastructure, known as platformers, are acting as a driving force against the backdrop of the development of the internet and the diffusion of mobile terminals. A look at the real GDP growth rate by industry in China in 2017 shows that information transmission, software and information technology services achieved an outstanding growth rate of 26.0%[96] (Figure II-3-2-1).

Figure II-3-2-1　Changes in real GDP growth rates in China by type of industry (2017)



Source: National Bureau of Statistics of China, CEIC Database.

95 These new industries are sometimes collectively referred to as the "new economy" as opposed to the "old economy," the collective name for traditional industries, such as steel. Depending on the viewpoint, they may be referred to by various names, including digital economy, electronic commerce (e-commerce), online business, and IT platforms.

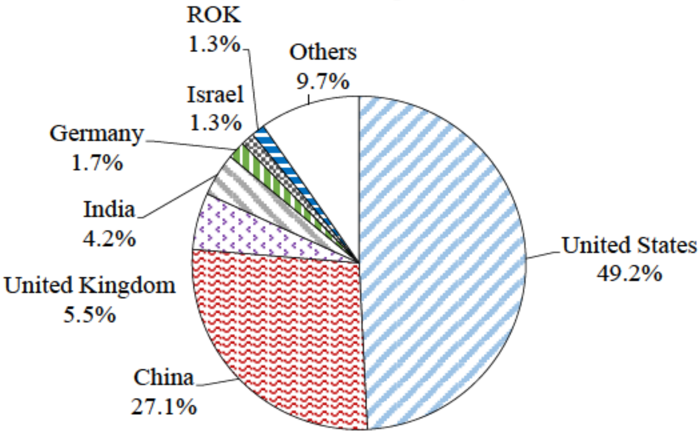
96 "Information transmission, software and information technology services" is a new category within the tertiary industry that was created in 2017.

In this situation, rapidly growing emerging companies have been born in China. For example, of the 236 unlisted startup companies valued at one billion dollars or higher, which are known as unicorn companies, in the world, 64 are Chinese companies (a share of 27.1%). This number is the second highest, after the number of U.S. unicorn companies, which is 116 (49.2%) (Figure II-3-2-2).[97] In terms of market capitalization, Chinese unicorn companies have a higher share than their share in terms of the number of companies, with their combined market capitalization at 281.0 billion dollars (34.6%), out of the total market capitalization of all unicorn companies, which is 811.0 billion dollars.

Regarding super-unicorn companies, which are even larger (valued at 10 billion dollars or higher), there are only 16 companies in the world, of which seven are Chinese companies and eight are U.S. companies (Table II-3-2-3). Another notable point is that there are many internet-related companies. For example, there are many companies providing internet-based services for consumers, including internet financial and settlement services, taxi dispatching service, and restaurant search and coupon issuing services, and news site operation. In the manufacturing industry as well, manufacturers of internet-related equipment including smartphones are among the top positions in the rankings.

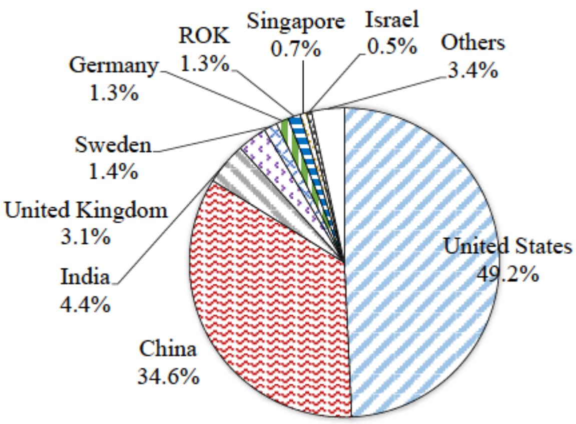
Figure II-3-2-2 Unicorn companies by country

(Number of companies)



Source: *CB Insights*.

(Assessed value)



Source: *CB Insights*.

97 Compiled based on the data available on the website of CB Insights as of March 13, 2018.

Table II-3-2-3 Super-unicorn companies

Nationality	Type of industry	Market capitalization (USD)
United States	Transportation-related services	68.0 billion
China	Financial services	59.9 billion
China	Transportation-related services	50.0 billion
China	Devices and hardware	46.0 billion
United States	Tourism-related services	29.3 billion
United States	Business services	20.0 billion
China	Financial services	18.5 billion
China	Lifestyle-related services	18.0 billion
United States	Real estate (office sharing)	16.9 billion
United States	Hardware	12.0 billion
China	Culture and entertainment (news application)	11.0 billion
United States	Social networking services (image sharing)	11.0 billion
China	Drones	10.0 billion
United States	Business services	10.0 billion
India	EC	10.0 billion
United States	Software	10.0 billion

Source: The data was compiled by Mitsubishi Research Institute, Inc. based on data released from CV Source & CB Insights, Crunchbase, etc.

We will look at changes in the usage of the internet, which forms the basis of those services, in China. In China, the number of internet users has been increasing year after year: over the past 10 years, the number rose nearly four-fold from 210 million people to 770 million people, with the internet diffusion rate at 55.8% as of the end of 2017 (Figure II-3-2-4).[98] Moreover, the number of people using the internet via mobile terminal has increased more than 10-fold from 50 million to 750 million, with the majority of the population having free access to internet-based services while on the road. As a factor behind the creation of new industries, the rapid expansion of the internet user base has been pointed out.

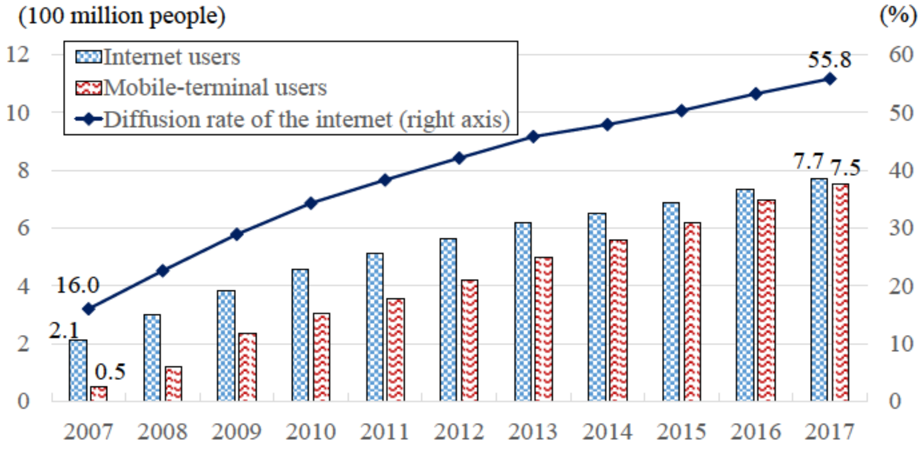
While internet usage is increasing in China as described above, the scale of the e-commerce market is also growing significantly. The scale of the market has continued to record year-on-year growth of around 30%, and in 2016, the value of the market is estimated to have reached approximately 23 trillion yuan (Figure II-3-2-5).[99] A breakdown of the market value shows that the value is around 16.7 trillion

98 Based on a survey conducted by the China Internet Network Information Center. This annual survey, conducted via phone, collects responses from permanent residents aged 6 or older in China who own a fixed or mobile phone. The data of the latest survey are as of December 31, 2017. This is a sample survey based on random sample selection, so the overall number of users in China is presumed to represent a figure arrived at through an extended estimation based on the random selection rate and other factors.

99 Based on data compiled by the China e-Business Research Center.

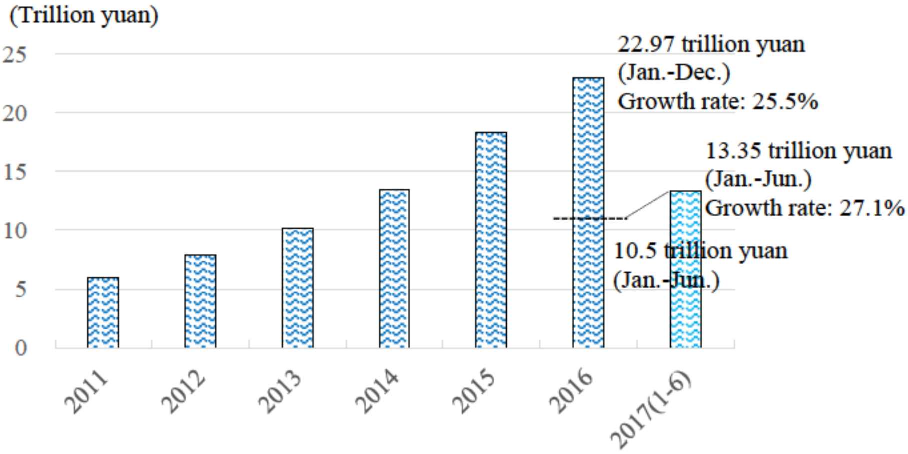
yuan for the business-to-business market, about 5.3 trillion yuan[100] for the internet retail market, and about 1.0 trillion yuan for the life services market. In line with the expansion of e-commerce, the number of workers employed in the market is also growing: the number of directly employed workers is estimated to have increased 1.7-fold from around 1.8 million people to around 3.1 million people over a period of five and a half years and the number of indirectly employed workers is estimated to have increased from around 13.5 million people to around 23 million people (Figure II-3-2-6).

Figure II-3-2-4 Changes in the usage of the internet in China



Source: *The 41st Statistical Report on Internet Development in China* (China Internet Network Information Center (CNNIC), Jan. 2018).

Figure II-3-2-5 Changes in the scale of the e-commerce market in China

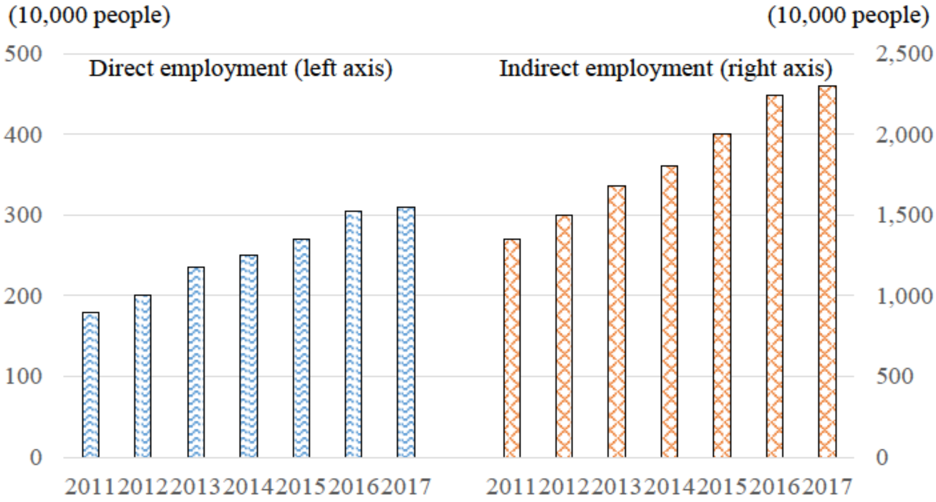


Notes: The figure of 13.35 trillion yuan as the value of the e-commerce market scale between Jan. and Jun. in 2017 represents the growth rate of 27.1% as a proportion to 10.5 trillion yuan as the value of the e-commerce market scale between Jan. and Jun. in 2016.

Source: China Electronic Commerce Research Center (CECRC) website.

100 According to an announcement by the National Bureau of Statistics of China, the value of internet-based sales (including sales of goods and services) in 2016 was approximately 5,156.0 billion yuan, almost matching the above figure. According to data published by the National Bureau of Statistics, the share of internet-based sales (sales of goods) in the total value of retail sales of social consumption goods in 2016 was 12.6% (see Section 4.2. Figure II-3-4-2-2 in this chapter).

Figure II-3-2-6 Changes in employment involved in e-commerce in China



Notes: The data in 2017 are those as of June of the year.
Source: CECRC website.

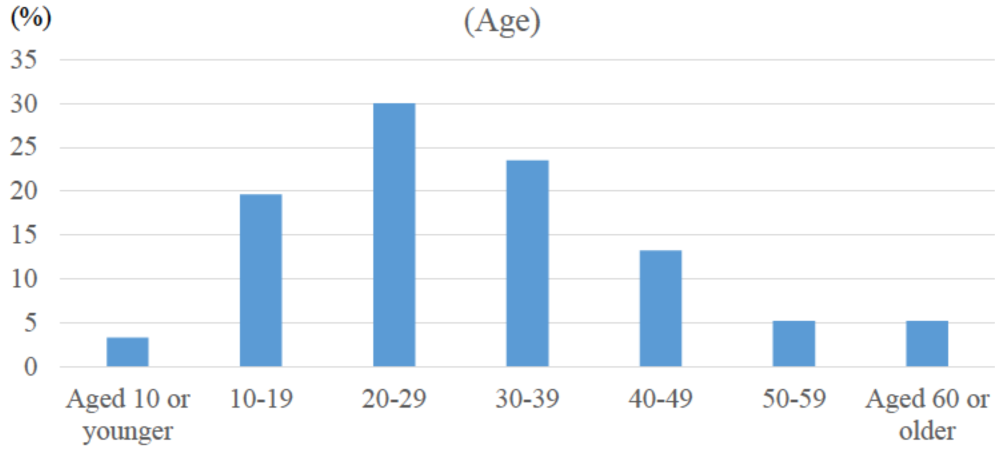
Here, we will look mainly at the market for services for consumers in the market for e-commerce transactions. What kind of people are internet users and what kind of services do they use? First, regarding the age mix of internet users, relatively young generations account for a large share in the total number of users: people aged 20 to 29 account for the largest share (30% of the total), followed by people aged 30 to 39 (23.5%) and people aged 10 to 19 (19.6%) (Figure II-3-2-7). On the other hand, users also include people aged 50 to 59 (5.2%) and people aged 60 or older (5.2%), indicating that the user base is expanding in terms of age mix.[101] By occupation, students account for the largest share (25.4% of the total), followed by self-employed people (21.3%) and company employees (14.6%). Looking at monthly income of users, people with income of 3,000 to 5,000 yuan (approximately 50,000 to 83,000 yen) account for the largest share (22.4%), followed by people with income of 2,000 to 3,000 yuan (approximately 33,000 to 50,000 yen) (16.6%).[102] By location of residence, people living in urban areas account for more than 70%, but there are also many users in rural areas.[103] By gender, the share is almost equal for male and female users.

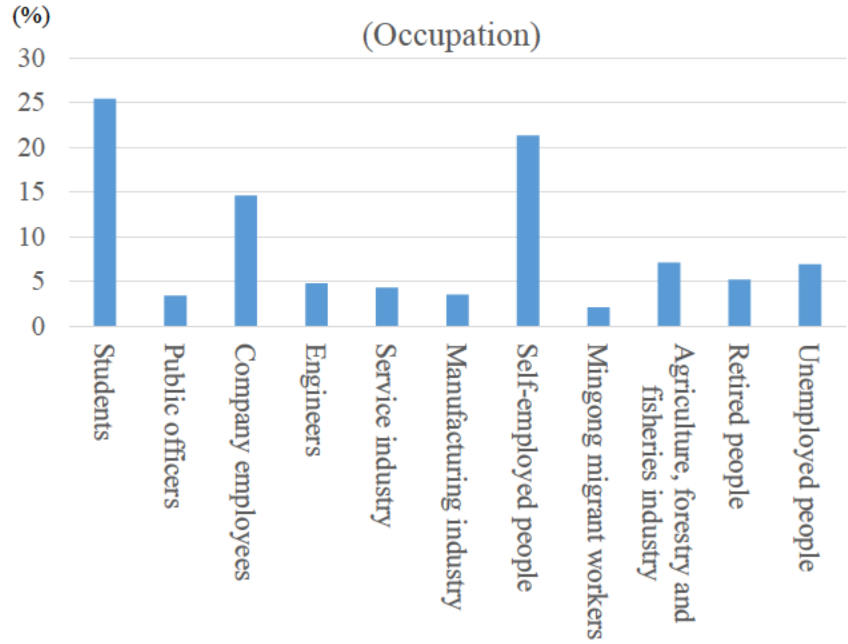
101 It should be kept in mind that as the survey asked whether respondents used the internet within the past six months, a positive reply does not necessarily mean the respondent is a regular internet user.

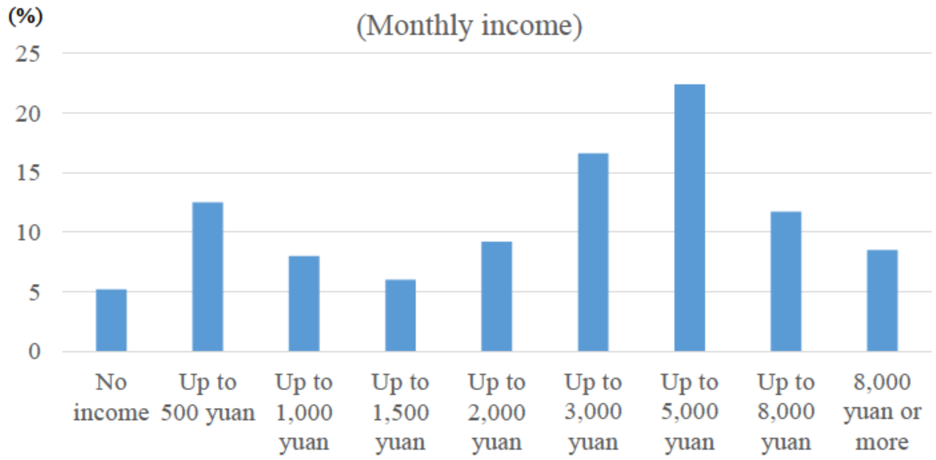
102 Although it is difficult to conduct a comparison regarding the average monthly income in China because of differences between statistical data sets, the average annual wage in urban areas (2016, as announced by the National Bureau of Statistics) is around 68,000 yuan at non-private-companies and around 43,000 yuan at private companies. The monthly income, calculated by simply dividing the annual income by 12, is around 5,600 yuan at non-private companies and around 3,600 yuan at private companies. Meanwhile, the sample of the abovementioned survey concerning internet users include people with relatively small income, such as students and retirees (people receiving regular financial assistance from their families, scholarship funds, pensions, etc.). The above figures were calculated based on an exchange rate of approximately 16.6 yen to the yuan (the average exchange rate in 2017).

103 As access to commercial facilities is more limited in rural areas, some experts point out that the potential for internet-based sales may be larger there.

Figure II-3-2-7 Profiles of internet users in China







Notes:

1. The categories of occupation are based on the Survey Report, but some breakdowns of the categories show simplified data after totalizing them. For example, the data on "executives of the party and the government" and those on "general employees of the party and the government" are shown as "public officers" after totalizing them, while the data on executives, mid-level managers and general employees of companies are shown as "company employees" after totalizing them.
2. The data on monthly income include those on living costs sent as allowance, scholarships, governmental subsidies and pensions.

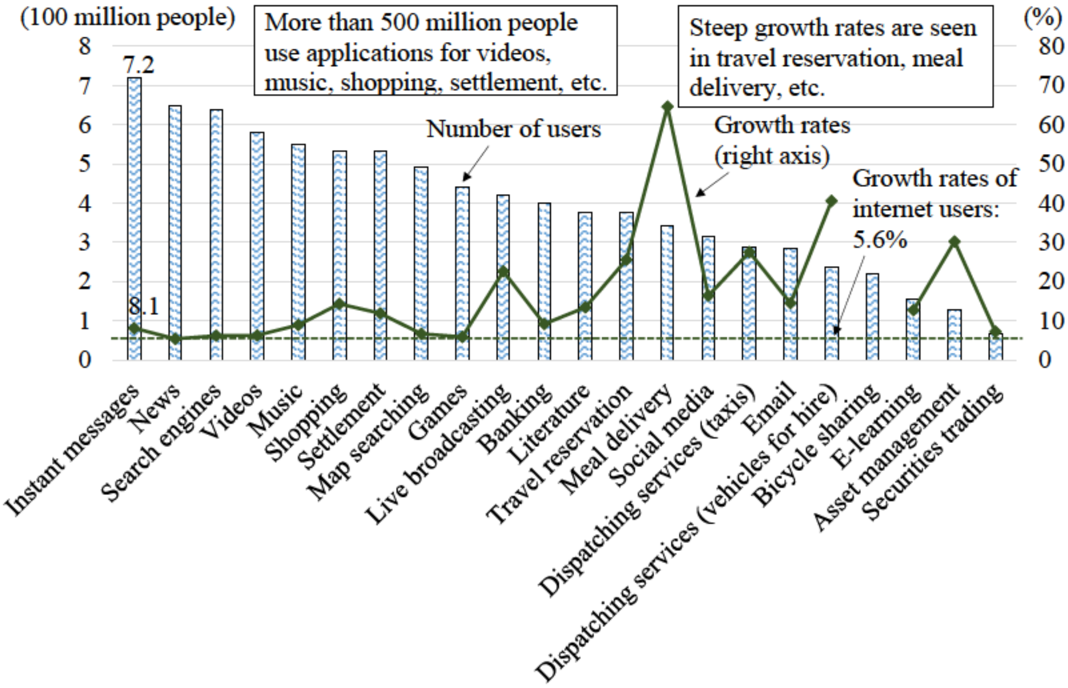
Source: *The 41st Statistical Report on Internet Development in China* (CNNIC, Jan. 2018).

Let us look at what kind of services are actually used via the internet based on the number of users by application. The most widely used application is instant messaging (the number of users is approximately 720 million people), which is used by 93.3% of all internet users (approximately 770 million people) (Figure II-3-2-8). While popular applications also include search engines and other services presumed to be free of charge,[104] applications that are presumed to generate business revenue from consumers' usage, such as video, music, shopping, and online settlement, are also used by many people: for each of those categories of application, the number of users is estimated at more than 500 million people. Furthermore, banking, travel reservation, meal delivery and taxi dispatching services have come to be provided via the internet. The rate of increase in the number of users is high with respect to travel reservation and meal delivery services, indicating a rapid market expansion.[105]

104 These services, although provided to users for free, function as commercial businesses by receiving advertising and other revenue.

105 The total number of internet users as of the end of 2017 was 5.6% higher than a year before. The number of users of instant messaging, for which the usage rate is already higher than 90%, grew 8.1%, only slightly higher than the growth rate for the total number of internet users. This is presumably an indication that instant messaging has almost reached a saturation point. In contrast, the number of users of services for which the usage rate is not so high, such as travel reservation (usage rate at 49%) and meal delivery service (usage rate at 45%), rose sharply, 26% for the former and 65% for the latter.

Figure II-3-2-8 Usage of internet applications by field in China (end of 2017)



Remarks: The rate of increase is on a year-on-year basis. With respect to bicycle sharing, the rate of increase is not available because this item was not covered in the previous year's survey.

Source: *The 41st Statistical Report on Internet Development in China* (CNNIC, Jan. 2018).

The so-called sharing economy is also emerging as a new field of economic activity conducted via the internet. The sharing economy is defined as economic activity that makes efficient use of resources through the sharing (sharing of the usage right) of vehicles, houses, funds and other things using internet-related and other technologies. The value of the sharing economy market in 2017 was reportedly at around 4.9 trillion yuan, up 47% from the previous year (Table II-3-2-9).[106] By transaction value by sector, the transaction value of financial services, including online financial services, amounts to around 2.8 trillion yuan, accounting for more than half of the total, followed by life services with around 1.3 trillion yuan, production capacity-related services with around 400 billion yuan, transportation-related services, including bicycle sharing, with around 200 billion yuan, and knowledge and skill-related services with around 140 billion yuan. The highest growth rate, 127%, was recorded for knowledge and skill-related services, followed by the growth rate of 83% for life services. As the sharing economy is a rapidly expanding sector, the total value of funds raised for new market entry and business expansion grew 25.7% from the previous year to 216.0 billion yuan. Of the total, transportation-related services accounted for the largest portion, 107.2 billion yuan, indicating that the business expansion is particularly active for those services.[107]

Among companies related to the sharing economy are many large venture companies. It has been

106 Based on China's Sharing Economic Development Report 2018 (中国共享经济发展年度报告(2018)) (February 2018), jointly issued by the State Information Center and the China Internet Network Information Center.

107 It has been pointed out that this is a field in which the cycle of renewal is very quick, with many companies entering the market while many others fail or shut down amid fierce competition.

pointed out that around half of the abovementioned 64 unicorn companies in China are related to the sharing economy.

Table II-3-2-9 The scale of the sharing economy (2017)

(Unit: 100 million yuan, %)

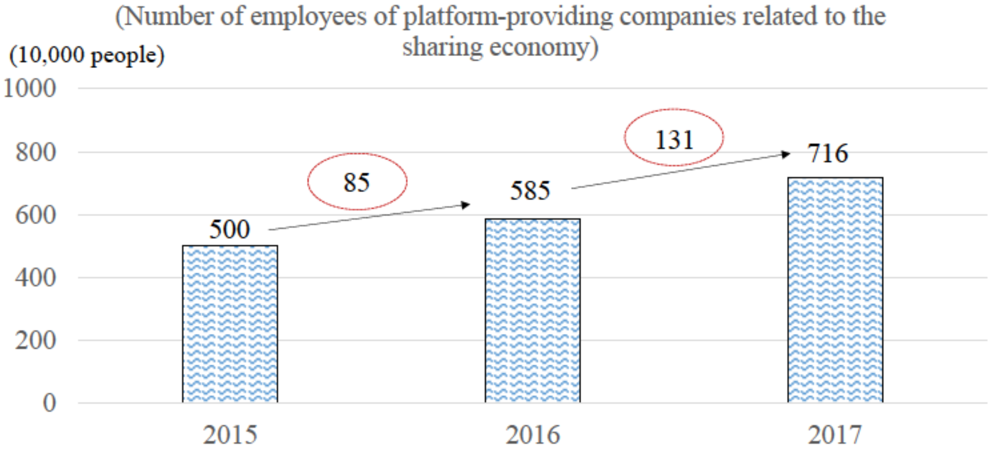
	Scale of the market			Value of funds provided
	Value of transaction	Share	Rate of increase	
Medical care	70	0.1	48.0	19
Housing and lodging	145	0.3	70.6	37
Knowledge and skills	1,382	2.8	126.6	266
Transportation	2,010	4.1	56.8	1,072
Production capacity	4,120	8.4	25.0	34
Everyday life services	13,214	26.9	82.7	512
Financial service	28,264	57.4	35.5	220
Total	49,205	100.0	47.2	2,160

Source: *China's Sharing Economic Development Report 2018 (中国共享经济发展年度报告(2018))* (Sharing Economy Research Center of the State Information Center of China and Sharing Economy Working Committee of the China Internet Network Information Center).

In addition, the number of workers employed by platform providing companies related to the sharing economy has increased, contributing to the promotion of employment. The number increased by 850,000 people in 2016 and by 1.31 million people in 2017, accounting for 6.5% and 9.7%, respectively, of the total number of newly employed workers in urban areas in China (Figure II-3-2-10). It has been pointed out that this employment expansion is creating jobs not only for new graduates but also for people made redundant as a result of employment adjustments associated with the change in the industrial structure, such as the consolidation of companies with excess production capacity.[108]

108 For example, China's Sharing Economic Development Report 2018 pointed out that of the 21.08 million people who provide services through a major bicycle sharing company, around 3.93 million are people who have lost jobs due to the reduction of excess production capacity.

Figure II-3-2-10 Creation of employees of platform-providing companies related to the sharing economy in China



	2016	2017
Number of new employees in urban areas (A)	13.14 million	13.51 million
Increase in the number of employees of companies related to the sharing economy (B)	0.85 million	1.31 million
Ratios (B) / (A)	6.5%	9.7%

Source: *China's Sharing Economic Development Report 2018 (中国共享经济发展年度报告(2018))* (Sharing Economy Research Center of the State Information Center of China and Sharing Economy Working Committee of the China Internet Network Information Center).

2. Innovation and start-up

(1) Current status of innovation

(A) Growth of innovation capability in China

In the previous section, we showed, based on data, that new industries in China are growing rapidly on a large scale. In this section, we will examine the current status of innovation capability in China based on various data and international comparisons.

First, let us look at how the level of innovation in China is globally evaluated. According to the Global Innovation Index (GII), published by the World Intellectual Property Organization (WIPO),[109] China's ranking rose steeply, from the 43rd in 2010 to 22nd in 2017, coming close to major advanced economies,[110] and in some fields, China is evaluated as already possessing world-leading innovation

109 The GII has been announced every year since 2007. The GII expresses institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs as index figures based on quantitative and qualitative data.

110 Under the 13th Five-Year Plan on Science, Technology and Innovation (“十三五”国家科技创新规划) (2016), the government of China offered an analysis showing that if China is to join the ranks of innovation-oriented countries and become a science and technology powerhouse, there are many problems to be resolved, such as the weak science infrastructure and capabilities to create original technologies, the dependence on other countries for core technologies in the critical scientific and industrial fields, a lack of highly-skilled workers, and thoughts and institutions that constrain the development of innovation.

capability[111] (Table II-3-2-2-1).

Table II-3-2-2-1 China's ranking in global innovation index

2010		2017	
1	Iceland	1	Switzerland
2	Sweden	2	Sweden
3	Hong Kong	3	Netherlands
4	Switzerland	4	United States
5	Denmark	5	United Kingdom
6	Finland	6	Denmark
7	Singapore	7	Singapore
8	Netherlands	8	Finland
9	New Zealand	9	Germany
10	Norway	10	Ireland
11	United States	11	ROK
12	Canada	12	Luxembourg
13	Japan	13	Iceland
14	United Kingdom	14	Japan
15	Luxembourg	15	France
43	China	22	China

Source: *The Global Innovation Index 2009-2010*, and *the Global Innovation Index 2017* (WIPO and others, 2010, 2017).

China's innovation capability is reflected, to some degree, in the number of international patent applications by country. Since China acceded to the Patent Cooperation Treaty (PCT) in 1994, the annual number of patent applications has almost consistently been rising. In 2000, China was ranked 16th in terms of the number of PCT applications with 782 applications (the number of applications was 38,015 for the United States, 12,581 for Germany and 9,569 for Japan). However, China overtook the ROK in 2010 and Germany in 2013, and it moved ahead of Japan as well in 2017 to become the global No. 2 after the United States (Figure II-3-2-2-2). Regarding this point, WIPO Director-General Gurry stated that innovators in China "are increasingly looking outward, seeking to spread their

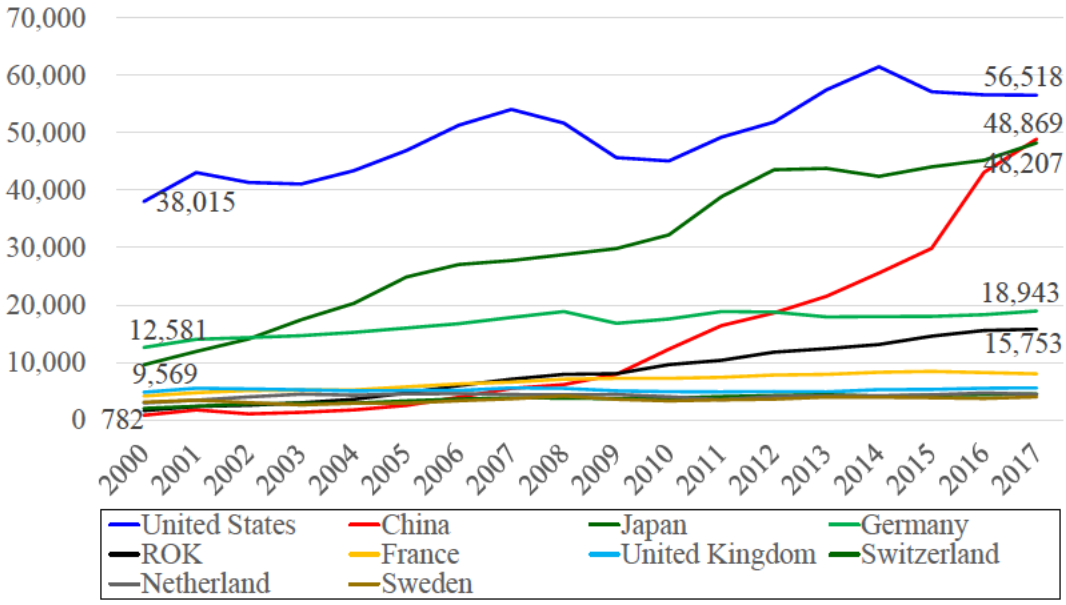
111 In the "Report to Congress of the U.S.-China Economic and Security Review Commission" (USCC, 2017), the U.S.-China Economic and Security Review Commission, an advisory body to the U.S. Congress, cited artificial intelligence (AI), quantum information science, and high-performance computing as fields in which the United States and China are neck and neck with each other in terms of technological competitiveness and exa-scale (1 exa = quintillion) computing and commercial drones as fields in which China has an advantage.

original ideas into new markets as the Chinese economy continues its rapid transformation."[112]

In 2000, the United States alone accounted for 40% of the global number of PCT applications, but the U.S. share was down to 23.2% in 2017, while China's share increased to 20.1%. This indicates that China has grown into one of the countries where innovation activity is the most vigorous (Figure II-3-2-2-3).

Generally speaking, the number of patent applications is an important benchmark of a country's or company's technological capability, but the applications include those which may be inferior in quality. Moreover, in China's case, the rapid rise in the number of patents is partly a consequence of various innovation-related support measures by local governments, including subsidies concerning innovation, according to a certain analysis.[113] Therefore, it is not appropriate to evaluate China's innovation capability based on the number of applications alone. Even so, the fact that China overtook most major advanced economies over a period of less than 20 years to reach the global No. 2 position in terms of the number of PCT applications suggests that China is making country-wide efforts to achieve results through innovation.

Figure II-3-2-2-2 Change in PCT applications by major countries

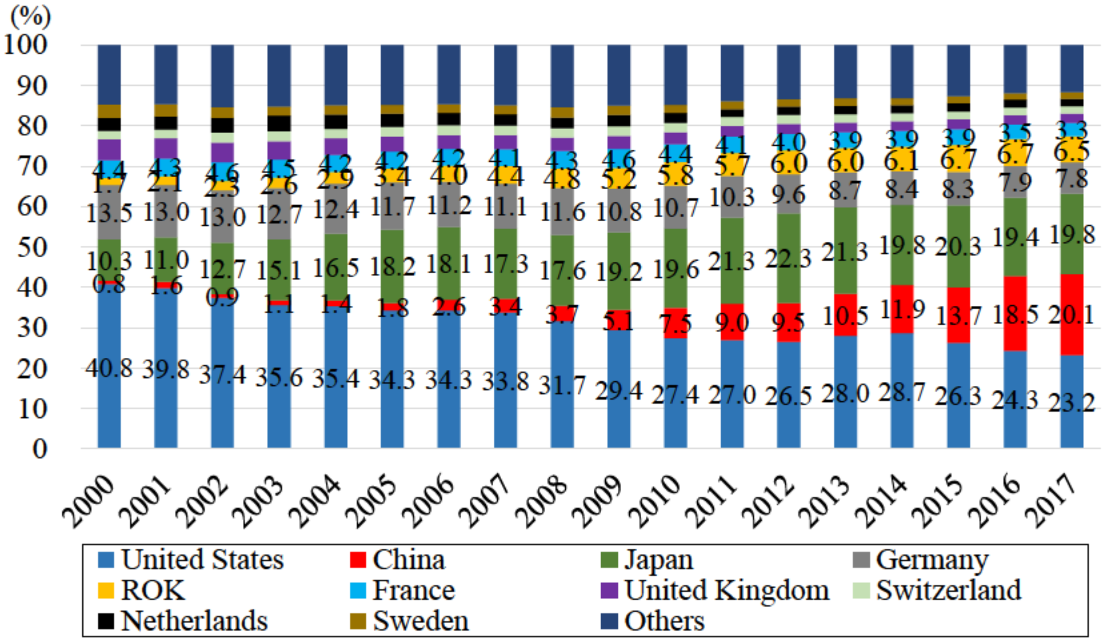


Source: WIPO statistics database (WIPO, April 2018) (https://www3.wipo.int/ipstats/pmhindex.htm?tab=pct).

112 WIPO, "China Drives International Patent Applications to Record Heights; Demand Rising for Trademark and Industrial Design Protection," (http://www.wipo.int/pressroom/en/articles/2018/article_0002.html).

113 Ito, Li and Wang (2014) and Dang and Motohashi (2013).

Figure II-3-2-2-3 Share in the number of PCT applications by countries

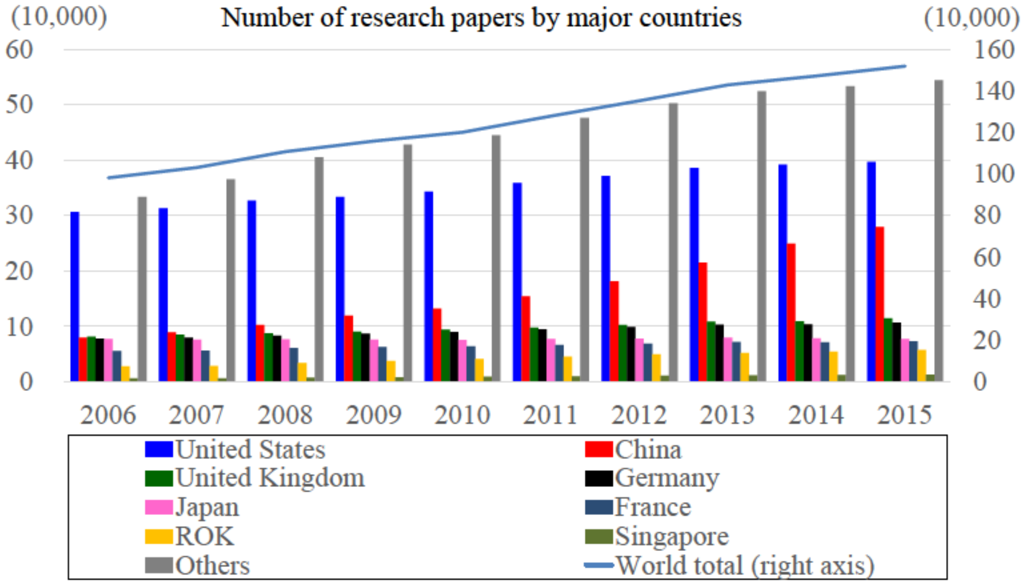


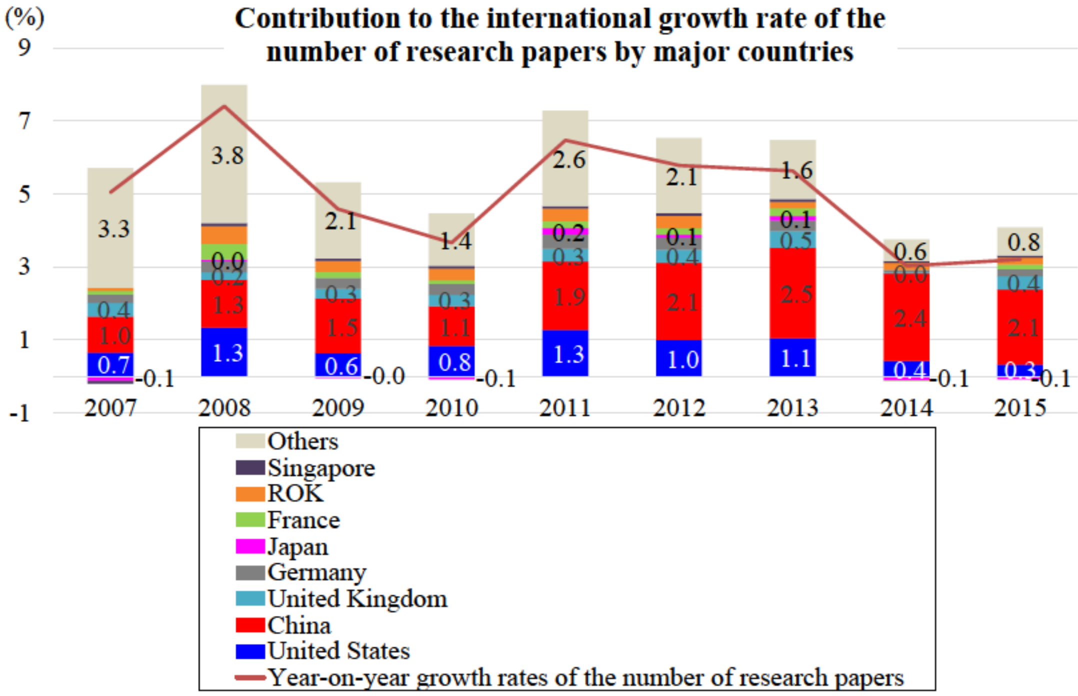
Notes: The data is as of April 13, 2018.

Source: WIPO Statistics Database (WIPO, April 2018).

In terms of the number of research papers, the number of papers written by Chinese researchers is also increasing steeply. Looking at the contribution to the increase in the global number of papers by major country, China's share is growing, while other countries' shares are declining, meaning that China's presence in the academic field is growing (Figure II-3-2-2-4).

Figure II-3-2-2-4 Number of research papers and contribution to the international growth rate of the number of research papers by major countries

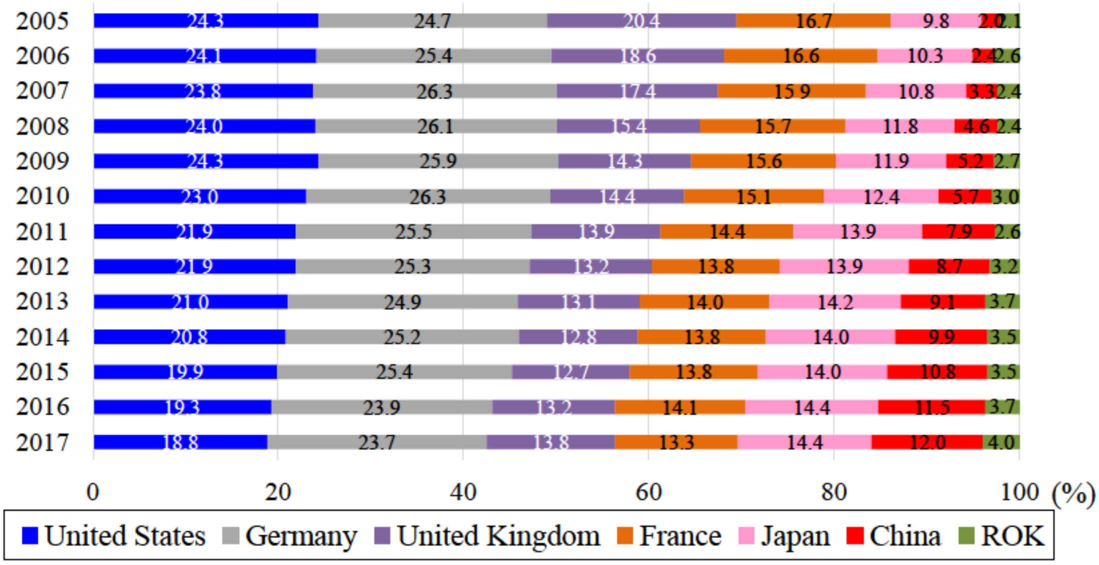




Source: *WAGAKUNI NO SANGYOU GIJUTSU NI KANSURU KENKYUU KAIHATSU KATSUDOU NO DOUKOU - SHUYOU SHIHYOU TO CHOUSA DEETA (DAI 17.2 HAN)* (METI, 2017).

In addition, China takes on the leadership role in more and more expert committees responsible for deliberating and formulating international standards at the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), and this fact, coupled with the decline in the number of committees in which the United States and European countries take on the leadership role, has led to an increase in China's share as a committee leader in the overall number of committees (Figure II-3-2-2-5). This is also considered to reflect the growth of China's innovation capability. Under the 13th Five-Year Plan on Science, Technology and Innovation, which was announced in August 2016, the government of China encouraged competent companies to engage in international technological partnerships through various methods and to participate in the establishment of international standards in order to improve the level of companies' internationalization. The rise in the number of committees in which China takes on the leadership role is in line with this policy.

Figure II-3-2-2-5 Changes in shares of countries serving as ISO/IEC Committee Secretaries



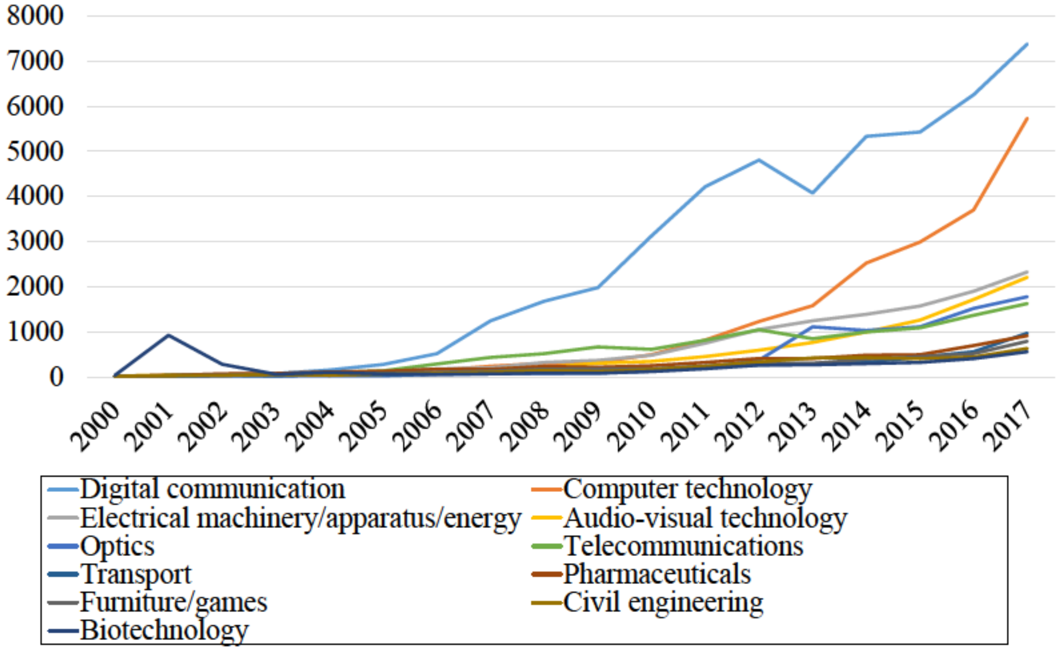
Source: Aggregate results are based on an interview with the ISO/IEC Secretariats by METI (Mar. 2018).

(B) China's technological structure and variation observed from the viewpoints of PCT Publications and academic papers

Let us look at changes in the technological structure by focusing on the number of PCT Publications by China. PCT Publication, which is implemented after the passage of a certain period of time from application, indicates the applicant's intention to obtain a patent more clearly (if a patent is granted in the future, patent protection may be provided). The number of patent publications is a useful yardstick in that, unlike in the case of the number of patent applications, it is possible to conduct analysis by field of technology and by country.

In terms of the number of PCT Publications by China, digital communication and computer technology have for a long period of time remained No. 1 and No. 2, respectively, as active fields of patent publication (Figure II-3-2-2-6). This figure ranks, in descending order, the top five fields in terms of the annual number of patent publications between 2000 and 2017. Digital communication has continuously occupied the No. 1 position in terms of the number of publications since 2004, while computer technology has stayed in the No. 2 position since 2011 (Figure II-3-2-2-6).

Figure II-3-2-2-6 Changes in the number of PCT publications

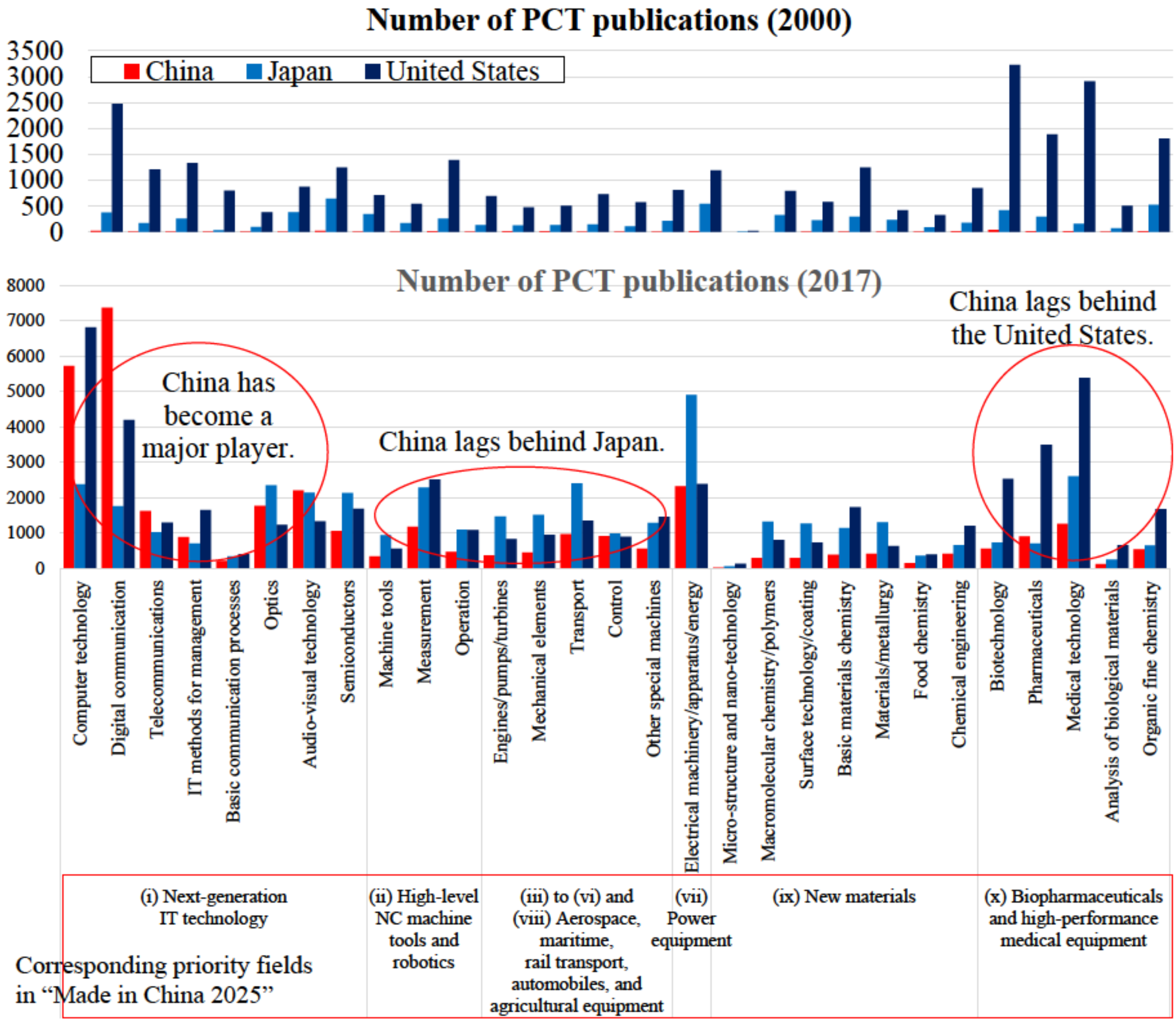


Source: WIPO Statistics Database (WIPO, April 2018).

Looking at the number of PCT Publications by China by field of technology, the overall number of publications has risen to a similar level to the numbers of publications by the United States and Japan over the past 18 years, and in some fields of technology, China has overtaken those two countries. In terms of the number of PCT Publications in the 10 priority industrial fields of "Made in China 2025," China has not only caught up with major countries in IT technology-related fields in particular but has also overtaken them in some fields, such as digital communication.

On the other hand, China lags behind the United Sates in biotechnology and medical technology and behind Japan in the field of machinery-related technology, including robotics, in terms of the number of patent publications. This indicates that China has focused on particular fields, including IT-related technology, rather than on all fields, in efforts to enhance its technological capability (Figure II-3-2-2-7). However, as China is attempting to enhance competitiveness in fields where it does not have an advantage relative to other countries, designating them as priority fields, it is possible that the country will make rapid advances in some of those fields in the future, as it did in the field of IT-related technology. Some inventors choose the option of treating core technology as a "black box" and refrain from filing a patent application concerning it. Therefore, it should be kept in mind that the number of patent publications does not directly indicate the level of countries' or companies' technological capability.

Figure II-3-2-2-7 Comparison of the number of PCT publication by technological field among China, U.S., and Japan



Source: WIPO Statistics Database (WIPO, April 2018).

Concerning the production of research papers by field, China has a large global share in such fields as materials science, chemistry, engineering, and computer science. In the field of biotechnology, which is specified by the government of China as one of the strategic emerging industries, and which is also regarded as one of the priority fields under the Made in China 2025 strategy, China is not at an advantage relative to other major countries in terms of the number of PCT Publications that was mentioned earlier. However, China's share is growing markedly in terms of the number of research papers in related fields (e.g., molecular biology/genetics) (Figure II-3-2-2-8). As the government devotes efforts to biotechnology as a priority field, it is possible that in the future, China will gain an advantage at the stage of practical application (in terms of the number of patents), in addition to its advantage at the research stage (in terms of the number of papers).

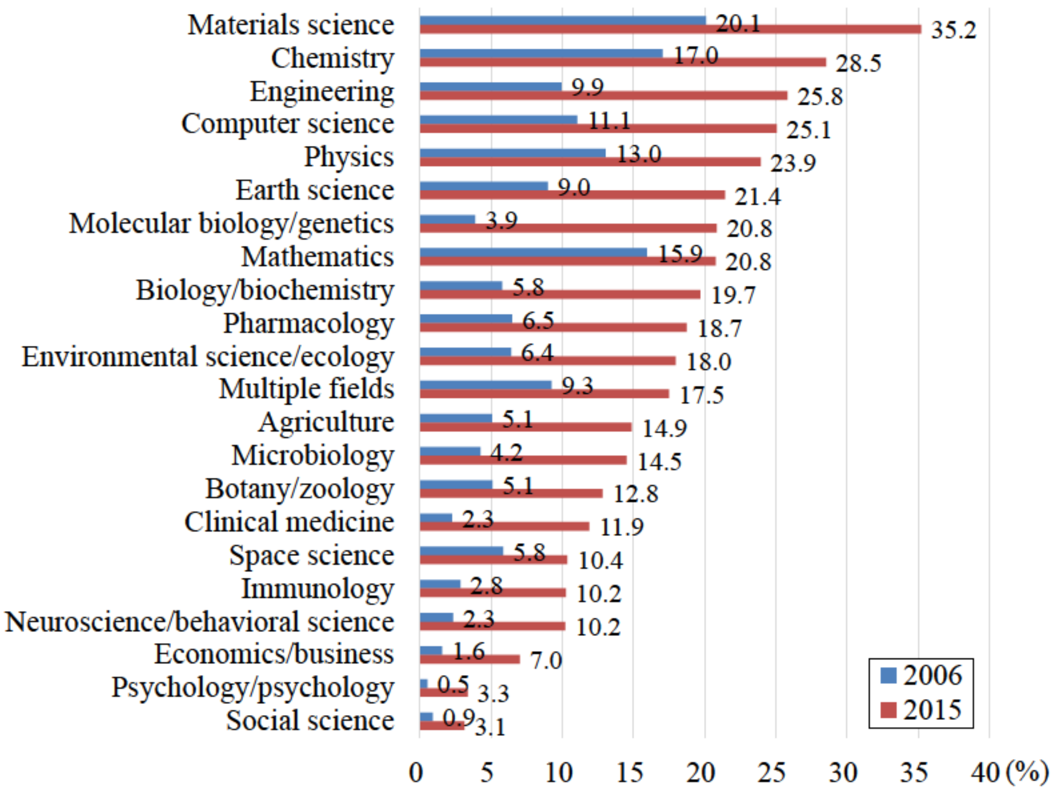
One factor behind the large number of papers in China[114] is the huge number of Chinese researchers,

114 See "Total researchers" of the OECD Main Science and Technology Indicators (http://stats.oecd.org/).

but the number of paper citations has also risen remarkably in recent years. In all fields of research, China's ranking has risen, and the country is ranked second, after the United States, in terms of both the overall number of papers and the overall number of paper citations.

A comparison of the rankings in 2003-2005 and 2013-2015 by field shows that China overtook the United States as No. 1 in the fields of chemistry, materials science and engineering in terms of the number of papers and the number of paper citations. In the fields of computer science and mathematics, China overtook the United States as No. 1 in terms of the number of papers in the top 1% based upon citation count[115] (Figure II-3-2-2-9).

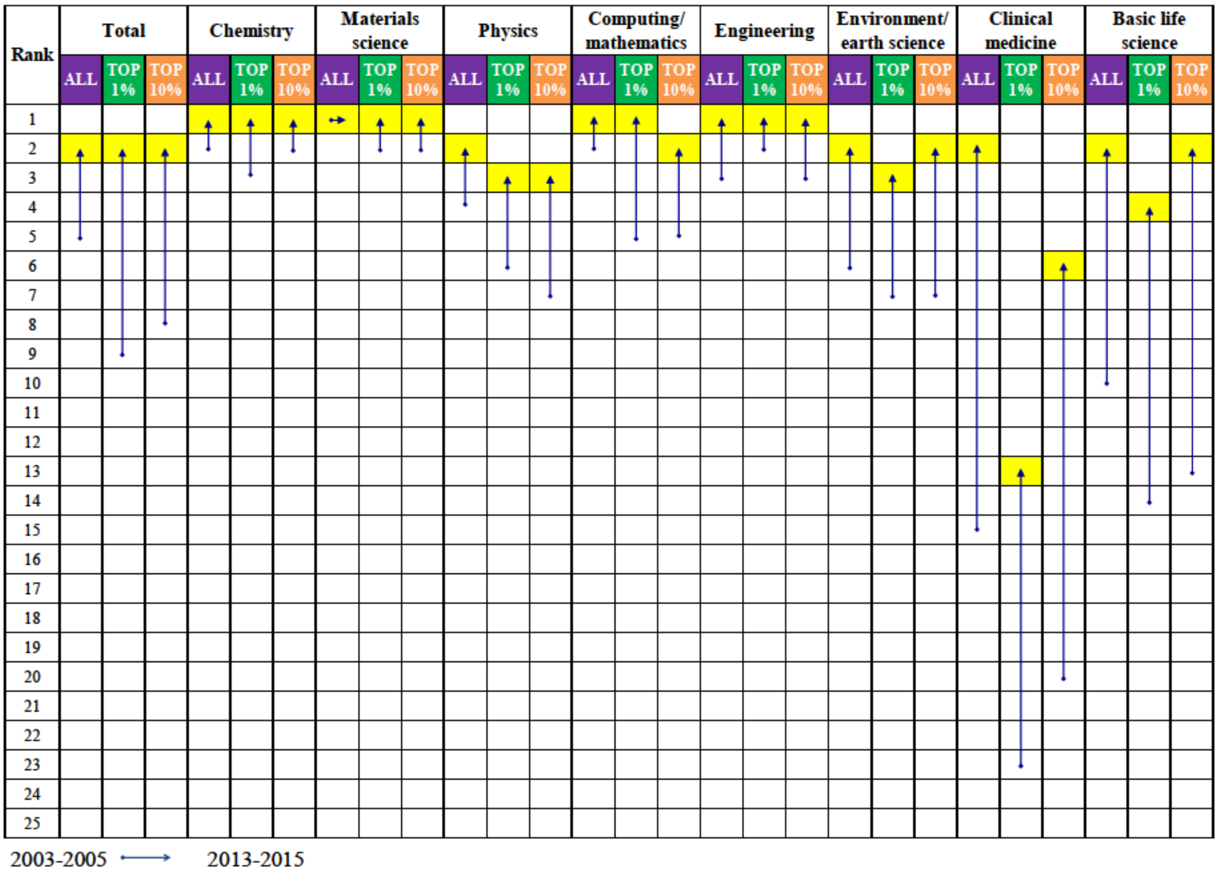
Figure II-3-2-2-8 Shares of Chinese research papers to the number of international research papers



Source: *Web of Science* (Clarivate Analytics).

115 Attention should be paid to the observation that frequently cited papers are not necessarily ones held in high regard internationally. Japan Science and Technology Agency (2016).

Figure II-3-2-2-9 Ranks of the number of China's research papers and citations in international research papers



Notes: The figure show changes in target data between 2003 and 2005 and between 2013 and 2015 (three-year moving average).

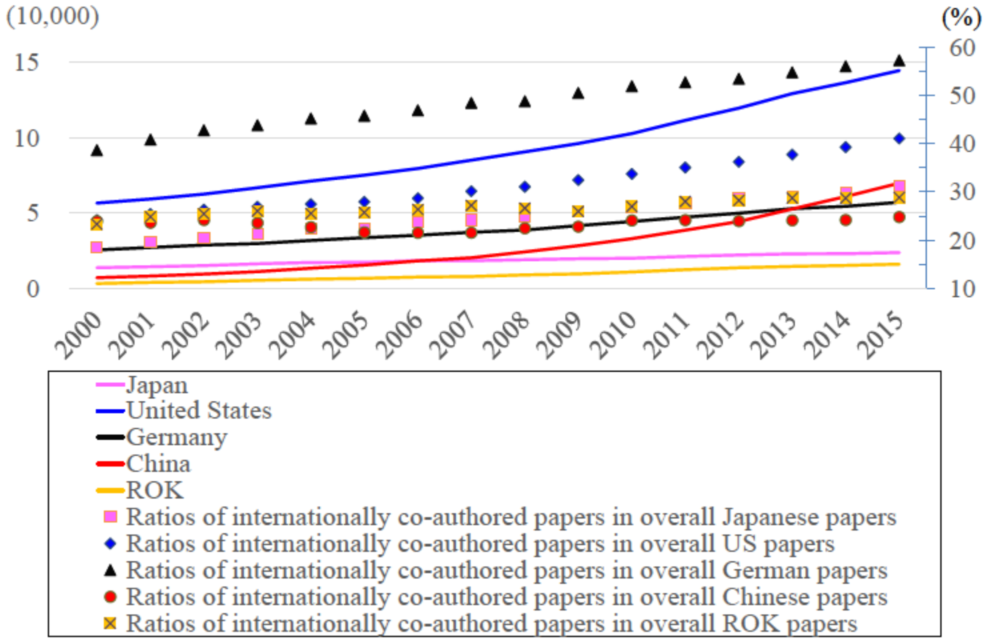
Source: *WAGAKUNI NO SANGYOU GIJUTSU NI KANSURU KENKYUU KAIHATSU KATSUDOU NO DOUKOU - SHUYOU SHIHYOU TO CHOUSA DEETA (DAI 17.2 HAN)* (METI, 2017).

The proportion of internationally co-authored papers among overall Chinese papers is smaller than the proportions among U.S., German and Japanese papers. However, as the number of internationally co-authored papers involving Chinese researchers is increasing markedly, China has already surpassed Germany and Japan in terms of the number of internationally co-authored papers. In addition, China is ranked No. 1 as the co-authorship partner country of the United States in many fields. It has also been pointed out that in the United Kingdom, Germany and France as well, China is remarkably developing its presence as an international co-authorship partner compared with Japan.[116] This means that China's international position on the academic front is rising (Figure II-3-2-2-10).

Under the 13th Five-year Plan on Science, Technology and Innovation, China aims to promote the acquisition of technologies in the following fields as a priority, so it is possible that the impact of the plan will appear in the form of changes in the numbers of papers and patents in the future (Table II-3-2-2-11).

116 National Institute of Science and Technology Policy (2017).

Figure II-3-2-2-10 Changes in the number internationally co-authored research papers, and changes in ratios of internationally co-authored research papers of China



Source: *Japanese Science and Technology Indicators 2017* (Ministry of Education, Culture, Sports, Science and Technology (MEXT) National Institute of Science and Technology Policy, 2017).

Table II-3-2-2-11 Priority fields stipulated in the 13th Five-Year Science and Technology Innovation Plan

(August 2016)

Priority projects for national science and technology
■Innovative electronic devices, high-end chips, etc.
■Facilities and technologies for manufacturing large-scale integrated circuits
■Next-generation broadband wireless mobile networks
■Highly-accurate machine tools and manufacturing technologies therefor
■Development of large-scale gas fields and coal-bed gas
■Large-scale, advanced pressurized-water nuclear power generation, and high-temperature gas-cooled reactors
■Water pollution control and flood control
■Development of a new variety of genetic modification
■Drug development targeting serious diseases
■Prevention and curing of serious infections, e.g., AIDS and viral hepatitis
■Large aircraft
■Highly-accurate earth observation systems
■Plans of manned space flight and lunar exploration

Source: *The 13th Five-Year Plan on Science, Technology and Innovation (“十三五”国家科技创新规划)* (State Council of China, Aug. 2016).

(C) Changes in the priority fields of technology as measured by a technological advantage index

In China, while the number of PCT applications is rising steeply, the mix of technical fields in which patents are actively published is dramatically changing. In order to make clear China’s international position in terms of innovation, we will examine changes in countries/regions’ advantage and specialization in fields of technology using the Revealed Technological Advantage (RTA) index,[117] one of the indicators used for measurement and international comparison of the advantage of innovation activity at the macroeconomic level.

The RTA index represents the ratio of the domestic share of a particular field of technology in a country to the global share based on the number of patent applications or patent publications. An index above 1.0 means that the country’s share in the sector is higher than the global share, which in turn indicates that the country has a technological advantage or is more specialized in the specific field compared with other countries. An index below 1.0 means that the country has a technological disadvantage or lags behind in specialization compared with other countries.

According to the definition of the formula used to calculate the RTA index, the value of the index is obtained by dividing the domestic share of a particular field of technology by the global share. In other words, the RTA index benchmarks the domestic share of a particular field of technology against the global share. Therefore, it enables not only a comparison between different fields of technology within a country but also an international comparison with respect to a particular field of technology.

In the analysis in this white paper, we used the WIPO Statistics Database, disclosed by WIPO, in order to calculate the RTA index based on the number of PCT publications between 2000 and 2017 by China, OECD member countries and other relevant countries (Table II-3-2-2-12).

Table II-3-2-2-12 Specifications of calculating RTA indices

Period	2000-2017 (18 years)
Country and region	Austria, Australia, ASEAN 4 (Indonesia, Malaysia, Philippines and Thailand), other ASEAN economies (Brunei Darussalam, Cambodia, Lao PDR, Myanmar and Viet Nam), Brazil, Canada, Switzerland, Chile, China, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, the United Kingdom, Greece, Hungary, Israel, India, Iceland, Italy, Japan, ROK, Luxembourg, Latvia, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Russia, Singapore, Slovakia, Turkey, the United States, South Africa, and other countries and regions (ROW) (42 countries and regions)
Technical field	Electrical machinery/apparatus/energy, audio-visual technology, telecommunications, digital communication, basic communication processes, computer technology, IT methods for management, semiconductors, optics, measurement, analysis of biological materials, control, medical technology, organic fine chemistry, biotechnology,

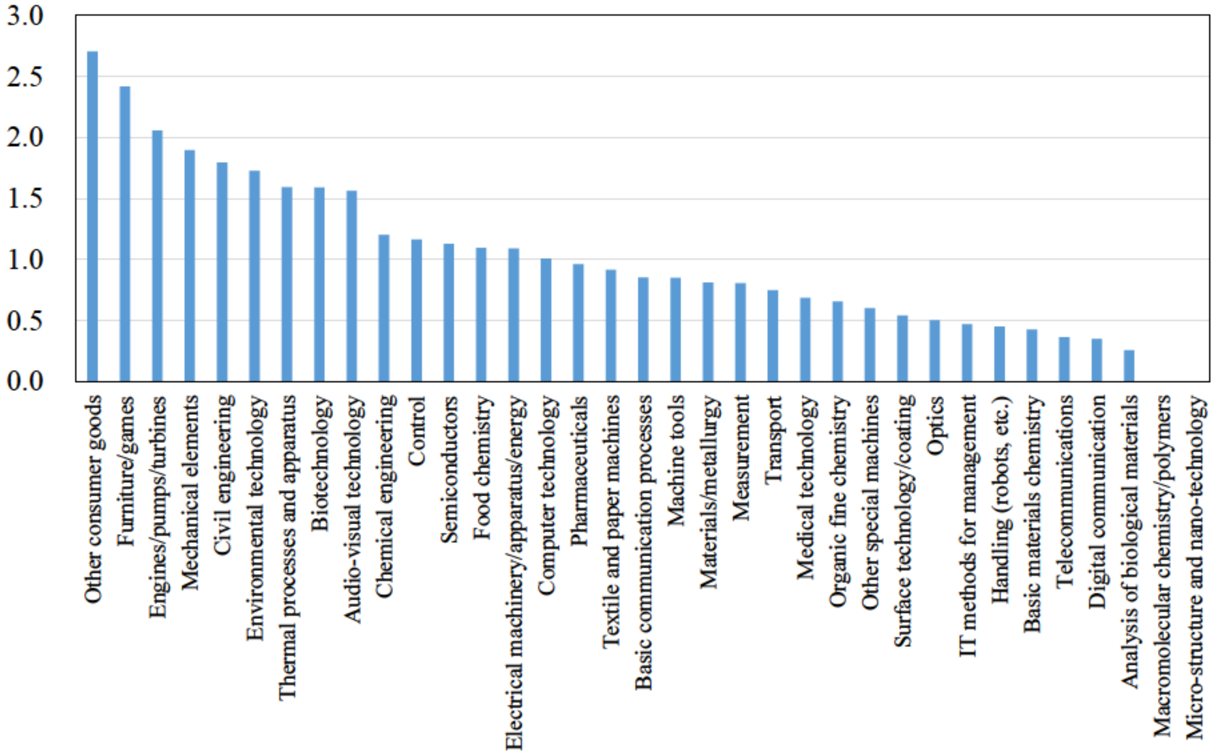
117 Soete (1987).

	pharmaceuticals, macromolecular chemistry/polymer, food chemistry, basic materials chemistry, materials/metallurgy, surface technology/coating, micro-structure and nano-technology, chemical engineering, environmental technology, handling (elevators, cranes, robots, packaging devices, etc.), machine tools, engines/pumps/turbines, textile and paper machines, other special machines, thermal processes and apparatus, mechanical elements, transport, furniture/games, other consumer goods, and civil engineering (35 fields)
Database	WIPO Statistics Database (http://www.wipo.int/ipstats/en/; as of February 2018)

Source: METI.

Figure II-3-2-2-13 shows the distribution of the RTA index concerning China in 2000. Other consumer goods (2.707), furniture/games (2.419), engines/pumps/turbines (2.058), mechanical elements (1.897), and civil engineering (1.795) were the top five fields in terms of the RTA index. In contrast, telecommunications (0.366), digital communication (0.353), analysis of biological materials (0.258), macro-molecular chemistry/polymers (0.000) and micro-structure and nano-technology (0.000) were the bottom five fields.[118] An RTA index of 1 or higher, which indicates the presence of a technological advantage, was recorded in 15 of the 35 fields.

Figure II-3-2-2-13 China's RTA indices by technical field (2000)



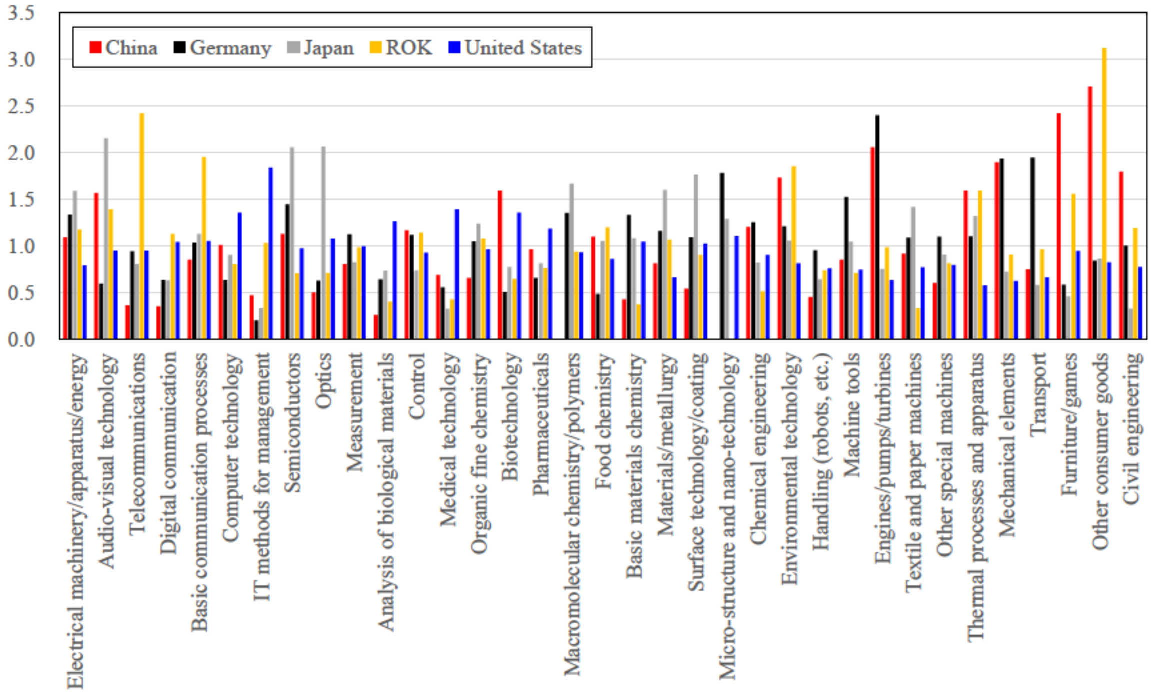
Source: METI.

118 There were no PCT International Publications in the fields of macro-molecular chemistry/polymers and micro-structural and nano-technology.

Below, we will show China's international position in 2000 through comparison with Japan, the United States, Germany and the ROK (Figure II-3-2-2-14). China's RTA was the highest of the five countries in five fields--control (1.165), biotechnology (1.592), thermal processes and apparatus (1.594), furniture/games (2.419) and civil engineering (1.795) (Table II-3-2-2-15). As for the rankings of those fields in China, furniture/games was No. 2, civil engineering was No. 5, thermal processes and apparatus was No. 7, biotechnology was No. 8, and control was No. 11.

There are also fields in which the RTA is relatively high in China but in which China lags behind Japan, the United States, Germany and the ROK in international comparison (other consumer goods, engines/pumps/turbines, mechanical elements, etc.). This is attributable to the fact that the RTA index represents relative evaluation of a country's international advantage.

Figure II-3-2-2-14 Comparison of RTA indices among five countries (2000)



Source: METI.

Table II-3-2-2-15 International comparison of RTA indices in which China has advantage (2000)

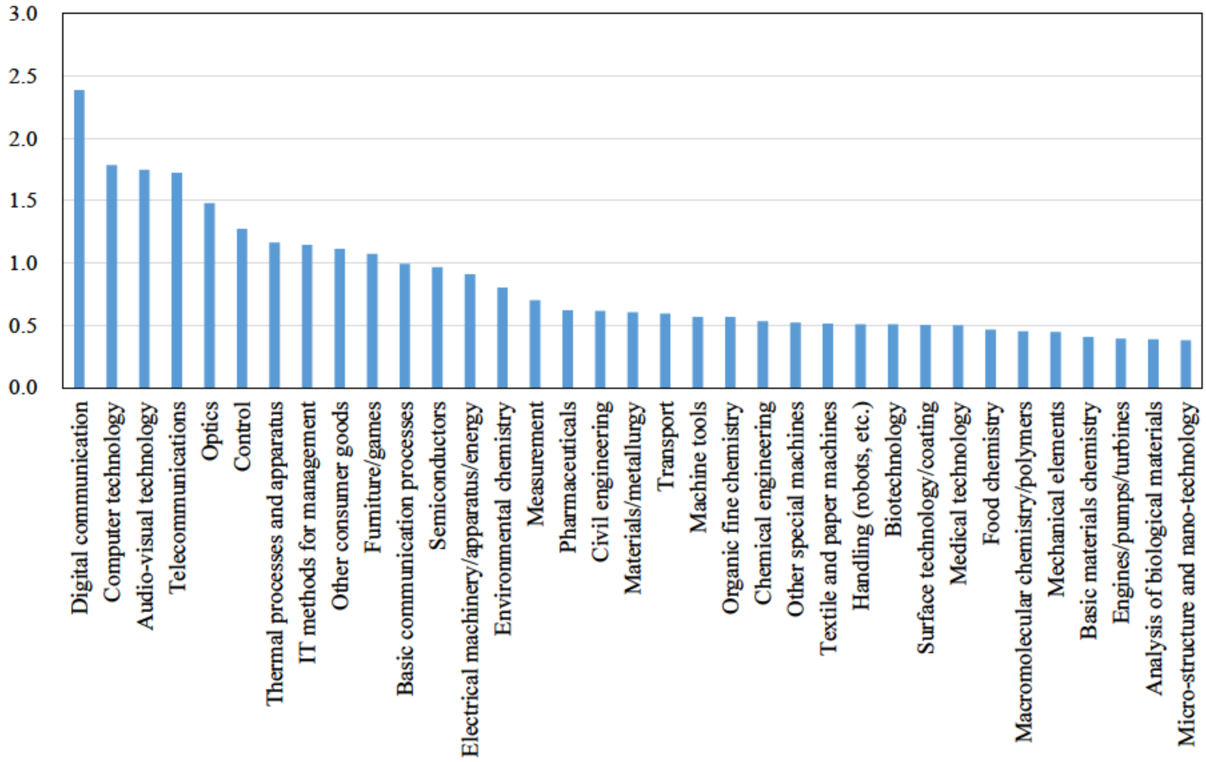
Technical fields	RTA index				
	China	Japan	United States	Germany	ROK
Control	1.165	0.739	0.926	1.117	1.144
Biotechnology	1.592	0.775	1.356	0.507	0.645
Thermal processes and apparatus	1.594	1.32	0.579	1.103	1.593
Furniture/games	2.419	0.46	0.946	0.586	1.555
Civil engineering	1.795	0.329	0.773	1.004	1.191

Source: METI.

Figure II-3-2-2-16 shows the distribution of the RTA index concerning China in 2017. Digital communication (2.388), computer technology (1.785), audio-visual technology (1.747), telecommunications (1.722), and optics (1.480) were the top five fields. In contrast, mechanical elements (0.446), basic materials chemistry (0.406), engines/pumps/turbines (0.391), analysis of biological materials (0.388) and micro-structure and nano-technology (0.3797) were the bottom five fields. An RTA value of 1 or higher, which indicates the presence of a technological advantage, was recorded in 10 of the 35 fields, down from 15 in 2000.

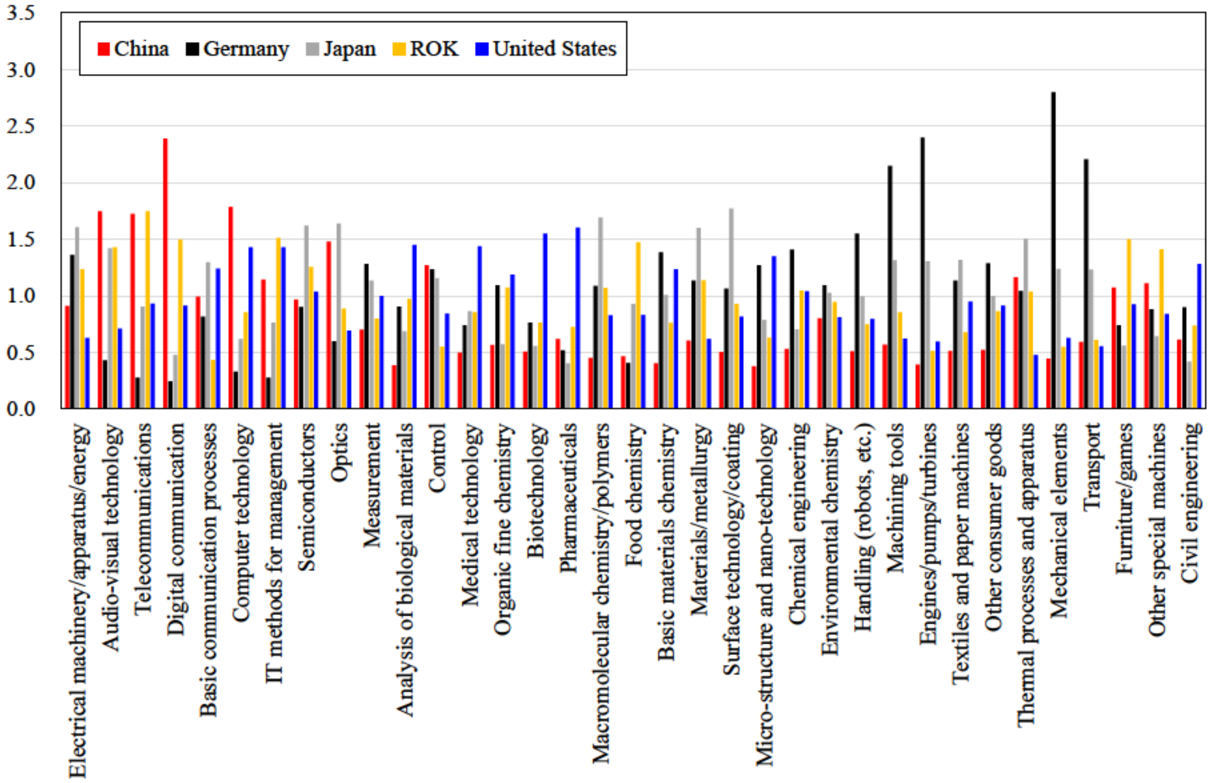
Regarding China's international position in 2017 (Figure II-3-2-2-17), a comparison with the abovementioned four countries shows that China's RTA is the highest in four fields--digital communication (2.388), computer technology (1.785), audio-visual technology (1.747) and control (1.272) (Table II-3-2-2-18).

Figure II-3-2-2-16 China's RTA indices by technical field (2017)



Source: METI.

Figure II-3-2-2-17 Comparison of RTA indices among five countries (2017)



Source: METI.

Table II-3-2-2-18 International comparison of RTA indices in which China has advantage (2017)

Technical field	RTA index				
	China	Japan	United States	Germany	ROK
Audio-visual technology	1.747	1.421	0.71	0.429	1.427
Digital communication	2.388	0.477	0.915	0.247	1.497
Computer technology	1.785	0.619	1.429	0.332	0.856
Control	1.272	1.153	0.841	1.234	0.552

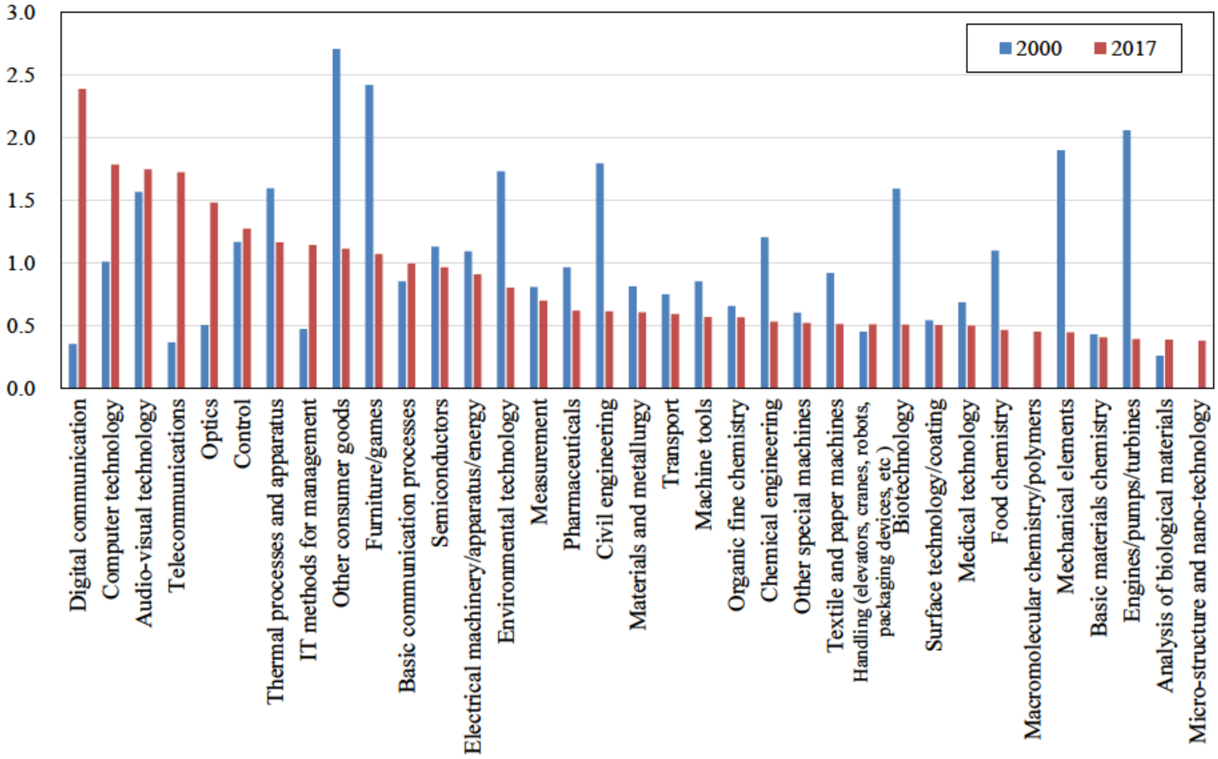
Source: METI.

Regarding the rankings of those fields of technology in China, digital communication was No. 1, computer technology was No. 2, audio-visual technology was No. 3 and control was No. 6. One big change compared with the situation 2000 is that the fields in which China has an advantage mostly overlap with the fields which are ranked high in China.

Figure II-3-2-2-19 shows that China's technological advantage as measured by the RTA index has dramatically changed between 2000 and 2017. This figure ranks, in descending order, fields of technology in which China's RTA in 2017 is high. A comparison of the RTA between 2000 and 2017 in the top five fields is as follows: digital communication: 2.387 in 2017 and 0.353 in 2000; computer technology: 1.785 in 2017 and 1.01 in 2000; audio-visual technology: 1.747 in 2017 and 1.565 in 2000;

telecommunications: 1.722 in 2017 and 0.366 in 2000; and optics: 1.480 in 2017 and 0.505 in 2000. The RTA was higher in 2017 than in 2000 in all five fields. A comparison in the bottom five fields is as follows: micro-structure and nano-technology: 0.379 in 2017 and no patent publication in 2000; analysis of biological materials: 0.387 in 2017 and 0.258 in 2000; engines/pumps/turbines: 0.391 in 2017 and 2.058 in 2000; basic materials chemistry: 0.405 in 2017 and 0.429 in 2000; and mechanical elements 0.445 in 2017 and 1.897 in 2000. The RTA was lower in 2017 than in 2000 in three of the five fields, namely engines/pumps/turbines, basic materials chemistry, and mechanical elements.

Figure II-3-2-2-19 Changes in China's RTA indices (comparison between 2000 and 2017)



Source: WIPO Statistics Database.

With respect to the change in the technological structure between 2000 and 2017, the RTA index recorded the highest rate of increase, 191.3%, in the field of digital communication. That was followed by the growth of 155.0% for telecommunications, 107.6% for optics, 88.6% for IT methods for management, and 56.9% for computer technology. In contrast, the RTA declined steeply, by 166.0% for engines/pumps/turbines, 144.9% for mechanical elements, 114.3% for biotechnology, 107.5% for civil engineering and 89.0% for other consumer goods (Table II-3-2-2-20).

One distinctive feature of the change in the technological structure between 2000 and 2017 is that the advantage in fields of technology related to new industries, such as digital communication and computer technology, increased, while the advantage in fields of technology related to traditional industries, such as engines/pumps/turbines and mechanical elements, declined.

Table II-3-2-2-20 Technical fields of top and bottom five in RTA indices growth rates

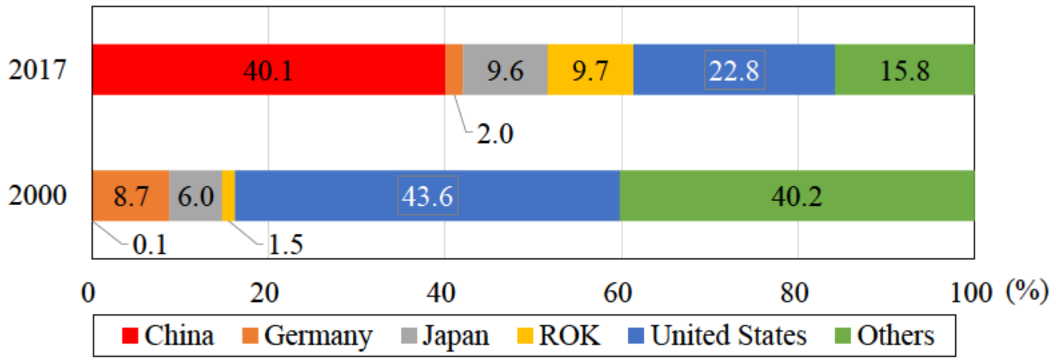
Technical field	Growth rate of RTA index (2000-2017)	RTA index	
		2000	2017
(Top five fields)			
Digital communication	191.3%	0.353	2.387
Telecommunications	155.0%	0.366	1.722
Optics	107.6%	0.505	1.480
IT methods for management	88.6%	0.471	1.144
Computer technology	56.9%	1.010	1.785
(Bottom five fields)			
Engines/pumps/turbines	-166.0%	2.058	0.391
Mechanical elements	-144.9%	0.429	0.446
Biotechnology	-114.3%	1.592	0.508
Civil engineering	-107.5%	1.795	0.613
Other consumer goods	-89.0%	2.707	1.112

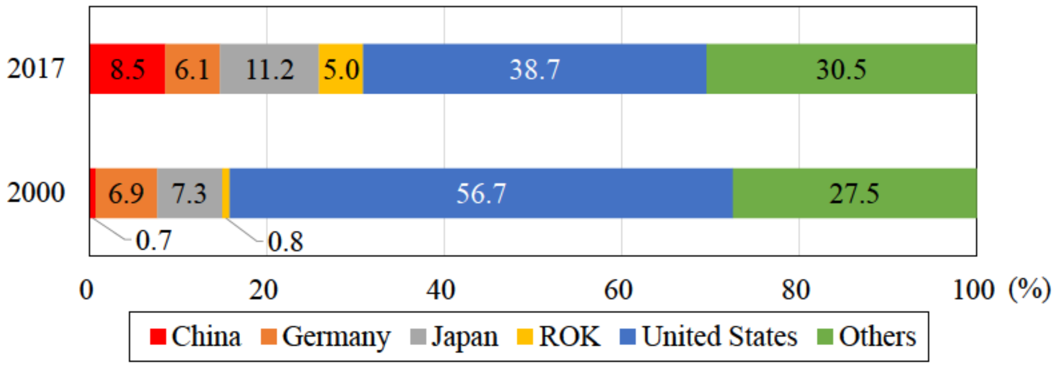
Source: METI.

If we also look at the abovementioned Figure II-3-2-2-19, it is clear that China's advantage grew compared with 2000 in fields of technology in which the RTA index was higher than 1 in 2017, except for some fields (thermal processes and apparatus, other consumer goods, and furniture/games). In contrast, the rate of increase was low in fields in which the RTA index was lower than 1, including engines/pumps/turbines and biotechnology. In those fields, the RTA index was higher than 1 in 2000. With respect to thermal processes and apparatus, other consumer goods, and furniture/games, the RTA index declined compared with 2000, but China still maintained an advantage (the RTA index is higher than 1).

One point to which attention should be paid with respect to the domestic distribution of the RTA is the RTA's relationship with the global share. The degree of advantage or disadvantage indicated by the RTA index is based on relative comparison within each field because of the indicator's nature. This means that the global share may be large in fields where the RTA index is low, or it may be small in fields where the index is high, depending on the status of domestic and global patent publications. For example, China's global share in the field of digital communication expanded from 0.14% to 40.10% in line with the rise in the RTA in this field. Meanwhile, in the field of biotechnology, China's global share grew from 0.65% to 8.53% although the RTA declined from 1.592 to 0.508 between 2000 and 2017 (Figure II-3-2-2-21).

Figure II-3-2-2-21 Changes in share of PCT publications in the fields of digital communication and biotechnology





Source: WIPO Statistics Database.

As described above, China's technological structure as observed from the viewpoint of technological advantage in terms of PCT Publications dramatically changed between 2000 and 2017. While China's advantage in fields of technology considered to be closely related to new industries has increased, its advantage in fields considered to be closely related to traditional industries is declining. The shift in the field of technological advantage from traditional to new industries is proceeding not only because of the growth of companies and research institutions and invigorated research and development activity in China, but also the promotion of science and technology policy measures by the government of China is considered to be making no small contribution to the shift. This suggests that over the period of slightly less than 20 years, the changes in the industrial and technological structures have proceeded in parallel.

(D) Changes in external relations regarding the technological structure

The advance of innovation in China is also generating a change in the external relationship in terms of the technological structure. Through comparison between China, Japan, the United States, Germany and the ROK in terms of the RTA index in 2000 and 2017, we can identify the characteristics of the fields of technology in which the countries have an advantage and changes in those characteristics.

The RTA index may take values ranging from 0 to ∞ because of the nature of its definition formula. In order to make it easier to conduct comparison between two countries in terms of the technological structure and to identify changes, we will first define and calculate the Revealed Symmetric Technological Advantage (RSTA) index, a modified version of the RTA that may take values ranging from -1 to +1.[119]

Next, with respect to each pair of countries, we will adopt identical sets of fields of technology and divide those fields into groups classified by the level of the RSTA and calculate the correlation coefficient. The coefficient represents similarity between each pair of countries in terms of technological structure, so if the coefficient regarding a certain pair indicates the absence of correlation, the two countries are considered to have a neutral relationship in terms of the technological structure. The presence of a positive correlation indicates that the two countries have a similar degree of advantage or disadvantage in the same field, which means that they are considered to have a competitive relationship. The presence of a negative correlation indicates that one of the pair has an advantage or disadvantage relative to the other in the same field, which means that they are considered to have a complementary relationship. (Table II-3-2-2-22).

Table II-3-2-2-22 Bilateral relationships of technological structures measured by RTA index

Partner country	Higher advantage of partner country over own country / Higher disadvantage of own country to partner country (complementing the advantage of partner country)	High competitiveness (advantageous competitiveness)
	Low competitiveness (disadvantageous competitiveness)	Higher advantage of own country over partner country / Higher disadvantage of partner country to own country (complementing the advantage of own country)
	Own country	

Source: METI.

In order to make clear a competitive or complementary relationship between each pair of countries, we will show regression lines whose intercept is located at the coordinate origin in distribution graphs regarding the pairs of China and each of Japan, the United States, Germany and the ROK. The regression line, which represents the relationship between each pair of countries, forms a relationship axis that turns with the coordinate origin as the center. In this case, when the pair of countries have a competitive relationship with each other, the relationship axis is located in the first and third quadrants. When the two countries have a complementary relationship, the relationship axis is located in the second and fourth quadrants. The larger the change in the angle of the relationship axis between the two points in time, the larger the change in the relationship between the two countries is in terms of the technological structure. However, one point that should be kept in mind is that micro-level changes in fields of technology cannot be captured because this approach focuses on the macro analysis of the technological structure.

119 The symmetrization equation is as follows: RSTA = (RTA - 1) / (RTA + 1).

Therefore, in order to conduct micro analysis of changes in specific fields of technology, we identify fields in which a significant change occurred regarding each pair of countries by vectorizing the value regarding each field at each point in time and assessing the angle of the inner product between the two points in time.

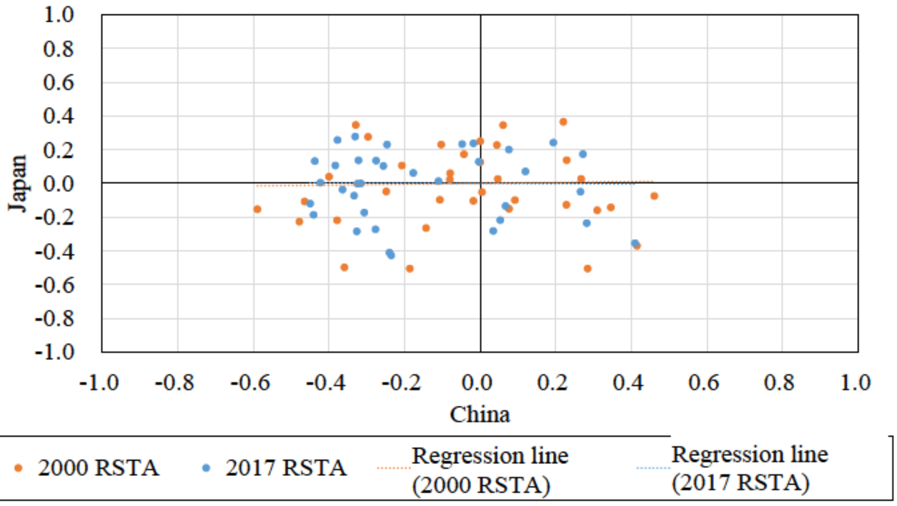
We will look at the characteristics of changes in China's bilateral relationship with Japan, the United States, Germany and the ROK in terms of the technological structure.

As for China's relationship with Japan in terms of the technological structure, the correlation coefficient regarding the two countries' relationship in 2000 was 0.009, a level considered to be an indication of the absence of correlation. This means we may presume that their relationship was neutral. In 2017, the correlation coefficient declined to -0.059, but this is still a level considered to indicate the absence of correlation, so the two countries' relationship is presumed to have remained neutral.

Although we may presume that there is no correlation in terms of the overall technological structure, the following characteristics can be observed in the two countries' relationship in specific fields. First, in three of the five fields in which the rate of increase in China's RTA index was high (telecommunications, digital communication, and optics), China gained an advantage over Japan (their relationship has become complementary) or became highly competitive with it. In three fields--telecommunications, digital communication, and IT methods for management--China gained an advantage over Japan, while it became competitive with it in two fields--control and optics.

In contrast, China's advantage over Japan declined in the fields of transport, semiconductors, engines/pumps/turbines, mechanical elements and three other fields. The number of fields in which China's advantage over Japan declined is greater than the number of fields in which the advantage over either of the United States, Germany or the ROK declined. In particular, engines/pumps/turbines and mechanical elements are among the five fields in which the rate of increase in China's RTA index was low (Figure II-3-2-2-23).

Figure II-3-2-2-23 Changes in China-Japan relationships of technological structures



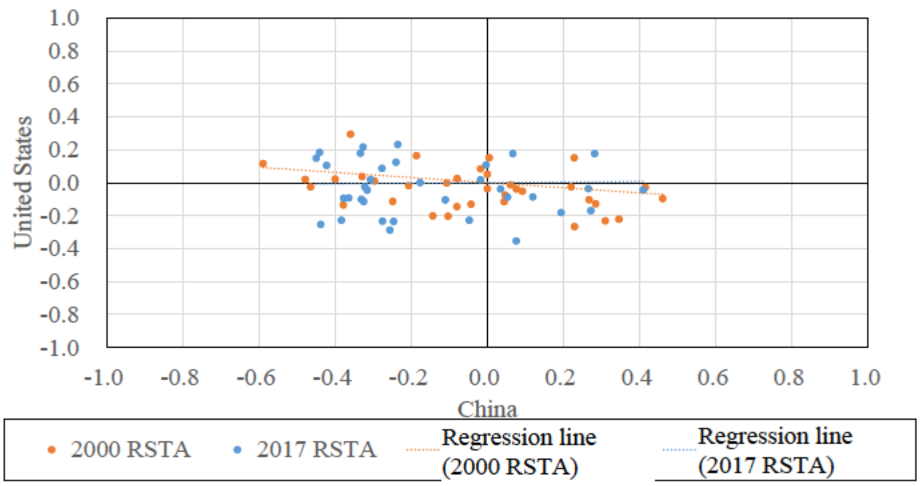
Source: METI.

The relationship between China and the United States in terms of the technological structure, which was somewhat complementary in 2000, changed and was neutral in 2017. The angle of the relationship axis in 2000 was -0.156°, while the correlation coefficient regarding the two country's relationship was -0.392. In 2017, the angle of the relationship axis was 0.018 but the correlation coefficient was -0.105, a level mostly considered to indicate the absence of correlation, so the two countries' relationship is presumed to have become neutral.

On the whole, there appears to have been little change, but in specific fields, some distinctive changes can be identified. Concerning China's relationship with the United States in terms of the technological structure, China's advantage increased in three fields--telecommunications, digital communication and optics. These three fields are the same ones in which the three highest rates of increase were recorded for the RTA index. Meanwhile, in the field of IT methods for management, the United States had an advantage in 2000, but the two countries' relationship shifted to a highly competitive one, which means that as in the case of the abovementioned three fields, China's advantage is considered to have increased.

In contrast to the situation in those fields, the United States' advantage over China increased in the field of biotechnology. In 2000, the two countries' relationship in this field was one of a high level of competition, but in 2017, the United States maintained its advantage while China's advantage declined (Figure II-3-2-2-24).

Figure II-3-2-2-24 Changes in China-US relationships of technological structures



Source: METI.

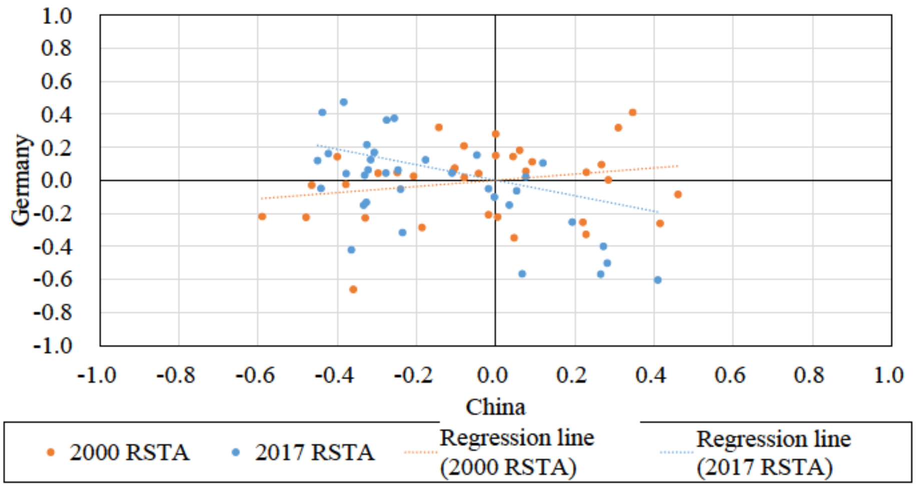
China's relationship with Germany in terms of the technological structure changed more than its relationship with Japan, the United States or the ROK over a period of slightly less than 20 years. The relationship, which was somewhat competitive in 2000, was complementary in 2017. The correlation coefficient was 0.127 in 2000 and -0.651 in 2017. The relationship axis between China and Germany turned -35.774°, representing a larger degree of turn than the turns recorded by the relationship axes between China and the three other compared countries. The degree of turn of the relationship axis was -1.976° for the China-Japan pair, 9.890° for the China-the United States pair, and -1.772° for the China-

ROK pair.

The large degree of turn indicates that the technological advantage of China and Germany over each other increased or declined in various fields. China gained an advantage over Germany in four fields--telecommunications, digital communication, optics, and IT methods for management. As in the case of China's relationship with Japan and the United States, China gained an advantage in fields in which its RTA index recorded a high rate of increase (telecommunications, digital communication, and IT methods for management).

On the other hand, Germany gained an advantage over China in six fields--environmental technology, chemical engineering, engines/pumps/turbines, mechanical elements, Electrical machinery/apparatus/energy, handling (elevators, cranes, robotics, packaging devices, etc.). As in the case of the relationship with Japan, China's advantage declined in fields in which its RTA index recorded a low rate of increase (engines/pumps/turbines and mechanical elements) (Figure II-3-2-2-25).

Figure II-3-2-2-25 Changes in China-Germany relationships of technological structures



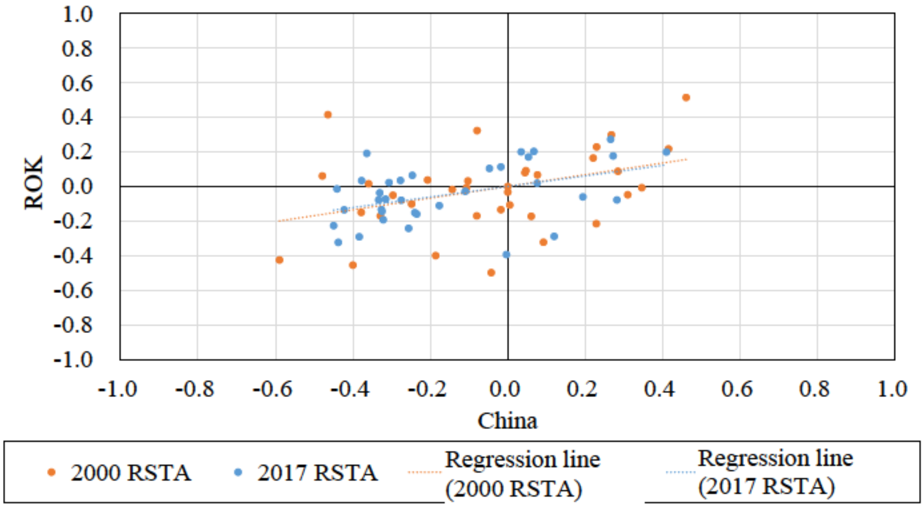
Source: METI.

China's relationship with the ROK in terms of the technological structure remained competitive, unlike its relationship with Japan, the United States and Germany. The correlation coefficient was 0.384 in 2000 and 0.454 in 2017, so China's relationship with the ROK is presumed to be relatively competitive compared with its relationship with the other three countries. The degree of the turn of the relationship axis was -1.772°, smaller than the turns recorded for China's relationship with the other three countries.

On the whole, the change in the structural change was small, but in specific fields, the degree of advantage changed significantly as in the case of China's relationship with the other three countries. What is most distinctive is that the relationship became highly competitive in three fields (telecommunications, digital communication, and IT methods for management). In these three fields, the rate of increase in China's RTA index was relatively high. The number of fields in which the relationship became highly competitive was larger than in the case of China's relationship with the other three countries. This fact, combined with the value of the correlation coefficient in 2017, indicates that the degree of competitiveness in terms of the technological structure increased.

China gained an advantage over the ROK in the fields of control and optics. Control is a field in which China became highly competitive with Japan, while optics is a field in which China also gained an advantage over the United States and Germany as well as in which it became highly competitive with Japan (Figure II-3-2-2-26).

Figure II-3-2-2-26 Changes in China-ROK relationships of technological structures



Source: METI.

Table II-3-2-2-27 summarizes China's relationships with the four compared countries in terms of the technological structure. One notable point is that in four of the five fields in which the five highest rates of increase in China's RTA index were recorded (digital communication, telecommunications, optics, and IT methods for management), China gained an advantage over or became highly competitive with Japan, the United States, Germany and the ROK. In the remaining one of those five fields, computer technology, China remained highly competitive with the United States, while it maintained an advantage over Japan, Germany, and the ROK.

In the fields of engines/pumps/turbines and mechanical elements, in which the rate of increase in China's RTA index was low, China's advantage over Japan and Germany declined. Likewise, in the field of biotechnology, China's advantage over the United States declined. What is distinctive about the fields in which China's advantage declined, namely the fields in which the partner countries' advantage increased, is that fields in which the rate of increase in China's RTA index was low, such as engines/pumps/turbines, mechanical elements, and biotechnology, include fields in which either Japan, the United States or Germany had an advantage (Table II-3-2-2-27).

Table II-3-2-2-27 Changes in China-Japan, US, Germany or ROK relationships of technological structures

Partner country	Technical field		
	China enhancing comparative advantage (partner country losing comparative advantage)	High competitiveness	Partner country enhancing comparative advantage (China losing comparative advantage)
Japan	Telecommunications Digital communication IT methods for management	Control Optics	Environmental technology Electrical machinery/ apparatus/energy Semiconductors Transport Measurement Other special machines Engines/pumps/turbines Mechanical elements
United States	Telecommunications Digital communication Optics	IT methods for management	Biotechnology
Germany	Telecommunications Digital communication Optics IT methods for management	(None)	Environmental technology Chemical engineering Engines/pumps/turbines Mechanical elements Electrical machinery/ apparatus/energy Handling (elevators, cranes, robots, packaging devices, etc.)
ROK	Control Optics	Digital communication IT methods for management Telecommunications	Food chemistry Electrical machinery/ apparatus/energy Semiconductors Chemical engineering

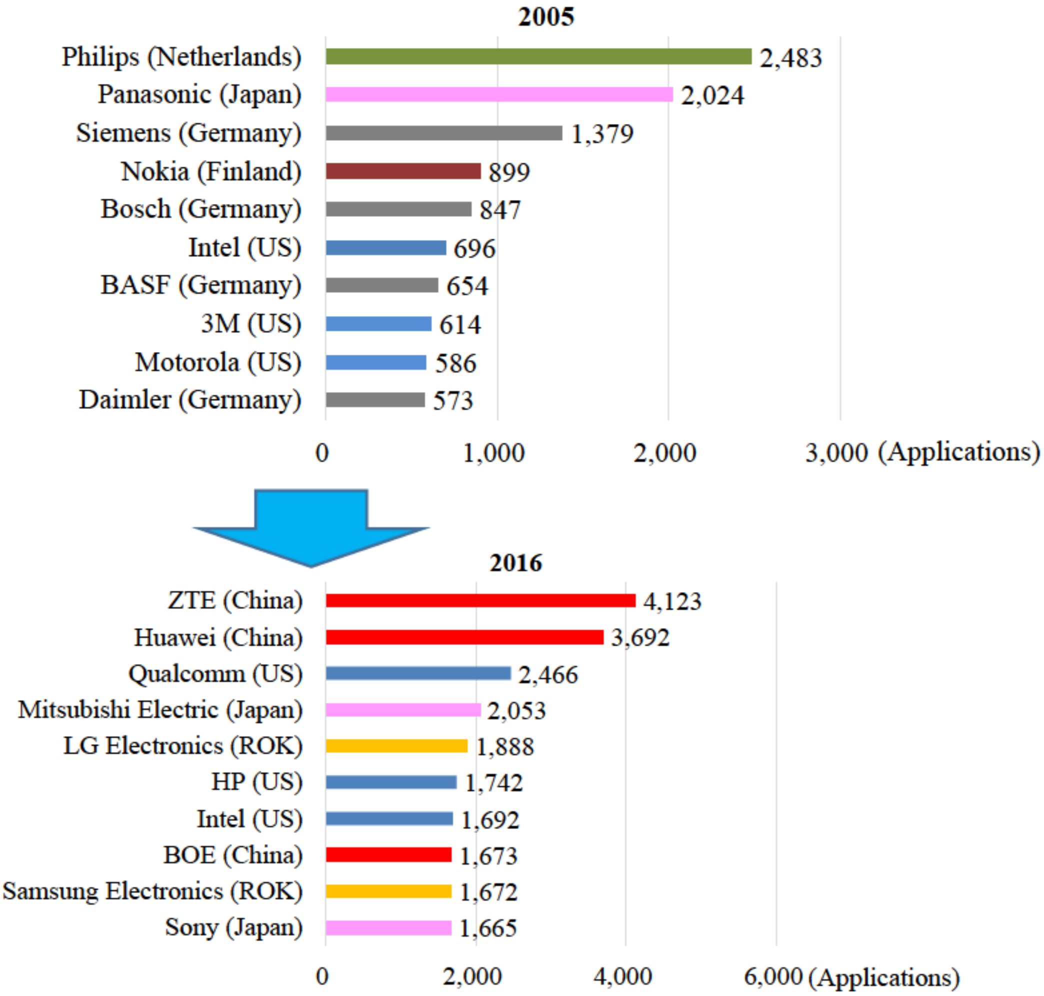
Source: METI.

(E) Widening of the base of patent applicants and changes in their attributes

Next, we will look at the widening of the base of patent applicants and changes in patent applicants' attributes in China.

First, in 2005, the top 10 positions in the global rankings of PCT applicants were dominated by major traditional manufacturers, such as U.S. and European electric and electronics companies, automakers, and chemical companies, with only one Asian company, from Japan, included among the top 10. However, in 2016, only one of the global top 10 companies in 2005, a U.S. electrical and electronics company, remained in the top 10. By sector, all of the top positions were occupied by information and communication companies or electric and electronics companies. By country/region, seven of the top 10 companies were Asian, including three from China, two from the ROK and two from Japan, and the remaining three were U.S. companies (Figure II-3-2-2-28).

Figure II-3-2-2-28 Changes in top 10 companies in the number of PCT applications



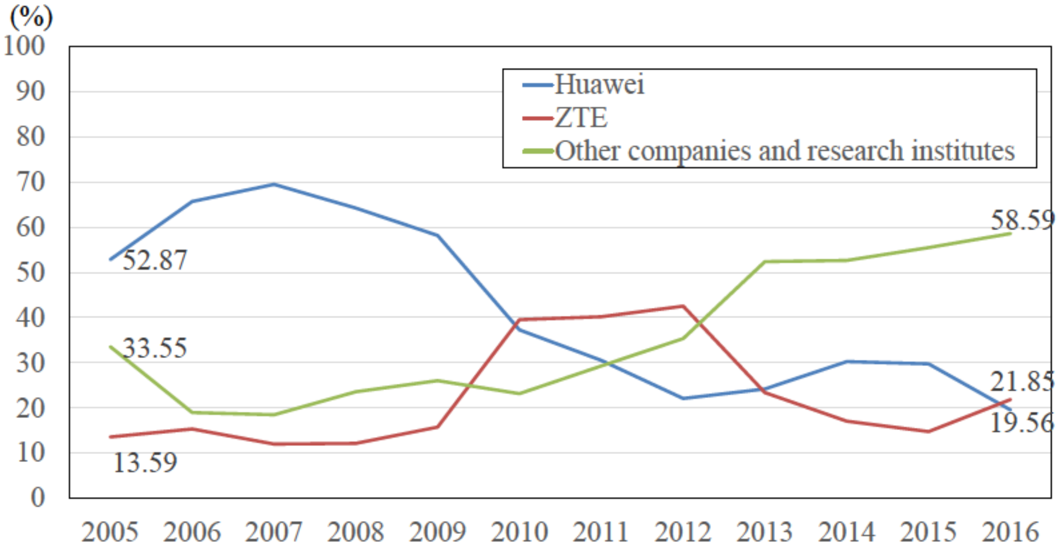
Source: WIPO Statistics Database.

In 2005, only 13 Chinese companies, including Huawei and ZTE, filed PCT applications, but the number of Chinese applicant companies in 2016 was 275.[120] Between 2005 and 2016, Huawei and ZTE filed a total of 7,355 and 3,153 PCT applications, respectively, together accounting for 75.4% of the overall number of PCT applications filed by Chinese companies, which was 13,934.

120 WIPO Statistics Database (as of March 2018) (http://www.wipo.int/ipstats/en/). The number of companies which filed 10 or more international patent applications.

From this data, patent applications strongly appear to be concentrated among a disproportionately small number of companies, but in recent years, the shares of Huawei and ZTE in the total number of PCT applications filed in China has been gradually declining (Figure II-3-2-2-29). On the other hand, the number of Chinese companies filing PCT applications has continued to increase as was mentioned above, indicating that the base of applicant companies and research institutions is widening.

Figure II-3-2-2-29　Changes in shares of Huawei and ZTE in PCT applications



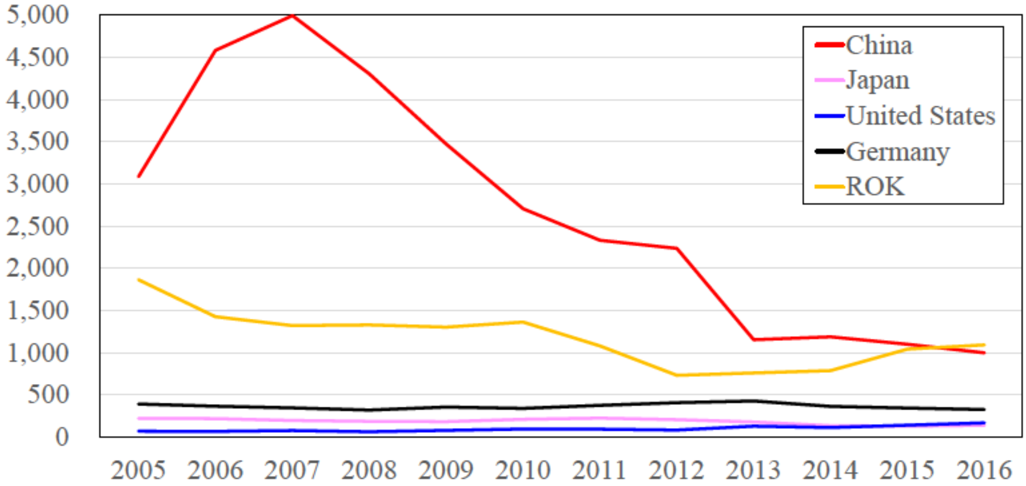
Source: WIPO Statistics Database.

Regarding the concentration of PCT applications among a disproportionately small number of companies and changes in the number of applicant companies, we will measure the degree of and changes in the concentration of PCT applications filed by Chinese companies by making use of the Herfindahl-Hirschman Index (HHI),[121] which is usually used to measure market concentration. The HHI index ranges from 0 to 10,000.[122] Here, when the HHI is 10,000, it means that one company monopolizes PCT applications. In other words, when the HHI approaches 0, monopoly or oligopoly of PCT applications weakens. Conversely, when the HHI approaches 10,000, the situation of PCT applications moves toward monopoly or oligopoly.

We calculated the degree of the concentration of PCT applications filed by Chinese companies based on the number of applications filed by individual companies over the 12 years between 2005 and 2016, and the results show that the concentration has been weakening over the long term and indicates the degree of concentration in China relative to the situations in other countries (Figure II-3-2-2-30[123]).

121 "Explanations of Terms" on the website of the Japan Fair Trade Commission (as of April 24, 2018) (http://www.jftc.go.jp/soshiki/kyotsukoukai/ruiseki/yougo.html).
122 Strictly speaking, the index does not take the value "0," but when the number of companies is sufficiently large and the share per company is sufficiently small, the value of the index asymptotically approaches "0."
123 WIPO Statistics Database (as of March 2018) (http://www.wipo.int/ipstats/en/).

Figure II-3-2-2-30 International comparison of concentration ratio of PCT application's companies



Source: WIPO Statistics Database.

China's HHI has been declining year after year since 2008, since peaking at 4,922 in 2007. In particular, it fell steeply (to -1,083) from 2012 to 2013. Later, China's HHI dropped below the ROK's HHI (1,093) to 999 in 2016.

The HHI for Japan, the United States and Germany have stayed stably below 500 over the same period, so it is presumed that PCT applications in China are concentrated in a disproportionately small number of companies compared with the situations in those three countries.

Above, we made clear that the base of patent applicants in China is widening in terms of the number of PCT applications and publications. Next, we will look at changes in the attributes of patent applicants in China based on information concerning domestic patent applications in China. In this respect, Motohashi (2018) conducted a detailed analysis using data compiled by the State Intellectual Property Office (SIPO) of China.

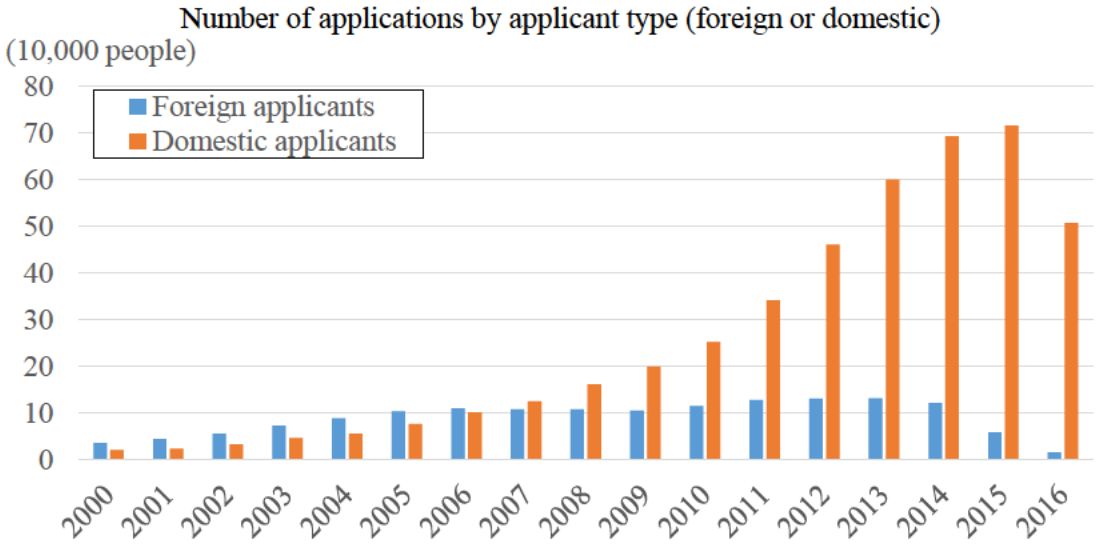
First, the total number of domestic patent applications in China has risen steeply since 2007. Next, regarding the attributes (foreign or domestic) of applicants for domestic patents, the number of patent applications by foreign applicants was higher than the number of patent applications by domestic applicants until 2005. However, since 2006, the number of patent applications by domestic applicants has continued to be higher than the number of patents filed by foreign applications. While the number of patent applications by foreign applicants has increased only slightly since 2006, the number of patent applications by domestic applicants has continued to rise steeply. As a result, patent applications by domestic applicants, rather than applications by foreign applicants, have become prevalent.

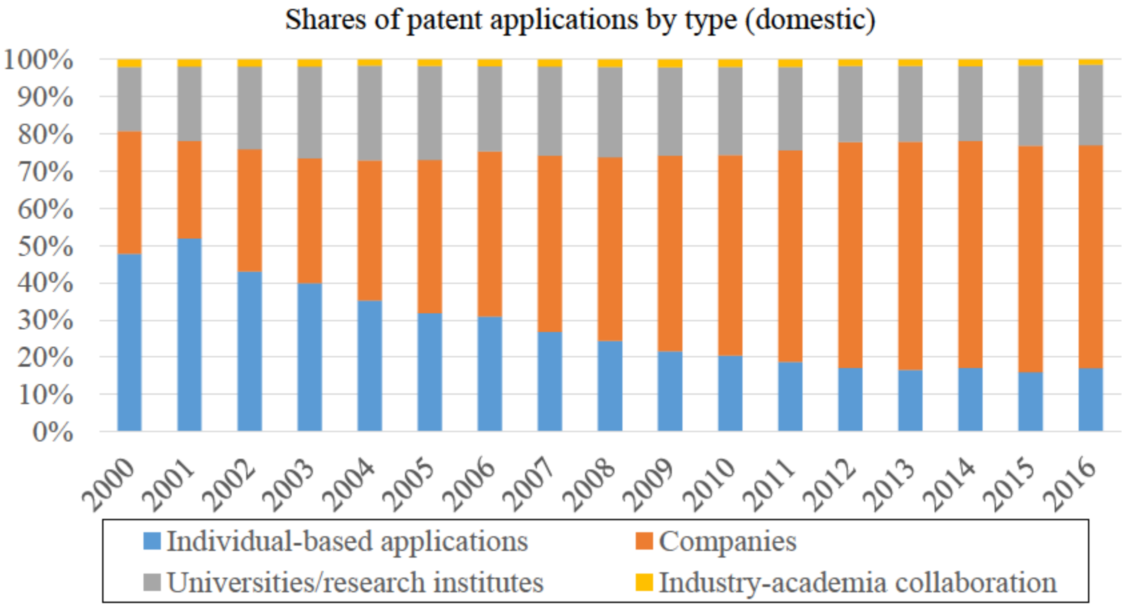
Next, looking at the attributes of patent applicants in China by individual or institution, the share of applications by companies has grown significantly since 2000,[124] which means that companies have become the main driver of innovation. However, universities/research institutes also have maintained a

124 Motohashi (2018) pointed out that one factor behind the decline in the number of applications by individuals is the improvement of systems to reward employees for their inventions at companies, universities and other institutions.

share of around 20% in the total number of patent applications, indicating that they play an important role (Figure II-3-2-2-31).

Figure II-3-2-2-31 Number of patent applications by applicant type (foreign or domestic), and shares of patent applications by type





Source: Motohashi (2018).

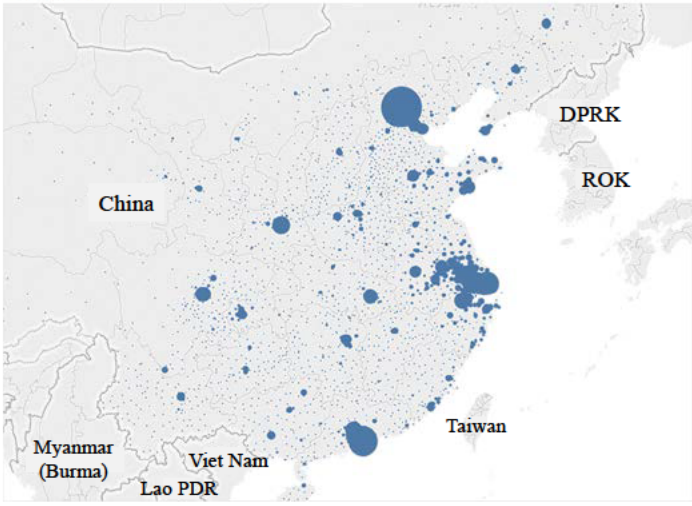
Column 6 Characteristics of major patent applicant regions in China

In China, Beijing, Shanghai, and Shenzhen were considered to be at the leading edge of the development of the "new economy" at the beginning of the 2000s, before the number of patent applications rose steeply. As Beijing had robust science and technology infrastructure, it devoted efforts to the commercialization of scientific and technological achievements, and Shanghai adopted a development strategy intended to reform traditional industries through high technology and new technology at the same time as creating industries based on high technology and new technology. Shenzhen established a research and development base and promoted the development and high-tech and new technology industries by borrowing brains from the outside and inviting universities, science and technology institutions, and companies, including multinational ones, from the outside while emphasizing the establishment of a technology development system led by companies because its science and technology infrastructure was weak.[125]

In 2016, these three clusters continued to be the most active regions in China in terms of patent application (Column Figure 6-1).

Column Figure 6-1 Regional distribution of patent applications

Number of patents applications by Chinese administrative area



Source: Motohashi (2018).

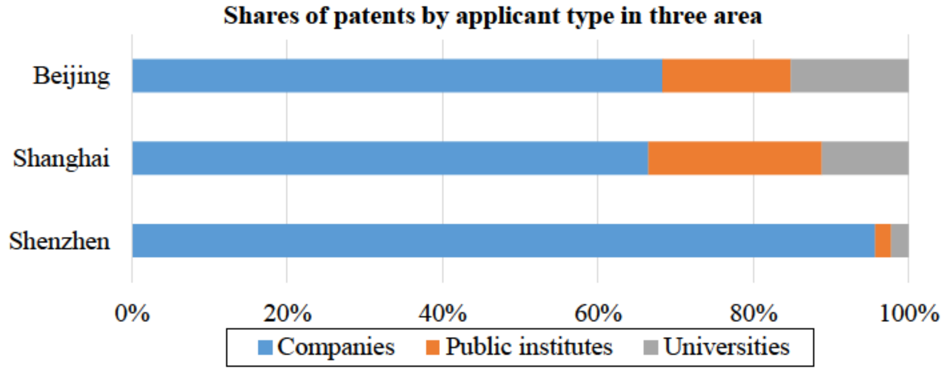
A comparison of the three clusters in terms of applicant attribute shows that companies have the largest share in the number of applications in all three clusters. In Beijing, universities' share is relatively large, while public research institutes' share is relatively large in Shanghai. Companies' share is relatively large in Shenzhen.

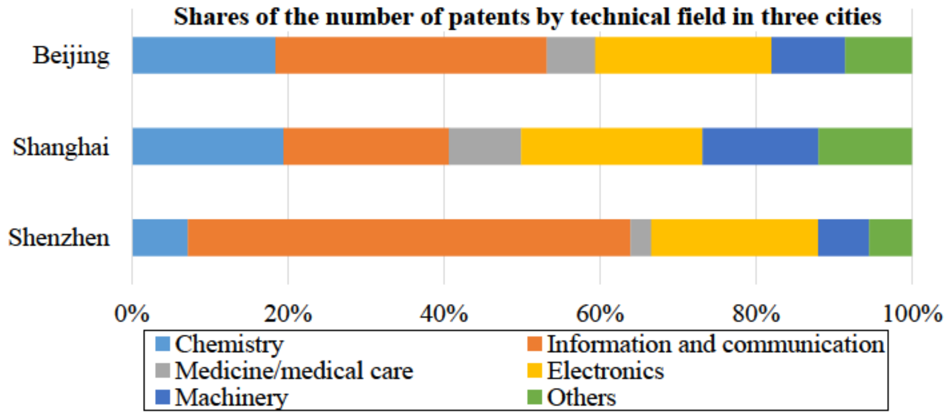
From the Revealed Comparative Advantage (RCA) index, it is clear that the three clusters have a comparative advantage in different fields of technology. Shenzhen has a comparative advantage in such fields as electronic circuits/communication technology, nuclear engineering, and

125 Seki (2002).

watches/control/computers (Column Figure 6-2).

Column Figure 6-2 Share of patents by applicant type and technical field in each cluster

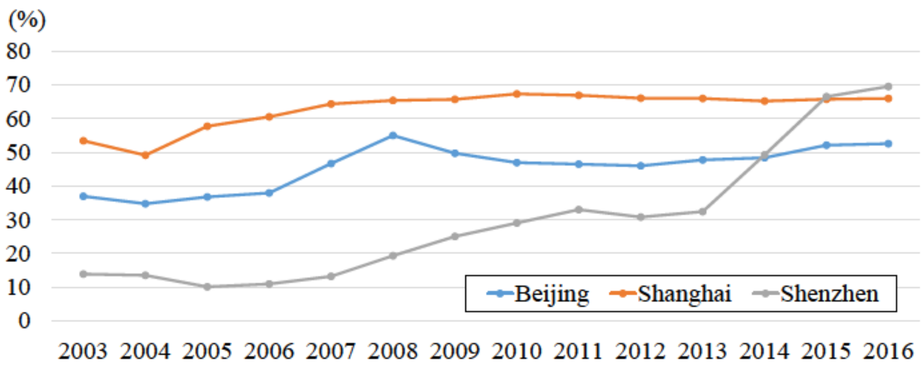




Source: Motohashi (2018).

As to whether patent applications are filed only by particular government research institutions and major companies or there is a wide base of applicants, a significant change has occurred in the share of small-scale applicants in Shenzhen since 2013. This suggests that not only are major companies such as ZTE, Huawei and Tencent filing patent applications but also there is an increasing number of companies filing patent applications for the first time (Column Figure 6-3).

Column Figure 6-3 Shares of small-scale applicants (less than 1,000 patent applications)



Source: Motohashi (2018).

(2) Measures to realize innovation

(A) Government plans

In this paragraph, we will look at what policies and plans China has formulated, what financial and human resources it has allocated and what sorts of entrepreneurship activity it has invigorated in order to realize innovation.

Under the 13th Five-Year Plan for Economic and Social Development (2016-2020), the government of China expressed continued cautiousness about the risk of falling into the middle-income trap and positioned the development of innovation as a breakthrough to avert the risk, and it formulated plans that hinge mainly on information technology but also on the sharing economy and big data as the keys.[126] Later, under the 13th Five-Year Plan on Science, Technology and Innovation, which was published in August 2016, the word "innovation" was added to the name of the five-year plan for national science and technology for the first time. It is said that this was intended to emphasize that this plan was formulated with a view to covering the whole processes of innovation creation, from research and development to the creation of new industries, by integrating science and technology with the economy and innovation[127] (Table 3-2-2-32).

Table II-3-2-2-32 Major policies related to innovations in China

Released year	Title of policy	Governing authority
Feb. 2006	Outline for National Medium & Long-term Program for Science and Technology Development (国家中长期科学和技术发展规划纲要) (2006-2020)	State Council
May 2009	Pilot measures for Price Offering and Transfer of Stocks of Non-Listed Stock Limited Companies Targeting Zhongguancun Science Park (证券公司代办股份转让系统中关村科技园区非上市股份有限公司股份报价转让试点办法) (rules for stocks of unlimited companies)	China Securities Regulatory Commission (CSRC)
	Jul. 2012 Pilot Measures for Price Offering and Transfer Of Stocks of Non-Listed Stock Limited Companies Targeting Zhongguancun Science Park (证券公司代办股份转让系统中关村科技园区非上市股份有限公司股份报价转让试点办法) (expansion of the rules to cover not only Zhongguancun Science Park but also other science and technology parks in Shanghai, Tianjin and Wuhan)	

126 Hoshokawa (2016).
127 Japan Science and Technology Agency (2016), "China issues the 13th Five-Year Plan on Science, Technology and Innovation (“十三五”国家科技创新规划)," (http://crds.jst.go.jp/dw/20161004/201610049475/).

Mar. 2011	The 12th Five-Year Plan for Economic and Social Development of the People’s Republic of China (国民经济和社会发展第十二个五年规划纲要) (2011-2015)	Central Committee of the Communist Party of China
Jul. 2011	The 12th Five-Year Plan for Science and Technology Development (国家“十二五”科学和技术发展规划) (2011-2015)	Ministry of Science and Technology
Mar. 2015	“Mass Entrepreneurship and Innovation”	State Council
	May 2016: Opinions for Building Model Bases to Implement the “Mass Entrepreneurship and Innovation” Policy (关于建设大众创业万众创新示范基地的实施意见)	State Council Information Office
May 2015	Made in China 2025	State Council
	Apr. 2016: Robotics Industry Development Plan (机器人产业发展规划) (2016-2020)	Ministry of Industry and Information Technology (MIIT), National Development and Reform Commission (NDRC)
Mar. 2015	Internet Plus	State Council
	Jul. 2015: Guidance on Actively Promoting Internet Plus Action Plan (关于积极推进“互联网+”行动的指导意见) (2015-2018)	MIIT
	Sep. 2015: Action Plan for Promoting the Development of Big Data (关于印发促进大数据发展行动纲要的通知)	State Council
	May 2016: Three Year Action Plan to Promote the Development of New-Generation Artificial Intelligence Industry (“互联网+”人工智能三年行动实施方案)	NDRC
Mar. 2016	The 13th Five-Year Plan for Economic and Social Development of the People’s Republic of China (国民经济和社会发展第十三个五年规划纲要) (2016-2020)	Central Committee of the Communist Party of China
May 2016	Outline of the National Strategy of Innovation-Driven Development (国家创新驱动发展战略纲要) (2016-2030)	State Council
Aug. 2016	The 13th Five-Year Plan for National Science and Technology Innovation (“十三五”国家科技创新规划) (2016-2020)	State Council
	May 2016: Action Plan for Transformation and Transfer of Scientific and Technological Achievements (促进科技成果转移转化行动方案)	State Council Information Office

	Apr. 2016: Guidance on Investment / Lending Integration Tests Targeting Innovative Companies in Science and Technology Areas (关于支持银行业金融机构加大创新力度开展科创企业投贷联动试点的指导意见)	China Banking Regulatory Commission (CBRC), Ministry of Science and Technology, People's Bank of China

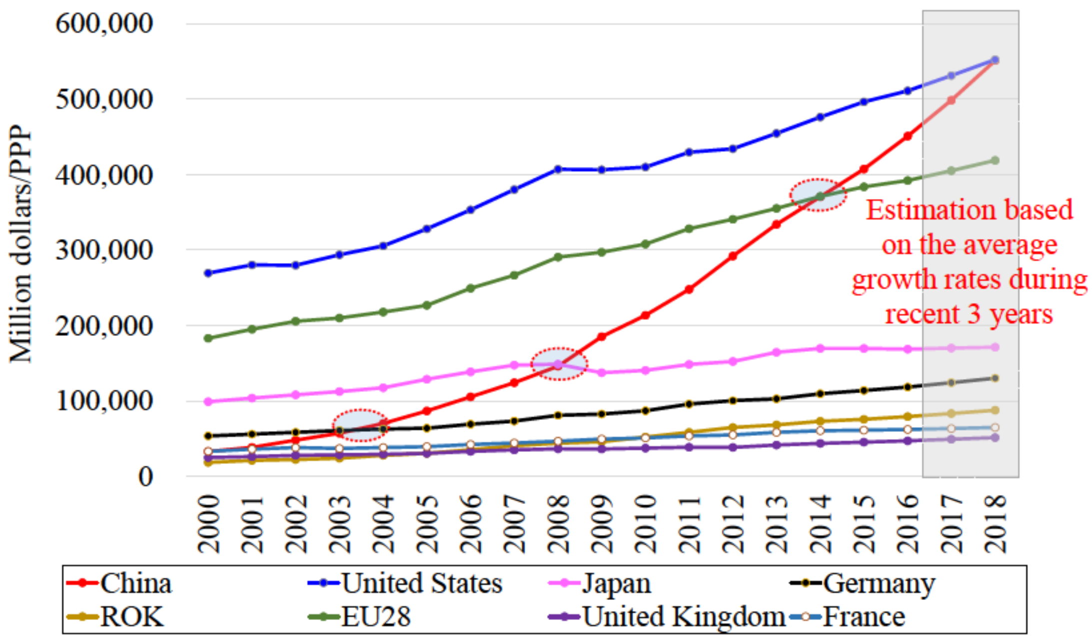
Source: *AITSUGU CHUUGOKU NO INOBEISHON SEISAKU TO KINYUU MEN DENO SHIEN NI MUKETA UGOKI* (Sekine, 2016), *CHUUGOKU KAGAKU GIJUTSU SEISAKU NO GENJOU TO TENBOU* (Japan Science and Technology Agency, 2017), etc.

(B) Financial resources

Next, we will look at financial resources, which is an input factor necessary for innovation.

Since 2000, the value of R&D expenditures (purchasing power parity basis) in China has increased rapidly, with the average annual growth rate until 2016 at 17.9%, much higher than the average growth rates of 4.1% in the United States, 5.1% in Germany and 3.5% in Japan. In terms of the value of R&D expenditures, China overtook Germany in 2004, Japan in 2009 and the EU28 in 2015, becoming the global No. 2, after the United States. On the assumption that R&D expenditures in China and other countries will increase in 2017 and later at the average growth rates in the most recent three years, when the growth rate in China is relatively low, R&D expenditures in China will surpass expenditures in the United States in 2018. This indicates that China is conducting innovation activity aggressively compared with other countries (Figure II-3-2-2-33).

Figure II-3-2-2-33 International comparison of R&D expenditures

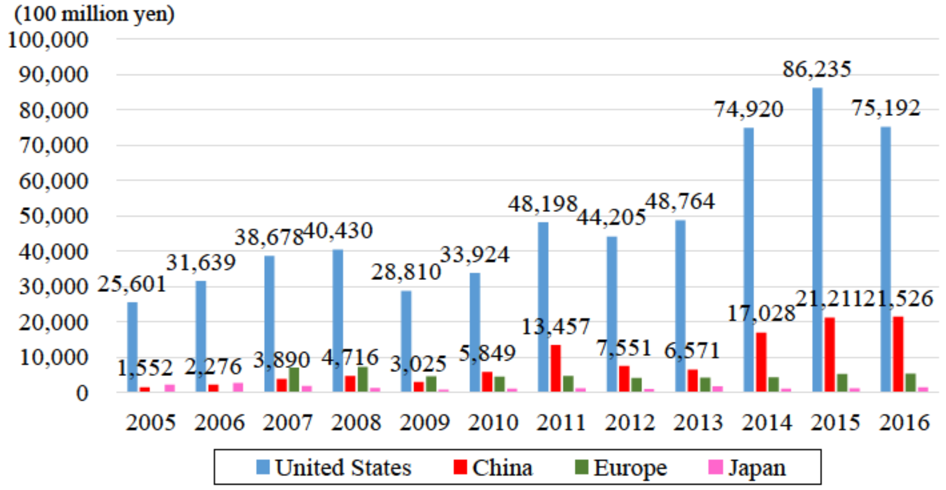


Notes: The data in 2017 and 2018 are estimates based on the average growth rates of each economy between 2014 and 2016.

Source: *Main Science and Technology Indicators* (OECD).

In terms of the value of venture fund investments in venture companies, which are among major innovation creators, China was the global No. 2 with an investment value of 2.2 trillion yen, after the United States with a value of 7.5 trillion yen. This means that the financing environment in China is very favorable for entrepreneurs (Figure II-3-2-2-34).

Figure II-3-2-2-34 International comparison of value of venture capital investment

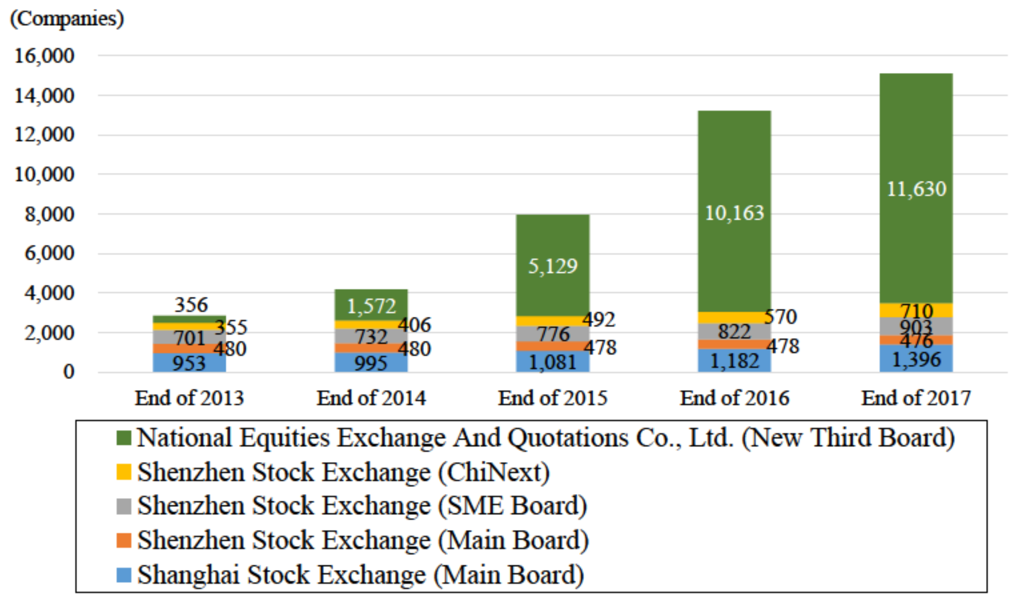


Source: *VEC YEARBOOK 2017 / Annual Report on Japanese Startup Businesses* (Venture Enterprise Center, 2017).

We will also look at the stock market for emerging companies, which, as well as venture funds, is important as a fund-raising means for venture companies. In China, the National Equities Exchange and Quotations Co., Ltd. was established in 2012 as a "New Third Board," after the Shanghai Stock Exchange and the Shenzhen Stock Exchange, in order to promote the development of venture companies. Since then, the number of companies listed on the New Third Board has increased markedly, growing thirty-seven fold between 2013 and 2017 and amounting to more than 11,000 companies at the end of 2017 with a total market capitalization of 4.9 trillion yuan (81 trillion yen) (Figure II-3-2-2-35). This size is only 7% of the total market capitalization on the U.S. NASDAQ market but is around 15 times as large as the total market capitalization on the Tokyo Mothers market and around seven times as large as the total market capitalization on the JASDAQ market.[128]

128 The comparison was conducted with data published by the World Federation of Exchanges in the case of the NASDAQ market and data published by the Tokyo Stock Exchange in the case of the Mothers and JASDAQ markets.

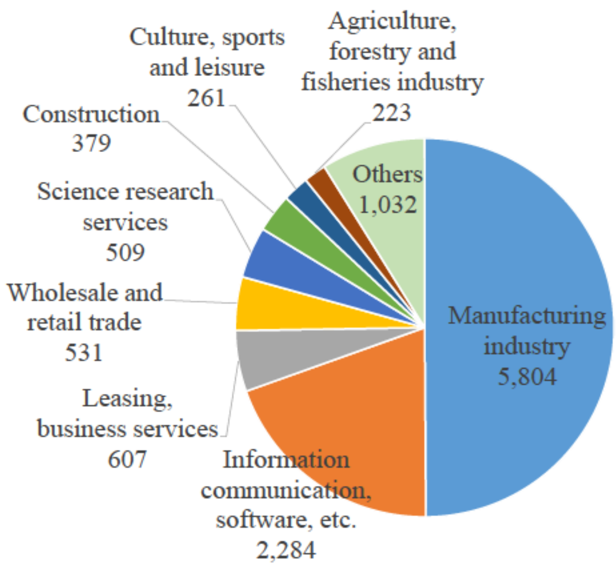
Figure II-3-2-2-35 Changes in the number of listed companies by stock exchange in China



Source: Nomura Institute of Capital Markets Research.

A breakdown of companies listed on the New Third Board by industry shows that the manufacturing industry accounts for the largest number, around 5,800 companies, followed by the information, communication and software industry with 2,300 companies. Even in China, where the rise of the information and communication industry is prominent, the manufacturing industry has the largest share on the New Third Board (Figure II-3-2-2-36).

Figure II-3-2-2-36 Number of companies by industry listed on the New Third Board (end of 2017)



Source: National Equities Exchange and Quotations (NEEQ).

In China, corporate venture capital, which is provided by IT platform companies, is also a major fund supply source for venture companies. Of the 226 unicorn companies around the world, 25 have received investment from Chinese IT platform companies. Of the 61 Chinese unicorn companies, 20 have received investments from Chinese IT platform companies.[129]

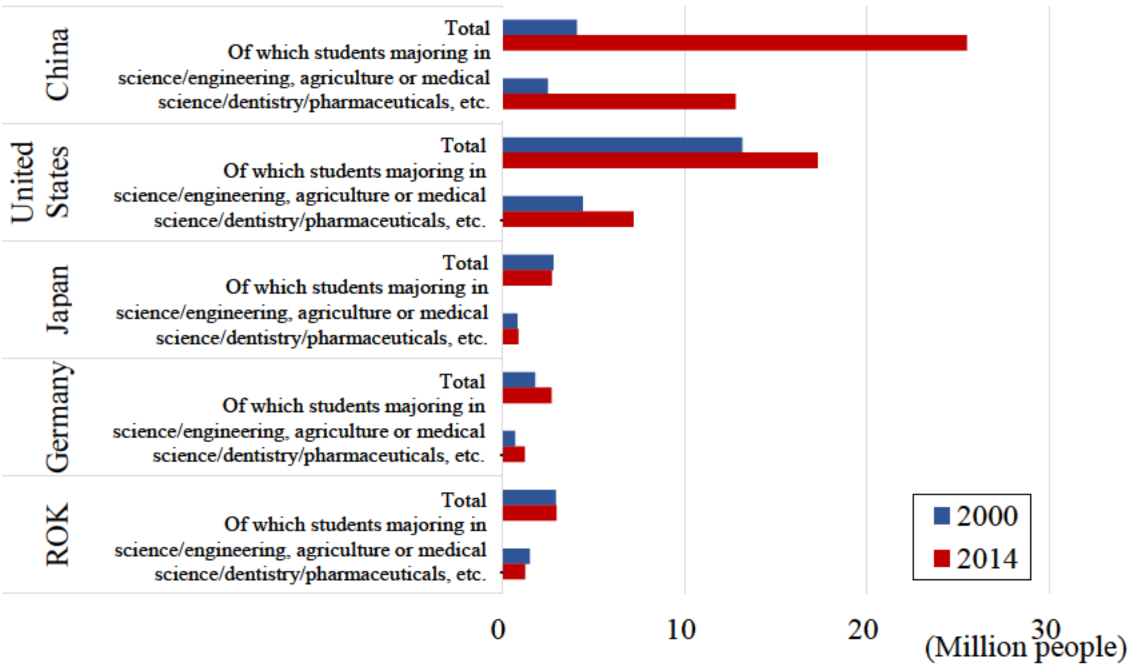
(C) Human resources

Next, we will look at the status of the development of highly skilled human resources, which represent one of the input factors necessary for innovation.

The number of undergraduate university students in China grew at an outstandingly high rate between 2000 and 2014 compared with the numbers of students in other countries. The number of students in China increased 6.2-fold from around 4 million in 2000 to around 25.5 million in 2014. Over the same period, the numbers of students in other countries grew at a rate ranging from around 0% to 100%.

Meanwhile, in China, students in science and engineering fields accounted for 50.2% of the overall number of students, compared with the shares of less than 50% in other countries--41.6% in the United States, 32.7% in Japan, 46.1% in Germany, and 42.1% in the ROK (2014) (Figure II-3-2-2-37).

Figure II-3-2-2-37 Number of students by field of major in major countries



Notes: The data on the number of enrolled students by field of major in the United States were the results of multiplying the ratios of people having a bachelor's degree by the number of enrolled students since no such data is accessible.

The data on China in 2000 are those released in 1999, and the data on the ROK in 2000 and 2014 are those released in 2004 and 2013, respectively.

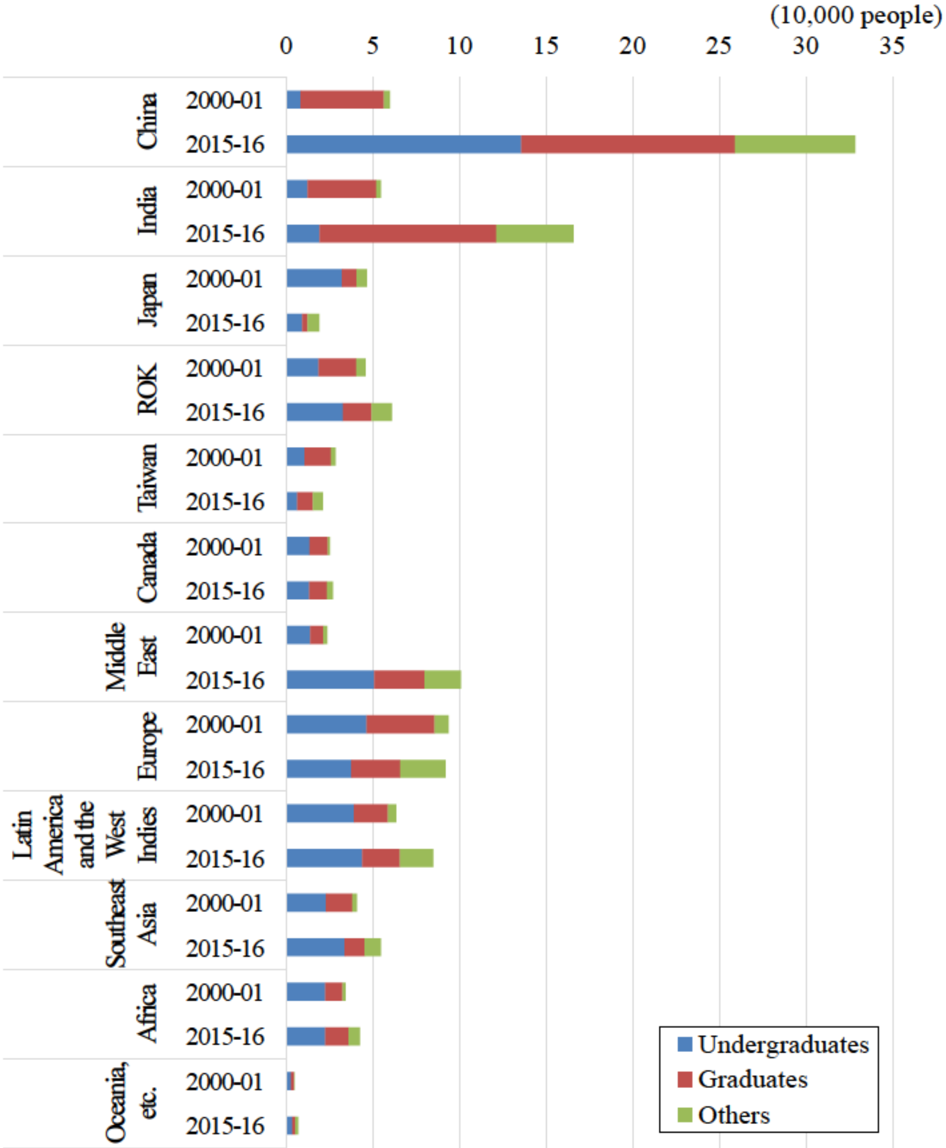
Source: *KYOUIKU SHIHYOU NO KOKUSAI HIKAKU*, *SHOGAIKOKU NO KYOUIKU TOUKEI* (MEXT), and *Digest of Education Statistics* (National Center for Education Statistics (NCES)) (as for the data on the United States).

129 CB Insights (as of January 24) (https://www.cbinsights.com/reserch-unicorn-companies).

The massive supply of highly skilled human resources in the science and engineering fields is considered to be one reason for the large numbers of patent applications, research papers and unicorn companies in China.

While we compared the number of domestic students in individual countries above, we will look at the number of foreign students by major country and field in the United States, the largest destination of Chinese students studying abroad. China outperforms other countries by a large margin in terms of both the number of students in the United States and the growth in the number between 2000-2001 and 2015-2016. The large growth in the number of Chinese students reflected a 16-fold increase in the number of undergraduates and a 19-fold increase in the number of "other" students. The number of Chinese graduate school students tripled, just as the number of Indian graduate school students did. In 2000-2001, graduate school students accounted for 80.1% of the overall number of Chinese students abroad, but in 2015-2016, the number was down to 37.5%. The share of graduate school students was largest, 61.4%, among Indian students (Figure II-3-2-2-38).

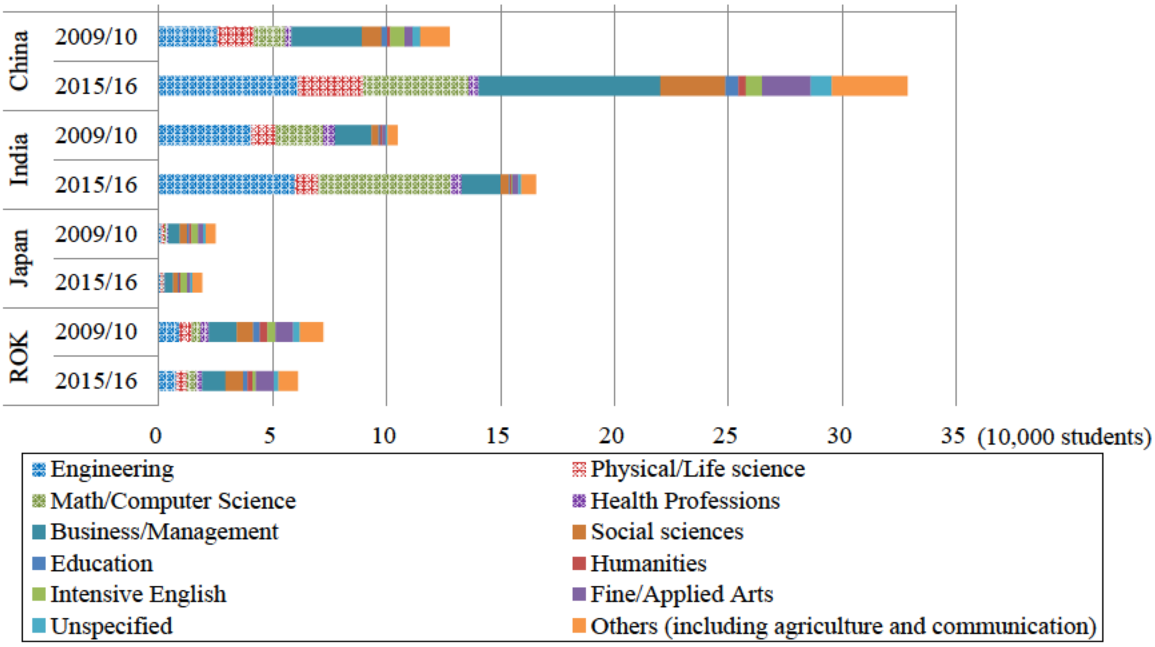
Figure II-3-2-2-38 Number of foreign students by country and region in the United States



Source: Institute of International Education (IIE) (https://www.iie.org/Research-and-Insights/Open-Doors/Data/International-Students/Places-of-Origin/Academic-Level-and-Place-of-Origin).

Nearly half of Chinese students in the United States major in the STEM (Science, Technology, Engineering and Mathematics) fields. The share of students majoring in the STEM fields among Chinese students was 45.6% in 2000-2001 and 42.7% in 2014-2015. The share of STEM students among Indian students was larger than the share among Chinese students: it increased from 73.7% in 2000-2001 to 80.1% in 2014-2015. On the other hand, the share of STEM students among Japanese students declined from 16.2% in 2000-2001 to 13.7% in 2014-2015. The share of STEM students among Japanese students is smaller than among the share among ROK students, which was 30.5% in 2000-2001 and 31.2% in 2014-2015 (Figure II-3-2-2-39).

Figure II-3-2-2-39 Number of students studying in the United States by nationality and major

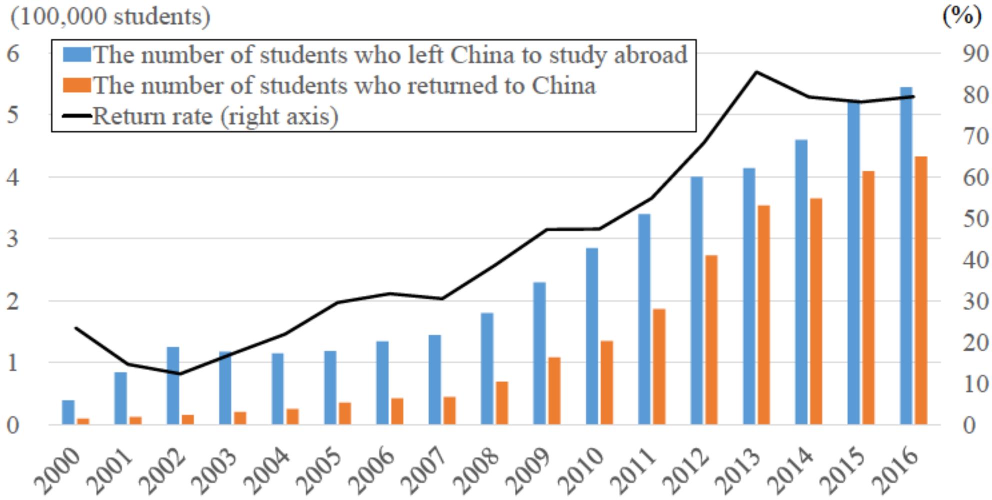


Notes: The number of students by field of major was the result of multiplying the total number of students of "Academic Level and Place of Origin" by the ratio of each field of "Fields of Study by Place of Origin."

Source: IIE (https://www.iie.org/Research-and-Insights/Open-Doors/Data/International-Students/Places-of-Origin/Academic-Level-and-of-Origin).

Next, we will look at the government of China's policy measures to encourage students to return home after studying abroad. From 2000 onwards, the number of Chinese students studying abroad continued to rise, but the return rate among such students remained as low as less than 30% until 2008. However, the government of China announced a series of policy measures to encourage Chinese students studying abroad to return to China in order to secure highly skilled human resources, and as a result of the effects of the measures, the return rate has risen rapidly since then. In 2013, the return rate was 85% (Figure II-3-2-2-40). While the goal of promoting the return of Chinese students abroad was achieved, the difficulty for returnee students, particularly those who studied abroad at their own expense, to find jobs in China emerged as a problem. Therefore, as an economic policy measure[130] aimed at simultaneously promoting the development of innovation within the country and promoting the return of Chinese students abroad, the government of China launched the "Mass Entrepreneurship and Innovation" initiative.[131]

Figure II-3-2-2-40 Changes in the number of Chinese students going abroad for study and those returning to China



Source: "China's Reform and Opening-up and Study Abroad Policies" (Meng, 2018).

(D) Entrepreneurial environment

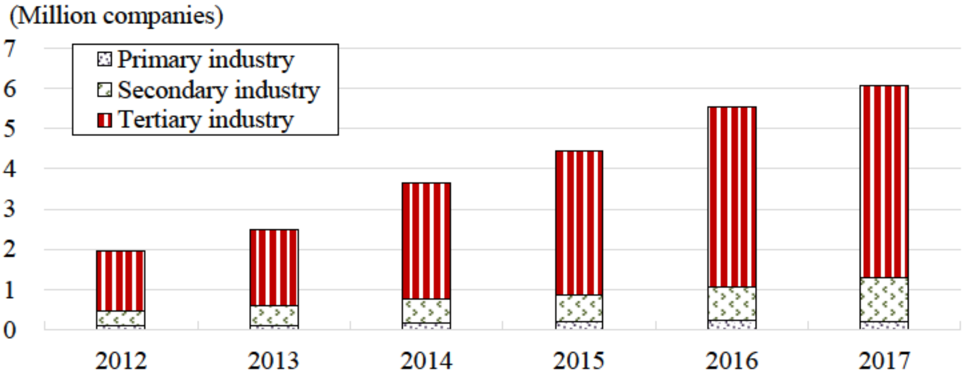
Finally, we will look at the entrepreneurial environment, which is an important factor for the creation of innovation.

In China, which has produced a large number of unicorns, as the United States has done, entrepreneurial activity is even more vigorous than in the United States. In particular, since around 2014, when the "Mass Entrepreneurship and Innovation," an entrepreneurial support initiative promoted by the government of China, was announced, the number of startups has increased rapidly. As evidenced by the huge number of newly registered companies, the business entry rate in China is much higher than the rates in the United States and Japan[132] (Figure II-3-2-2-41).

130 Meng (2018), "China's Reform and Opening-up and Study Abroad Policies".
131 Advocated by Premier Li Keqiang at the Davos conference of the World Economic Forum in 2014.
132 The business entry and exit rates in China are not published, so the figures were estimated from the overall number of registered companies and the number of newly registered companies.

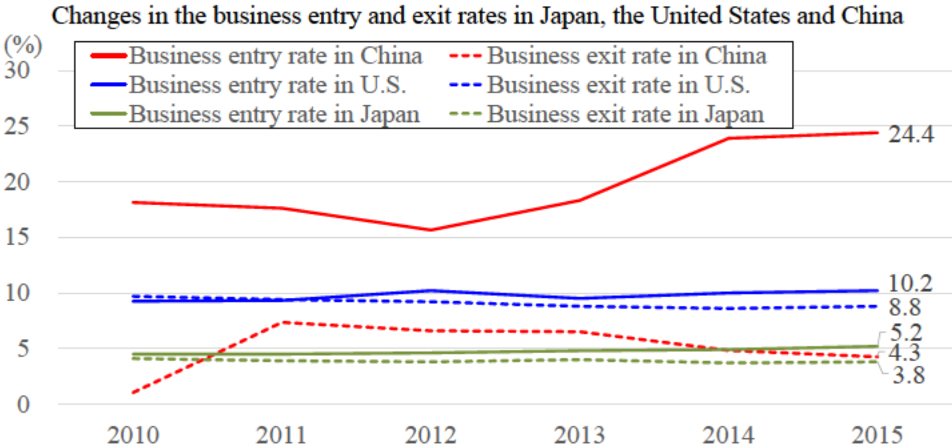
Figure II-3-2-2-41 Changes in the number of newly registered companies in China, and the business entry and exit rates in Japan, the United States and China

Changes in the number of newly registered companies in China



Source: The State Administration for Industry & Commerce of the People's Republic of China, CEIC database.

Changes in the business entry and exit rates in Japan, the United States and China



Notes: Since there is no China data about the number of newly registered companies in 2009, the figure is the average of those in 2008 and 2010. With regard to business entry and exit rates, they were estimated that the number of registered companies at the start of the year was the same as the number at the end of the previous year (e.g., the business entry rate in 2010 = the number of newly registered companies in 2010 / the number of registered companies at the end of 2009).

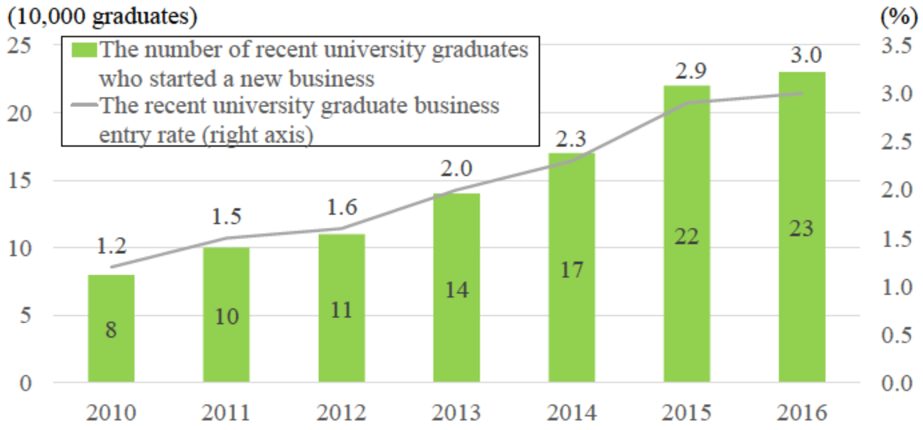
Source: China: CEIC; U.S.: *Business Dynamics Statistics*; Japan: *Annual Report on Employment Insurance*.

On the other hand, it should be kept in mind that while there are some emerging companies possessing innovative technologies or business models, a large majority are small companies managed by self-employed people that do not possess such technologies or business models. It has been pointed out that as engagement in side businesses is widely permitted in China, starting a new business is relatively easy.

What is notable about China is not only the huge number of newly registered companies but also the large number of new businesses started by recent university graduates. Of the more than 7 million students who graduate from university annually, around 200,000 new graduates start a new business

(Figure II-3-2-2-42). On the other hand, it should also be kept in mind that the vigorous business startup activity by new graduates comes against the backdrop of a lack of a sufficient number of existing companies with enough capacity to employ the massive numbers of new graduates in China compared with the situations in Japan, the United States and Europe.

Figure II-3-2-2-42 The number of recent university graduates who started businesses and the business entry rate by recent university graduates in China



Source: Website of Dream Incubator (original text: *Chinese College Graduates' Employment Annual Report* (MyCOS, 2016) (http://www.dreamincubator.co.jp/bpj/2017/07/07/)).

While the government of China has announced a series of policy measures to promote innovation, it is said that another factor driving entrepreneurship is the government's tendency to first adopt a laissez-faire approach to a new industry or market created out of innovation and start considering regulation only after problems emerge in the market. Ride-hailing service is a typical example.

In this section, we first looked at the overall picture of the rise of new industries in China and analyzed the improvement in innovation capability in IT-related fields of technology that underlies this trend and the state of vigorous entrepreneurship activity. We also showed that the presence of an abundance of highly skilled human resources and financial resources is a factor that supports such vigorous economic activity. It is necessary for Japan to recognize anew the rapid changes in the Chinese economy and further promote measures to revitalize Japanese industries.