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Policies, Key Industries, and Science and Technology Underlying China's Manufacturing Power Strategy

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Executive Summary

This paper is the final report of the Research Study Group "Policies, Key Industries and Science and Technology underlying China's Manufacturing Power Strategy" (Fiscal year 2022). The specific findings from the case studies are summarized in the introduction (Yasuo ONISHI).

Chapter 1 (Yoichi MAIE) discusses the macro-political arrangements related to a "manufacturing power. The first is the area of trade policy. The second is the area of industrial policy. The third is the use of foreign investment policies. The fourth is the improvement of the quality of foreign trade.

Chapter2 (Zhijia YUAN) addresses the success or failure of the semiconductor industry development policy. The author gives points to 16 items in four areas and uses the total score to determine the development potential of the industry.

Chapter 3 (Jianmin JIN) analyzes the current status of policies to promote intelligent manufacturing (AI-enabled manufacturing) and the role models (case studies) that are being produced, and examines the implications that can be drawn from them.

Chapter 4 (Tomoo MARUKAWA) analyzes the process by which the automobile industry, which had been a "large but not strong" industry, grew into a "strong industry." First, the role played by emerging (latecomer) manufacturers was significant. Second, the government's industrial development measures were well aligned with these trends.

Chapter 5 (Hongyong ZHANG) analyzes the Chinese industrial robot market and its industry. It is confirmed that the country has already reached the stage where it imports industrial robots while also exporting them. The rapid increase in government subsidies is having a positive effect.

Chapter 6 (Kota TAKAGUCHI) focuses on the data industry. Although it is not a manufacturing industry, the government recognizes data as a factor of production. This chapter introduces the current status of the big data trading market, which has begun to be experimented with nationwide.

Chapter 7 (Haruo KURASAWA) introduces trends in the fields of space and nuclear power development. Space development is being promoted in all directions, and China is competing with the United States. China is also rapidly expanding its presence in the nuclear power field.

Chapter 8 (Goro TAKAHASHI) attempts to understand the current status of research and development of genome-edited food products. Although the number of published patents based on the Patent Cooperation Treaty (PCT) has not yet reached that of the United States, they are in competition with each other.

Chapter 9 (Taeko MOTOHASHI) examines the cases of administrative penalties and investigations concerning standard essential patents (SEPs), and finds that the penalties and investigations were all directed against foreign companies, which may have been aimed at protecting domestic companies. The report also points out the "Prohibited Punishment Order," and suggests that attention should be paid to future developments.

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Preface: The current status and future direction of "manufacturing powerhouses"

Introduction

The problems facing the Chinese economy continue to be the intensifying friction between the US and China and the response to COVID-19. China has already adjusted its development strategy and launched a "dual-circulation strategy" (2020). This is essentially a strategy that seeks to redefine the relationship between domestic and international circulation. The "14th Five-Year Plan and Outline of Long-Term Goals to 2035" (starting in 2021, below referred to as "14.5") has become a pillar of national policy.

In light of this situation, in FY2021, a research group was established to understand the changes in industry and science and technology after the "dual-circulation strategy" was proposed. First, with regard to domestic circulation, we analyzed macro-policy changes related to industry and science and technology; the rapid development of digital industries and technology; and the actual status of the social implementation of technology. Next, regarding international circulation, we attempted to examine the state of international intellectual property strategies and the impact of China's economic and corporate development on the rest of the world.

The reports and discussions in the research group revealed that concrete measures have been initiated in many industrial, technological, and basic research fields based on the industrial and science and technology policies articulated in "14.5." The pillar of these policies is China becoming a "manufacturing powerhouse."

Then, in FY2022, we conducted case studies focusing on industrial and technological fields related to "manufacturing powerhouses." We aimed to further expand the findings of the FY2021 research group and attempted to make more specific predictions regarding the future of individual fields. The following descriptions follow the structure of this report, which was compiled based on this awareness of the issues. With the main objective of gleaning suggestions for the future from the case studies, in this section, we will focus on giving an overview the issues discussed in each chapter. We conclude with a comprehensive introduction by extracting and summarizing common points from the findings obtained.

1 Macro-level policy alignment toward becoming a "manufacturing powerhouse"

The first challenge for the research group was to confirm the macro-level policy arrangement oriented toward the realization of a "manufacturing powerhouse" as a precondition for the general discussion.

Chapter 1 (Yoichi Maie) discusses policy placement with a focus on "optimizing and stabilizing industrial chains and supply chains." The focus is on "creating safer and more reliable industrial and supply chains"—or, in other words, focusing on economic security. The report identifies four policy priorities to achieve this goal.

The first is in the area of trade policy. From an "offensive perspective," China is pursuing a high level of external openness, relying on the expansion of free trade agreements (FTAs). The analysis shows that from a "defensive perspective," the country is rapidly developing economic security legislation similar to that of the US as a countermeasure against US export and investment restrictions. In addition, more concrete policy efforts are underway domestically. These include efforts to diversify industrial and supply chains; strengthen the competitiveness of industrial chains in areas such as high-speed rail, power equipment, and new energy; and optimize the regional arrangement of industrial chains.

The second is in the area of industrial policy, with policies emphasizing the fostering and development of quality manufacturing enterprises. Here, the process envisioned is to foster "10,000 little giant companies," "1,000 sector-specific champion companies," as well as "pilot companies" by promoting "specialization, refinement, and specialization" of small and medium-sized enterprises (SMEs). This is a conventional approach, but it is new in that it focuses on the importance of SMEs. It is estimated that 4,762 of these "little giant companies" (as stated in a November 2021 briefing of the State Council Information Office) have already been established and are beginning to produce results.

The third is the use of foreign investment policies. The Business Development Plan for the 14.5 period has been released. It emphasizes the modernization of each chain with a focus on key industrial and supply chain sectors in attracting foreign-owned enterprises.

The fourth is to improve the quality of foreign trade. This policy priority seeks to ensure food, energy, and resource security; relocate foreign companies in the processing trade sector to the Midwest and Northeast regions; and form clusters of companies that belong to a single industrial chain in foreign trade.

Given the international linkage of industrial and supply chains, the emphasis on the trade and investment sectors is unsurprising. The Political Report of the 20th National Congress of the Communist Party of China (October 2022) also emphasizes the importance of industrial and supply chain security. The policy measures taken after the Congress confirm that the above policies were firmly maintained.

2 Industrial promotion measures and policy promotion affecting emerging industries as a whole

The second point at issue for the research group was to conduct case studies on emerging industry cultivation policies and the current status of development of the same, which are considered to be the core of the "manufacturing powerhouse" policy, to examine the implementation status and effects of the policy.

The selection of case study areas was a trial and error process, but the first focus was on areas that affect industry as a whole. Specifically, the project focused on the promotion of the semiconductor industry, which has become a key component (the "rice of industry"), as well as the promotion of intelligent manufacturing (AI-enabled manufacturing), which is intended to provide a model for the modernization of the manufacturing industry.

2.1 Semiconductor industry promotion measures

Chapter 2 (Motoyoshi Sono), which deals with the former, directly addresses the success or failure of semiconductor industry promotion policies. The Chinese government's policy involvement in the semiconductor industry goes back as far as the 1980s, when it positioned the industry as a "pillar industry" and has been working ever since to foster it through various means. These range from (1) the establishment of public enterprises, (2) support from public funds, (3) tax exemptions and reductions, (4) implementation of national projects, (5) participation of public capital, and (6) preferential financial treatment. All but item (4) continue into the 2020s.

Are these expectations and support from the government meaningful? Chapter 2 attempts to answer this question by organizing the conditions for the development of the semiconductor industry in China. The four conditions are "industry conditions," "market conditions," "division of labor conditions," and "policy conditions." Each condition is composed of four elements, constituting 16 elements to be evaluated and analyzed.

(1) Industry conditions include capital, human capital, manufacturing equipment, and supporting industries.

(2) Market conditions include market demand, industry organization, market supply, and the market entry environment.

(3) Division of labor conditions include intellectual property, design, manufacturing, and management know-how.

(4) Policy conditions include industry-related laws and regulations, government intervention, support for the private sector, and technological development assistance.

Assessments are made based on points (from 5 points to 1 point) representing each of five ranks: "Strong," "Relatively strong," "Intermediate," "Relatively weak," and "Weak."

Many of the conclusions obtained are consistent with what has been previously stated. For example, the five "strong elements" that received high points were (1) funds, (2) market demand, (4) industry-related laws and regulations, government intervention, and technological development support, as described above. However, the three elements in (4) are not currently linked to breakthroughs in technological development. The three "relatively strong elements" are (2) industrial organization and market access environment and (4) support for the private sector.

The five "weak factors" and "relatively weak factors" that scored low points were (1) manufacturing equipment, human capital, supporting industries and (3) intellectual property and management know-how.

Of the 16 factors, 8 are "strong" or "relatively strong," 5 are "weak" or "relatively weak," and 3 are "intermediate." The problem, however, is that the weak factors include key factors such as manufacturing equipment, human capital, and support industries. Above all, the international division of labor, which is the hallmark of the semiconductor industry, has been fractured by friction between the US and China, which is a definite disadvantage.

2.2 Policy to promote intelligent manufacturing

Chapter 3 (Kim, Jianmin), which deals with the latter, analyzes the current status of policies to promote intelligent manufacturing (smart manufacturing) and the role models (case studies) that are being produced. It examines the implications that can be drawn from them.

China, a latecomer in this field, pursued a different methodology from the developed countries to simultaneously advance and catch up with the process of "smart manufacturing based on the modernization of production infrastructure, the automation of production systems, and informatization," a process that developed countries had achieved over a long period of time. They tried to shorten the process of smart manufacturing by leveraging Internet technology and digital innovation, which are as advanced as those in developed countries.

The policy document "The Evolution of the Combined Development of Manufacturing and the Internet," released in 2016 in response to "Made in China 2025" (2015), illustrates these ideas. As Kim pointed out, the "Intelligent Manufacturing Development Plan (2016–2020)," released at the end of the same year, set the goal of laying the foundations (hardware infrastructure, software, standards, etc.) for intelligent (smart) manufacturing by 2020. It also set out to establish a support system by 2025 to place key industries in the initial stages of intelligent manufacturing; based on this, it also set specific target indicators. The second phase of the plan, the "14.5" Intelligent Manufacturing Development Plan (2021–2025), has been established and more detailed guidelines have been published. However, Kim's goal was to analyze the actual conditions of the model projects and model companies that came out of the implementation of these policies. The leading group of model companies comprises 305 companies selected by the Ministry of Industry and Information Technology in 2015–18, which are said to have achieved production efficiency, energy efficiency, reduced operating costs and product development periods, reduced product defect rates, and other positive outcomes.

In response, in 2021, more than 12,000 (January) and 20,000 (December) manufacturing companies were asked to conduct independent diagnoses and evaluations using the Intelligent Manufacturing Diagnostic Evaluation Public Service Platform. The results for December show that 84% of the companies are either planning to implement intelligent manufacturing (Level 1 and below) or are applying it only to individual operations (Level 2), confirming the reality that the shift to intelligent manufacturing has only just begun. In addition, the details of the judging criteria are unclear, making international comparisons impossible.

Therefore, Kim conducted a case study of 14 Chinese companies (with Chinese owners) out of 132 "Global Light Houses" selected by the World Economic Forum (WEF), which have been working on this issue since the 2010s. Among them are CATL (Contemporary Amperex Technology Co., Limited), an EV battery manufacturer, and Alibaba, which is aiming for on-demand production (customer-to-manufacturer [C2M]) model that directly connects consumers with manufacturing sites, and the case example of its factory that employs the XUNXI method is presented in detail.

It is noteworthy that although the overall level of intelligent manufacturing has just begun, there are already 14 lighthouses (two in Japan) that have achieved the advanced level described above. The analysis in this chapter has many implications for Japan in terms of DX (digital transformation) deployment and model creation.

3 Case studies of successful emerging industries

The third point at issue for the research group was to clarify the actual state of emerging industries by studying successful cases. Analysis of their success factors will help determine the future of the "manufacturing powerhouse." The report attempts to delve deeper into the realities of the automotive, industrial robotics, and digital data industries.

3.1 The Automotive industry as a pioneer of "manufacturing powerhouse"

The automotive industry, discussed in Chapter 4 (Tomoo Marukawa), was a classic example of a "big but not strong" industry, as seen on the global scale. This is symbolized by the fact that while it was the world's largest producer with 26.08 million units (in 2021), its export volume loitered around 1 million units (2012–20). Strengthening this industry has been one of the long-held aspirations of industrial policy.

This number jumped to 2.14 million units in 2021 and exceeded 3 million units in 2022. The context of this process is interesting. Exports in the 2000s were led by emerging (latecomer) manufacturers such as Chery, Geely, and Great Wall, who made tremendous efforts to develop overseas markets because it was difficult for them to penetrate the domestic market. Target markets were niche countries that did not have developed automotive industries. Despite ups and downs, export volume gradually increased, and as mentioned above, breakthrough was achieved in 2021. Essentially, Marukawa states that efforts to improve quality and diversify export destination countries have been fruitful. It is the emerging manufacturers that have led the automotive industry to become a "manufacturing powerhouse."

In addition, what is noteworthy is the contribution made by EVs, or what are called "new energy vehicles" in China, including the total of BEVs (battery electric vehicles), PHEVs (plug-in hybrid vehicles), and FCVs (fuel cell vehicles). In 2021, this category accounted for 588,000 units, or 27% of all exports. China already accounts for 51% of the world's total EV production at 3.33 million units (in 2021). Because of this, the EV industry is also a driving force behind the move to become a "manufacturing powerhouse" because of the large number of vehicles it exports.

What is interesting is the contextual factors that shaped the strengths of China's EV industry. The first factor, in Marukawa's view, is that the size of the domestic market has reached a certain level. The profitability line for automakers is estimated at 100,000 units per year, which would allow for the presence of 35 companies under the current situation.

The second factor is the competition unfolding among the numerous manufacturers in this market. In addition to leading foreign companies such as Tesla, VW, BMW, Mercedes, Volvo, and Audi, there are domestic manufacturers such as BYD, SAIC-GM-Wuling, and SAIC Motor, as well as several venture companies offering EVs in a wide variety of models and price ranges.

The third factor is the government's policy of fostering the EV industry. In addition to providing subsidies for EV purchases, measures were taken to protect and foster domestic manufacturers of EV batteries. The latter of these has been discontinued as having already served its intended purpose.

The fourth factor is fierce competition in the key components of EVs. Here, sales strategies are cited as a factor that enabled domestic manufacturers to overtake foreign manufacturers in the competition over batteries and gain a large share of the market.

As Marukawa points out, it is important to note that we are beginning to see a different framework in the EV industry than in the conventional automotive production system. This is largely due to the characteristics of EVs, in which it has become the norm to have competing suppliers of key components. EV production itself can now be developed on a consignment basis, as with smartphones. Thus, manufacturers have begun to emerge in response to this trend. This is a trend to keep an eye on.

3.2 The potential of the robot industry

Chapter 5 (Zhang Winghong) focuses on the Chinese industrial robot market and its industry, which is now the largest in the world. Zhang first ascertains the structure of this market. China has reached the stage where it imports industrial robots but also exports them. In 2021, imports will reach 114,000 units (import value of $1.535 billion), while exports will reach 55,000 units ($340 million value). As with the automotive industry discussed in the previous chapter, the country is beginning to take steps toward becoming a "manufacturing powerhouse."

Next, from the perspective of exploring the potential of becoming a "manufacturing powerhouse," the report examines the current status of China’s domestic manufacturers and government measures to nurture them, based on a wealth of data, as well as the implications for foreign manufacturers that can be gleaned from this data.

The first finding from the analysis is that the domestic production ratio is still low in the rapidly expanding industrial robot market. The introduction of robots relies heavily on the imports mentioned above and on local production by foreign firms. This is due in part to the emphasis on local production by foreign companies.

Second, Chinese firms are catching up with Japanese firms in China by increasing sales, capital investment, and research and development (R&D) investment. On the other hand, their sales and profit margins and labor productivity are low, especially in state-owned enterprises, at only about 30% of those of Japanese-owned enterprises. Zhang uses financial statement data from six Japanese and Chinese robot manufacturers that produce 2,000 units or more as of 2018, from which a concrete picture of the companies can be obtained.

Third, government subsidies to Chinese companies have skyrocketed in recent years. The forms of such subsidies range from R&D subsidies to value-added tax refunds. In Zhang’s view, the subsidies have had some effect on the development and production of robots by Chinese companies.

Looking at the degree to which the Chinese government has achieved its industrial policy goals, the number of robots produced in 2020 is more than double the target at 212,000 units, and the ratio of robots installed per 10,000 employees is 187 units, exceeding the target of 150 units. The target as of 2025 is also expected to be achieved. However, since the domestic market share targets for independent brands and domestically produced core components had not been achieved by 2020 and would be difficult to achieve even if they were postponed to the 2025 target, these were modified into qualitative targets of "breakthroughs in core technologies, components, and high-end products" and "improved performance in finished-product indicators and core components to the international leading-edge level." These points, in other words, have been shown to be bottlenecks in the development of the robotics industry.

3.3 Digital data industry with continuing development of the growth environment

Chapter 6 (Kota Takaguchi) recounts the development process of an industry that handles data in a way that positions it as a "factor of production," without itself being a manufacturing industry. Business models using data were created by private companies. This is represented by IT platform companies such as Alibaba and Tencent. They have innovated by using customer data that was accumulated by providing e-commerce platforms and social networking applications to offer financial services and credit information that did not exist before. In addition, the lack of legal regulation in this field enabled its rapid development.

Now that this "savage development phase" has come to a halt, the industry is in a phase of increased government regulation and a renewed environment for the protection and use of data. The use of industrial data, apart from the personal data mentioned above, has also been attracting attention.

With regard to the former, progress is being made in the development of legislation for its protection, particularly with regard to personal information. China is using the EU's GDPR (General Data Protection Regulation), as a reference, and with the law coming into effect with severe penalties, pressure to comply with the law is expected to increase.

Regarding the latter, there are examples of how constructing a common database for logistics has enabled the provision of unprecedented solutions. In addition, in the field of the industrial internet, a trend toward upgrading manufacturing through the use of big data and AI is taking shape. These trends are also introduced in Chapter 3. The most cutting-edge part of the system provides a C2M structure that quickly analyzes consumer needs and communicates them to production operators.

When considering the future of this field, there is the question of how to distribute data, which has come to be regarded as the "oil of the 21st century." The government has positioned data as a "factor of production," but the key to making data a factor of production is to "collect data, determine rights holders, set a fixed price, and a place for transactions," the methodology for which remains to be seen. This chapter introduces the current status of the big data trading market, which is beginning to be experimented with across the country, with one possibility in mind.

4 Trends in basic research fields

The fourth issue for the research group is to look at trends in the field of basic research, which is also the foundation of a "manufacturing powerhouse." Since the scope of basic research is so broad, we have attempted to understand the current situation by selecting fields that have already begun to be industrialized from those emphasized in "14.5."

4.1 Trends in space and nuclear Development

Chapter 7 (Haruo Kurasawa) begins with an overview of China's capabilities in the field of basic research from the perspective of brain circulation or human resource exchange, and then introduces trends in the fields of space and nuclear power development, which are expected to become important arenas for scientific and technological supremacy in the future.

China has sent 1.65 million students abroad as of 2020, with the largest number studying in the US. However, the number of students choosing the US as their study destination has been declining in recent years. The decline was triggered by the US Trump administration's restrictions on visa issuance to Chinese students and researchers. There was opposition to these measures from within the US, but in January 2020, Harvard University Professor Charles Lieber was arrested by the FBI for covering up his involvement in China's "Thousand Talents Program" (a plan that includes inviting foreign researchers to China), and this has greatly impeded brain circulation between the US and China. Although there are signs that the restrictions are being eased by the Biden administration, it is unclear whether this will lead to an increase in the number of Chinese students there.

It is important to note that these restrictive measures do not necessarily lead to US dominance. The large number of Chinese researchers making important contributions as coresearchers and coauthors to the research output produced in the United States reinforces this presumption. The friction between the US and China stems from geopolitical changes, but its course is unpredictable.

After expressing the above concerns, Chapter 7 presents trends in both China's space and nuclear energy development. First, China has made remarkable strides in space exploration. Development is proceeding in all directions, including projects to send satellites to the Moon and Mars, space station projects, and the construction of satellite positioning systems. The analysis shows that the respective advantages of China and the US in this field are China's rapid decision-making by the Communist Party and abundant financial and human resources, while the US has strong private-sector ventures and broad international cooperation.

Next, China is also rapidly expanding its presence in the field of nuclear energy development. In terms of technology, it is developing state-of-the-art reactors distinguished by diversification and domestic production. In terms of development plans, the country is constructing a large number of nuclear power plants and is also focusing on exporting nuclear reactors. Although the construction of nuclear power plants has its own challenges, such as poor site conditions in inland areas and the response to opposition by local residents, the trend of China as a "nuclear powerhouse" is something that cannot be ignored.

4.2 Research and development of genome-edited foods and other products

Chapter 8 (Goro Takahashi) attempts to understand the current status of research and development of genome-edited foods and other products and to summarize the issues. In China, research and development is gaining momentum, partly due to the issuance of the "Guidelines for Safety Evaluation of Gene Editing Plants for Agricultural Use" in 2022.

Chapter 8 begins with two specific examples of R&D organizations, one under the Chinese Academy of Sciences and the other under the Chinese Academy of Agricultural Sciences, and describes their personnel, organizational structure, budget, and examples of major research results to give a picture of their actual research. The generous allocation of personnel and budget is remarkable.

The report then provides a macro overview of the field, including (1) a comparison of the number of published patents on a PCT (Patent Cooperation Treaty) basis between the US and China, and (2) an introduction to China's national research and development system. Item (1) shows that although China is still behind the US in terms of the number of patent cases (29,954 vs. 6,689 in life sciences and 5,138 vs. 1,606 in food chemistry), the two countries have reached a competitive relationship on a global scale. In item (2), a list of research institutes and universities is presented, divided into the abovementioned Chinese Academy of Sciences system and the Academy of Agricultural Sciences system. It is impressive that the national research system alone has such a large contingent.

In addition, Chapter 8 describes the economic security regime in the field and provides information on the research and technology patent protection regime not mentioned in the other chapters. The basic legislation is the "Patent Law" (enacted in 1984). The 2020 amendment to the same law states that "any organization or individual applying for a patent in a foreign country for an invention or utility model completed in China shall report to the patent administrative department of the State Council for a confidential examination," confirming that a provision similar to Japan's "Economic Security Law" already exists.

5 A "manufacturing powerhouse" and the development of legislation to protect intellectual property

The fifth point at issue for the research group was to understand the current status of the development of legal systems related to the industrial and technological fields analyzed in the above chapters, as well as the issues that have been identified as challenges therein.

Chapter 9 (Taeko Motohashi) summarizes and analyzes trends in the development and operation of intellectual property protection legislation for "5G mobile communication technology" among the "next-generation information and telecommunications technologies" listed as the top priority area for the "manufacturing powerhouse" plan, using as case studies smartphones and ICVs (connected cars), which are areas in which this technology is implemented.

The first analysis area was the developments surrounding standard essential patents (SEPs) related to 5G mobile communications. Of these, first of all, for SEP in 5G implemented in smartphones, Huawei, which was targeted by the US in the friction between the two countries, fell from third to fifth or lower in terms of smartphone shipments in 2020. The company has since shifted its focus in the smartphone sector to royalty revenues. There are the same responses made by Ericsson and Nokia, but Huawei has not filed a lawsuit, unlike these two companies, which have been sued in various countries as SEP right holders.

Next, regarding mobile communication SEPs implemented in ICVs, since there have been many cases in

Europe where right holders have filed lawsuits against automakers, China has published the "Automotive Standard Essential Patent Licensing Guidelines (2022 Edition)" to provide guidelines on how licensing should be done. Huawei aims to be an implementer of this SEP at the component level domestically, and is actively licensing it to automakers outside of China.

The second analysis area is the trend of law enactment and operation in response to the abovementioned trends surrounding SEPs. It is pointed out here that the main laws and guidelines related to SEPs are based almost exclusively on the Antimonopoly Law (Antitrust Law), and that their aim is to put some curbs on the exercise of SEPs. This is related to the fact that the amendment of the Antimonopoly Law was initiated in the first place with the intention of regulating the abuse of dominant market positions by Alibaba, Tencent, and others.

However, the Chinese government originally advocated the strengthening of IP protection (in SEP terms, protection of right holders) under the slogan "from an IP superpower to an IP power." This appears to be inconsistent with the abovementioned move to protect implementers in SEPs. Motohashi investigates administrative penalties and investigations concerning SEPs, and finds that all penalties and investigations have been carried out against foreign companies, and speculates that there may have been an aim to protect domestic companies.

Chapter 9 also analyzes developments in the "antisuit injunction (ASI)," a topic of interest in SEP litigation. As Motohashi analyzed in the FY2021 Research Group Report, the ASI was intended to block foreign companies' attempts to challenge China's domestic judicial procedures by filing lawsuits abroad. In response, in February 2022, the European Commission filed a complaint against China's ASIs with the WTO, and in March of the same year, the United States also introduced legislation to restrict enforcement of ASIs issued in foreign countries. It will be necessary to keep an eye on what further steps China will take as an important factor in the future of the SEP.

Conclusion: The Present Position of the "Manufacturing Powerhouse"

The following are tentative conclusions regarding the current status of the "manufacturing powerhouse" drawn from the above overview of the issues and analysis of the survey and research group activities.

First, the spread of intelligent (smart) manufacturing, and the automotive, industrial robotics, and digital data industries have shown some positive effects from the policies aimed at making the country a "manufacturing powerhouse." In these sectors, the level of industry has improved, exports have grown, and an environment has been created to encourage the emergence of new business models. The common factor in the success of these sectors is the growth of private enterprises as the main players in the industry, which was matched by government support measures to accelerate development.

Second, however, there are some areas where policy effects have not been sufficient. In particular, the semiconductor industry, which is regarded as the "rice of industry," has not achieved technological breakthroughs despite strong government support, and the future development of the semiconductor industry is under a cloud of uncertainty, as advanced semiconductors cannot be procured due to friction between the US and China. The reasons why the policy has not been effective include the fact that, due to the nature of the industry, a broad international division of labor is expedient, and technological breakthroughs can only be secured through international exchanges. The current situation exemplified by US–China friction is contrary to this.

Third, investment in research, which is the foundation of a "manufacturing powerhouse," has been generous. However, in international exchange, another prerequisite for achieving innovation in research, the negative effects of friction with developed countries, such as US–China friction, can no longer be ignored. The semiconductor industry mentioned above is one example, but similar concerns exist in the field of basic research, where brain circulation with the US and European countries is being restricted.

Fourth, it is necessary to understand trends in the development of legislation that supports innovation. Legislative and administrative measures in the area of intellectual property rights are a good example of this, and trends will affect business for Chinese and foreign companies alike. For the time being, it is important to keep abreast of developments in the treatment of standard essential patents and trends in ASIs in both domestic and external relations. Further research will be required on the implementation and impact of Japan's Economic Security Act.

And fifth, there continues to be a need for research that provides concrete perspectives on the future direction of development in each field. As each chapter demonstrates, a series of promotion policies at the individual sector level have been announced in response to the "14.5" provisions, and their contents will provide clues to the outlook for research.

Two years have passed since the launch of the "14.5" program, which called for China to become a "manufacturing powerhouse." As the analyses in the chapters show, while there have been some notable achievements in industrial and technological development, factors that have impeded development have also become apparent. We will need to keep a close eye on its future in light of the findings.

1 Restructuring China's Industrial and Supply Chains

1.1 Introduction

As the confrontation between the US and China intensifies, the Biden administration in the US sees China as its only competitor and is tightening restrictions on exports to and investment in China in the high-tech sector, particularly in the area of semiconductors. In response, China has shown its commitment to restructuring its industrial and supply chains, promoting domestic production of technology, and curbing its dependence on the US in order to prepare for the risk of decoupling (fragmentation). At the 20th Party Congress of the Communist Party of China (CPC) held in October 2022, it was decided that General Secretary (President) Xi Jinping will remain in office, but the third-term Xi administration is also expected to take a variety of countermeasures.

In light of this situation, this paper will first review the basic policy for restructuring China's industrial and supply chains based on the speech of General Secretary (President) Xi at the seventh meeting of the Central Financial and Economic Affairs Commission held in April 2020. Next, the paper will summarize the key points of the industrial chain and supply chain policies in the "14th Five-Year Plan and Outline of Long-Term Goals up to 2035" adopted at the fourth session of the 13th National People's Congress (NPC) held in March 2021. It will also examine policy measures to restructure industrial and supply chains that were put forth in light of the 14th Five-Year Plan, divided into trade policy and industrial policy. The objective is then to examine the report made at the 20th Party Congress and the policy measures announced after the Congress in order to examine the orientation toward restructuring China's industrial and supply chains.

1.2 Positioning of Industrial Chains and Supply Chains in the National Medium- and Long-Term Economic and Social Development Strategy

To begin, we will review the basic policies for restructuring China's industrial and supply chains. In his speech "Certain Major Issues for Our National Medium- to Long-Term Economic and Social Development Strategy," delivered at the seventh meeting of the Central Financial and Economic Affairs Commission in April 2020, President Xi Jinping identified "optimizing and stabilizing the industrial chain and supply chain" as one of the major issues, pointing out that "efforts should be made to rebuild new industrial chains, and scientific and technological innovation and import substitution should be fully strengthened. This is the key to deepening structural reforms on the supply side and the key to achieving quality development.[1]

[1] The Communist Party's official journal, "Qiushi" No. 21 (November 1, 2020) (http://www.qstheory.cn/dukan/qs/2020-10/31/c_1126680390.htm)

The US–China confrontation has once again revealed that while China retains the strength of an industrial base capable of mass production in the global supply chain, it also has the weakness of being dependent on semiconductors and other advanced components and core technologies from outside the country. In light of the current situation, the speech emphasized that in order to enhance its advantages, "the country will strengthen and improve its leading position in the world, forge 'trump card' technologies, continuously enhance the advantages of all industrial chains in areas such as high-speed rail, power equipment, new energy, and telecommunications equipment, improve the quality of its industries, strengthen the dependence of international industrial chains on China, and form a strong countermeasure and deterrent capability against artificial supply disruptions on the part of foreign countries."

On the other hand, to make up for its disadvantages, the speech indicated an orientation toward "building a domestic production and supply system that can be controlled independently, that is safe and reliable in areas related to national security, is self-circulating at critical times, and ensures the normal operation of the economy even under extreme circumstances."

1.3 Manufacturing Powerhouse Strategy and Key Points of Industrial Chain and Supply Chain Policies in the 14th Five-Year Plan

Next, the paper will summarize the key points of the industrial chain and supply chain policies in the "14th Five-Year Plan and Outline of Long-Term Goals up to 2035" adopted at the fourth session of the 13th National People's Congress (NPC) held in March 2021.

The "14th Five-Year Plan and Outline of Long-Term Goals up to 2035" sets out policy measures based on the speech of General Secretary Xi (President of the People"s Republic of China).[2] Policies related to the restructuring of industrial and supply chains are described in Section 2, "Increasing the Level of Modernization of Industrial and Supply Chains," as part of the Manufacturing Powerhouse Strategy. Specific measures include designing supply chain strategies and precise measures for each industry by complementing weaknesses and forging strengths, promoting the diversification of industrial chains and supply chains through the reinforcement and strengthening of manufacturing industry chains, and promoting the specialization advantage of SMEs to foster the development of specialized and innovative[3] "little giant" enterprises and manufacturing sector champion enterprises (Table 1-1).

Table 1-1: Measures to increase the level of modernization of industrial and supply chains

(1)	Adhere to a combination of economy and safety, complementing weaknesses and forging advantages, designing supply chain strategies and precise measures for each industry, forming a better capacity to innovate, higher added value, and safer and more reliable industrial chains and supply chains.

[2] The full text of the outline is available on the website of the Central People's Government of the People's Republic of China at http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm.

[3] "Specialization and innovation" refers to specialization, refinement, special features, and innovation.

(2)	Promote the reinforcement and strengthening of manufacturing chains; enhance support for resources, technology, and equipment; strengthen international industrial safety cooperation; and promote diversification of industrial chains and supply chains.
(3)	Based on the advantages of industrial scale, incidental advantages, and first-mover advantage in some fields, strengthen and improve the competitiveness of the entire industrial chain in the fields of high-speed railroads, power equipment, new energy, and ships, and build a strategic all-round industrial chain from finished equipment products that matches the direction of future industrial transformation.
(4)	Optimize the placement of regional industrial chains, encouraging an important part of the industrial chain to stay within the country, and build the capacity to take on industrial transfer in the Midwest and Northeast.
(5)	Implement projects to create reserves of production capacity for emergency products and build a regional emergency goods production security base.
(6)	Implement a pilot company development project to foster a group of leading companies that have the capacity to lead ecosystems and that have core competitiveness.
(7)	Promote the specialization advantage of SMEs, fostering "little giant" enterprises in specialized and new industries, and champion enterprises in the manufacturing industry.
(8)	Strengthen techno-economic safety assessments and conduct industrial competitiveness studies and evaluation projects.

Source: Based on the "14th Five-Year Plan and Outline of Long-Term Goals up to 2035" (March 2021).

1.4 Restructuring Industrial and Supply Chains from the Perspective of Trade and Industrial Policy

In this section, we will examine policy measures for restructuring industrial and supply chains put forth in light of the 14th Five-Year Plan, divided into the two categories of trade policy and industrial policy.

1.4.1 Restructuring Industrial and Supply Chains from the Perspective of Trade Policy

(1) Trade policy from an offensive perspective

From an offensive perspective, what was needed to maintain industrial and supply chains was to promote high-level external openness through free trade agreements (FTAs). As part of this, China signed the Regional Comprehensive Economic Partnership (RCEP) Agreement on November 15, 2020, which went into effect on January 1, 2022 for 10 countries: Japan, Brunei, Cambodia, Laos, Singapore, Thailand, Vietnam, Australia, China and New Zealand. After the RCEP went into effect, six departments, including the Ministry of Commerce, officially announced the "Guiding Opinions on the High-Quality Implementation of the RCEP" on January 26.[4] The Guiding Opinions set forth the following six key tasks: (i) promoting high-quality trade and investment development by accepting the agreement's plan to open markets through

[4] Ministry of Commerce website (http://gjs.mofcom.gov.cn/article/dongtai/202201/20220103239468.shtml)

the appropriate use of the rules; (ii) improving industrial competitiveness by promoting the upgrading of manufacturing industries; (iii) improving the promotion of standards for industrial development by promoting cooperation and transformation of international standards; (iv) developing financial support and related policy systems; (v) improving the business environment through the appropriate use of RCEP rules in accordance with local conditions; and (vi) continual implementation of related services for businesses.

In addition to RCEP, China is currently pursuing FTA negotiations with Japan, South Korea, Sri Lanka, and the Comprehensive and Progressive Agreement on Trans-Pacific Partnership (CPTPP). Regarding the CPTPP, President Xi Jinping announced on November 20, 2020, in a speech at the informal summit of the Asia-Pacific Economic Cooperation (APEC) that "we will actively consider membership." The Ministry of Commerce announced on September 16, 2021 that it has officially applied for CPTPP membership. For China, the CPTPP is seen as having fairly high hurdles for membership, due to its higher level of tariff liberalization and stricter trade and investment rules than the RCEP. At a regular press conference on February 17, 2022, Ministry of Commerce spokesperson Gao Feng responded saying, "China has completely and thoroughly studied and evaluated the contents of the CPTPP agreement in depth. We will strive to fully meet the rules and standards of the CPTPP through reforms," he replied.[5]

(2) Trade policy from a defensive perspective

In terms of defense, while the US and other countries are moving to tighten export and investment restrictions to maintain their technological superiority, China is rapidly developing related laws as a countermeasure. On September 19, 2020, the "Unreliable Entity (Enterprise) List Regulations" were promulgated.[6] This document states that foreign companies and other entities that have violated the principles of normal market transactions, suspended transactions with Chinese companies and other entities, or taken discriminatory measures and caused serious damage will be registered on a list, and trade and investment will be prohibited or restricted. It is considered to be the Chinese version of the "Entity List," on which the US registers companies and other entities of national security concern.

In addition, on December 1, the Export Control Law went into effect.[7] In addition to defining target "controlled items" such as military supplies and dual-use (military and civilian) items, importers and end-users who may pose a risk to national security and interests are registered on a "regulated list" to prohibit or restrict trade in controlled items. This is seen as a countermeasure to the US government's enactment of the Export Control Reform Act, which targets "emerging and fundamental technologies" that are not covered by conventional export controls but are necessary for US national security.

With the start of 2021, the "Measures to Block the Improper Extraterritorial Application of Foreign Laws and Measures" went into effect on January 9.[8] It stipulates that necessary countermeasures be taken in context of the extraterritorial application of US export control rules to transactions in other countries

5 Ministry of Commerce website (http://www.mofcom.gov.cn/xwfbh/20220217.shtml)
6 Ministry of Commerce website (http://www.mofcom.gov.cn/article/b/fwzl/202009/20200903002593.shtml)
7 National People's Congress of the People's Republic of China website (http://www.npc.gov.cn/npc/c30834/202010/cf4e0455f6424a38b5aecf8001712c43.shtml)
8 Ministry of Commerce website (http://www.mofcom.gov.cn/article/b/c/202101/20210103029710.shtml)

and regions over which the US has no jurisdiction. In addition, on January 18, the Measures on Foreign Investment Security Examination went into effect, requiring foreign companies with national security concerns to declare their investments to the Chinese authorities in advance.[9] This measure follows the US "Foreign Investment Risk Review Modernization Act" and tightens the screening process for investment in China. In addition, on June 10, China enacted the Anti-Foreign Sanctions Law, which sets forth China's countermeasures against foreign sanctions.[10] The Law stipulates, among other things, that "if a foreign country imposes discriminatory restrictive measures against Chinese citizens and organizations in violation of international law and basic rules of international relations, or interferes in the internal affairs of China, China shall have the right to take appropriate countermeasures.

(3) Trade Policy in the "Fourteenth Five-Year Plan"

(i) "The 14th Five-Year Plan for the Development of Commerce"

On July 8, 2021, the Ministry of Commerce released the "14th Five-Year Plan for the Development of Commerce" and laid out the basic policies related to commerce policy up to 2025.[11] The plan calls for, as key indicators, an average annual increase in foreign freight trade of 2%, to reach $5.1 trillion by 2025, and an increase in the share of trade in new business categories to 10%. In terms of foreign investment, the government aims to increase foreign direct investment by a cumulative total of $700 billion over the five-year period from 2021 to 2025, raise the ratio of foreign investment in high-tech industries to 30%, and increase the ratio of foreign investment in free trade pilot zones and free trade ports to around 19%.

Furthermore, in terms of outward investment cooperation, the goal is to increase outward direct investment and outward contracted construction sales by a cumulative total of US$550 billion and US$700 billion, respectively, over the five years from 2021 to 2025, and to maintain the ratio of overseas companies with stand profit levels at around 70%. In addition, regarding global economic governance, China has indicated that it intends to increase the percentage of cargo trade with free trade partners to around 36%.

(ii) The 14th Five-Year Plan for the Development of Foreign Capital Utilization

The Ministry of Commerce released the "14th Five-Year Plan for the Development of Foreign Capital Utilization" on October 22, 2021 as a development plan in the area of foreign capital utilization in the "14th Five-Year Plan for the Development of Commerce."[12] The plan states that China's "development environment" is characterized by "economic globalization encountering a countercurrent, unilateralism and protectionism prevailing, cross-border investment screening becoming stricter, international economic and political structures complex and changing, the world entering a period of turbulent change, global industrial chains and supply chains facing restructuring," opining that "the trend toward localization, regionalization, and diversification is intensifying."

9 National Development and Reform Commission website (https://www.ndrc.gov.cn/xxgk/zcfb/fzggwl/202012/t20201219_1255025.html?code=&state=123)

10 National People's Congress of the People's Republic of China website (http://www.npc.gov.cn/npc/c30834/202106/d4a714d5813c4ad2ac54a5f0f78a5270.shtml)

11 Ministry of Commerce website (http://www.mofcom.gov.cn/article/zwgk/gztz/202107/20210703174101.shtml)

12 Ministry of Commerce website (http://www.mofcom.gov.cn/article/zwgk/gkzcfb/202110/20211003210174.shtml)

Based on this view, the "Basic Principles" list the following policies: "allow multinational companies that deploy resources globally to exert their unique advantages, revamp mechanisms for attracting and introducing foreign capital, focusing on key domestic industrial chains and supply chains, and better utilize foreign capital to complement, anchor, strengthen, and expand these chains, and improve the level of modernization of industrial chains and supply chains."

As a part of restructuring industrial chains and supply chains, the plan also calls for the implementation of the "Project to Promote Domestic Reinvestment by Foreign-Invested Enterprises" to further develop the layout of the industrial chain through domestic reinvestment by foreign-invested enterprises and to support investment in key areas of high-end and high-tech industries such as artificial intelligence (AI), advanced materials, integrated circuits (IC), biotechnology and medicine.

In addition, to promote the "Project for Improving Efficiency in Attracting Enterprises and Introducing Foreign Capital" and to strengthen the attraction of industrial chains, the project will focus on key industrial sectors such as strategic emerging industries, guide local governments to create "industrial chain attraction maps" according to local conditions, and strengthen policies for attracting to attract industrial chains and expand and develop them by attracting upstream and downstream related industries, with a focus on core enterprises.

(iii) The 14th Five-Year Plan for the Quality Development of Foreign Trade

The Ministry of Commerce also released the "14th Five-Year Plan for the Quality Development of Foreign Trade" on November 23, 2021 as a development plan in the trade sector within the "14th Five-Year Plan for the Development of Commerce."[13] The plan establishes "ensuring the smooth operation of industrial chains and supply chains in foreign trade" as one of its key missions, and sets forth six policy measures: (1) food, energy, and resource security; (2) support for the transfer of the processing trade; (3) accelerating the construction of bases for model transformation and upgrading foreign trade; (4) promoting the coordinated development of trade and bilateral investment; (5) strengthening the establishment of an international marketing system; and (6) strengthening the stability of international logistics (Table 1-2).

Table 1-2: Policy Measures Related to "Ensuring Smooth Operation of Industrial and Supply Chains in Foreign Trade"

	Item	Overview
(1)	Food, energy, and resource security	Accelerate the promotions to diversify import sources and improve the security capacity of trade routes and key nodes. Strengthen cooperation between foreign trade enterprises and maritime transportation enterprises to improve their ability to guarantee imports of overseas energy resources.
(2)	Support for the transfer of the processing trade	Optimize the layout of regional industrial chains by utilizing the roles of key processing and trade relocation receiving sites, processing and trade industrial parks, etc. Strengthen the platform functions of free trade test zones and other areas, and exercise the role of the China Processing and Trade Products Expo and other events to improve the reception capacity of the Midwest and Northeast regions.

[13] Ministry of Commerce website (http://www.mofcom.gov.cn/article/gztz/202111/20211103220081.shtml)

(3)	Accelerate the construction of bases for model transformation and upgrading foreign trade	Using various industrial clusters as bases, strengthen leading industries and develop ancillary industries to create a cluster of foreign trade enterprises where large enterprises lead and SMEs give support, and where the strengths of each complement and cooperate with each other.
(4)	Promoting the coordinated development of trade and bilateral investment	Encourage foreign investment in areas such as middle- and high-end manufacturing, high-tech, model transformation and upgrading of traditional manufacturing, and modern services. Utilize the advantages of industrial clustering and the open platform of the national development zones to promote industrial upgrading and improve the quality and efficiency of trade. Build high-quality foreign economic and trade cooperation zones and promote the establishment of an industrial chain and supply chain cooperation system.
(5)	Strengthening the establishment of an international marketing system	Assist companies in building and developing marketing systems in priority markets. Promote the construction of an international marketing public service platform. Encourage local governments to foster provincial-level international marketing public service platforms that rely on locally dominant industries.
(6)	Strengthening the stability of international logistics	Implement an "overseas expansion" project for courier services by building an international logistics system commensurate with the scale and level of development of foreign trade. Enhance China's international air cargo transport capacity, promote the facilitation of international rail and road cargo transport routes, develop container and intermodal transport, and provide diversified logistics options for enterprises.

Source: Based on the Ministry of Commerce, "The 14th Five-Year Plan for the Quality Development of Foreign Trade" (November 2021).

1.4.2 Restructuring of industrial and supply chains from an industrial policy perspective

(1) Basic Electronic Components Industry Development Action Plan

In terms of industrial policy measures to restructure the industrial chain and supply chain, the Chinese government has shown its commitment to promoting the domestic production of technology and curbing dependence on the US. On January 29, 2021, the Ministry of Industry and Information Technology issued the "Basic Electronic Components Industry Development Action Plan" to strengthen the competitiveness of the components industry, which is the weak point of China's manufacturing industry.[14]

The plan states that the overall goals by 2023 are to strengthen the competitiveness of predominant products, improve industrial chains' level of secure supply, promote the realization of breakthroughs in

[14] Ministry of Industry and Information Technology website (https://www.miit.gov.cn/zwgk/zcwj/wjfb/dzxx/art/2021/art_4f96b993a0164e7aa79d7a536ae82254.html)

basic electronic components for key industries such as smart devices, 5G, and the industrial internet, improve the security capacity of key materials, equipment, and facilities in supply chains, and improve the level of modernization of industrial chains and supply chains.

As part of this effort, the goal is to (1) sustainably expand the scale of the industry, (2) promote breakthroughs in technology and innovation, and (3) clarify the results of corporate development, with the target of increasing total sales of electronic components to 2.1 trillion yuan by 2023 and developing 15 leading companies with sales of more than 10 billion yuan.

(2) Guiding Opinions on Accelerating the Fostering and Development of Excellent Manufacturing Enterprises

On July 2, 2021, six central government departments, including the Ministry of Industry and Information Technology, released the "Guiding Opinions on Accelerating the Fostering and Development of Excellent Manufacturing Enterprises."[15] The Guiding Opinions expressed the view that "accelerating the cultivation and development of good manufacturing enterprises is an inevitable requirement to bring out the vitality of market entities and promote the quality development of the manufacturing industry, and an urgent demand to prevent and eliminate risks and hidden harmful effects, and to enhance industrial chains' and supply chains' self-directed control capacities."

The Guiding Opinions then proposed the following 10 policy measures: (1) accurate understanding of overall requirements, (2) establishment of a framework for gradual development, (3) improvement of independent innovation capacity, (4) improvement of the level of modernization of industrial chains and supply chains, (5) guiding high-end, smart and green development, (6) establishment of an integrated development ecosystem for large enterprises and SMEs, (7) strengthening and promoting management innovation and cultural construction, (8) improving the level of openness and cooperation, (9) developing monetary, fiscal, and human resource policy measures, and (10) strengthening precise services (Table 1-3).

Table 1-3: Policy Measures in the Guiding Opinions on Accelerating the Fostering and Development of Quality Manufacturing Enterprises

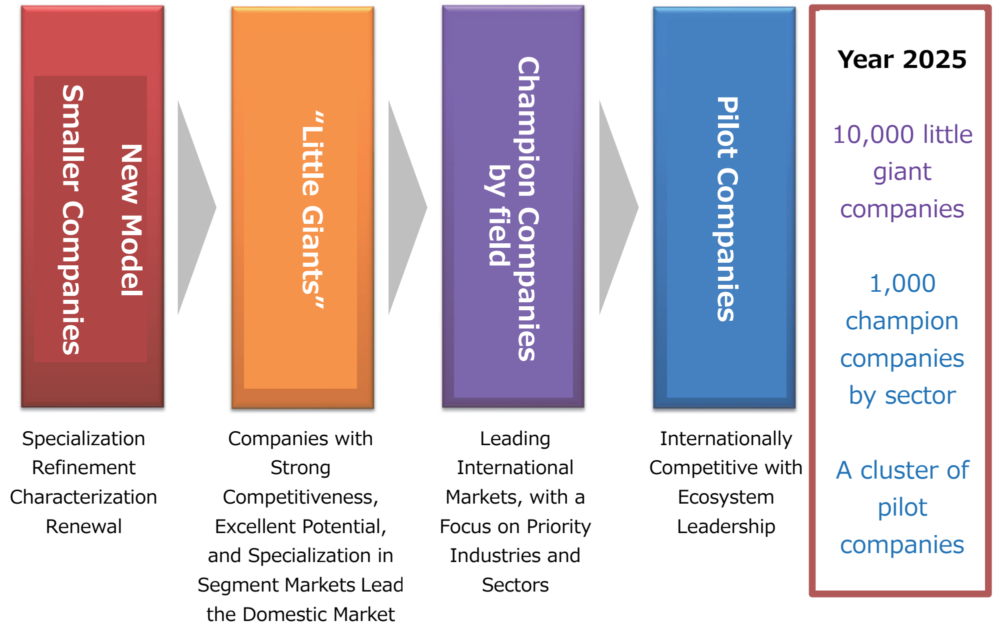
	Item	Main Measures
(1)	Accurate understanding of overall requirements	Promote the sustained strengthening, upgrading, and expansion of excellent enterprises, promote the improvement of the level of modernization of industrial chains and supply chains, and constantly bring the construction of a manufacturing powerhouse to a new stage.
(2)	Establishment of a framework for gradual development	Establish and develop classification selection criteria and selected benchmarks for "little giant" companies, sector champions, and pilot companies.

[15] Ministry of Industry and Information Technology Website (https://www.miit.gov.cn/zwgk/zcwj/wjfb/zh/art/2021/art_c05387fc8cfc4c77a4781b4336f6b576.html)

(3)	Improvement of independent innovation capacity	Promote the development of industrial digitalization and the popularization and application of industrial software. In addition, innovate through collaboration and strengthen difficult-to-reach and model applications of key core technologies, products, and equipment.
(4)	Improvement of the level of modernization of industrial chains and supply chains	Put together pilot companies to organize industrial and supply chains and integrate industrial resources through mergers, restructuring, and strategic alliances to improve competitiveness and risk resistance.
(5)	Guiding high-end, smart, and green development	Accelerate the promotion of integrated development for next-generation information technology and manufacturing, and implement smart manufacturing projects and green manufacturing projects.
(6)	Establishment of an integrated development ecosystem for large enterprises and SMEs	Have pilot companies collaborate with SMEs to build advanced manufacturing clusters, strategic emerging industry clusters, innovation-based industry clusters, etc.
(7)	Strengthening and promoting management innovation and cultural construction	Implement special actions to improve corporate management, encourage the promotion of organizational management reform, and renew production management models. Additionally, induce companies to focus on cultural construction.
(8)	Improving the level of openness and cooperation	Establish a global research, development and design center to encourage effective consolidation and utilization of resources. In addition, with an emphasis on "Belt and Road Initiative" joint construction, establish a regional industrial chain community.
(9)	Developing monetary, fiscal, and human resource policy measures	Encourage the establishment of a development fund and support the raising of capital through capital market listings and the issuance of bonds. In addition, construct an advanced manufacturing training center in collaboration with universities and scientific research institutions.
(10)	Strengthening precise services	Organize corporate needs and provide specialized services such as information and consulting, human resource development, and intellectual property rights.

Source: Based on "Guiding Opinions on Accelerating the Fostering and Development of Excellent Manufacturing Enterprises" (July 2021), six departments of the central government, including the Ministry of Industry and Information Technology.

In addition, the Guiding Opinions also sets forth a gradual framework for the development of excellent enterprises: (1) to develop specialized SMEs into "little giants" that lead the domestic market; (2) to develop "little giants" into "champions" that lead the international market by focusing on key industries and sectors; and then (3) to develop "pilot enterprises" with ecosystem leadership and international competitiveness. The blueprint calls for the development of 10,000 "little giant" companies, 1,000 sector-specific champion companies, and a cluster of pilot companies by 2025 (Figure 1-1).



Source: Based on "Guiding Opinions on Accelerating the Fostering and Development of Excellent Manufacturing Enterprises" (July 2021), six departments of the central government, including the Ministry of Industry and Information Technology.

Figure 1-1: Blueprint for the fostering and development of excellent manufacturing enterprises

On November 23, 2021, the Ministry of Industry and Information Technology announced at a regular policy briefing hosted by the State Council Information Office that 4,762 national-level special new "little giant companies" have been fostered to date. Xu Xiaolan, vice minister of the Ministry of Industry and Information Technology, emphasized, "Little giant companies can be characterized by the numbers 5-6-7-8. In other words, more than 50% of the companies have R&D investment of 10 million yuan or more, more than 60% are in basic industrial fields, more than 70% have been in the industry for more than 10 years, and more than 80% are in the top market segment in the region where their headquarters are located. The emergence of companies to strengthen weak spots is an important source of support for the construction of a manufacturing powerhouse."[16]

1.5 Future Direction of Industrial and Supply Chain Restructuring in Light of the 20th Party Congress

1.5.1 Report on the 20th Congress of the Communist Party of China

At the 20th Party Congress of the Communist Party of China held in Beijing on October 16–22, 2022, it was decided that General Secretary (President) Xi Jinping would continue in office for a third term. On the first day of the Party Congress, General Secretary Xi (President of the People's Republic of China) delivered a report titled "Hold High the Great Banner of Socialism with Chinese Characteristics and Strive in Unity to Build a Modern Socialist Country in All Respects." The report demonstrated the view

[16] Website of the Central People's Government of the People's Republic of China (http://www.gov.cn/xinwen/2021-11/23/content_5652843.htm)

that China's economic power has achieved a historic leap forward by focusing on promoting high-quality development and building a new development structure.[17]

On the other hand, the report also notes that "some shortcomings still exist in our activities and we face no small number of difficulties and problems." Specifically, (1) there are many barriers and bottlenecks to quality development, and scientific and technological innovation capacity is not yet strong; (2) there are many serious problems in food, energy, industrial and supply chain security, and financial risk prevention; (3) disparities between urban and rural areas and between regions remain large. These and other observations suggest that this will be a challenge for the Xi Jinping administration in the future.

In the report, "quality development" is positioned as the most important task in the overall construction of a modernized socialist state. The report emphasizes, "We must focus on promoting 'quality development' by organically combining the implementation of strategies to expand domestic demand and deepen supply-side structural reforms, strengthening the endogenous dynamics and reliability of the general domestic circulation, enhancing the quality and level of the international circulation, accelerating the construction of a modernized economic system, focusing on increasing total factor productivity, improving the resilience of industrial chains and supply chains, and promoting effective quality improvements and the logical quantitative expansion of the economy."

1.5.2 Policy Measures Following the 20th Party Congress

(1) Notice on Several Policy Measures on Promoting, Attracting, Stabilizing and Enhancing Manufacturing-Oriented Foreign Investments

On October 25, after the Party Congress, six central government departments, including the National Development and Reform Commission, released the "Notice on Several Policy Measures on Promoting, Attracting, Stabilizing and Enhancing Manufacturing-Oriented Foreign Investments," which aims, among other things, to better leverage the role of foreign investment in the quality development of the manufacturing industry and its integration into global industrial chains and supply chains.[18] The notice proposes relevant policy measures from three perspectives: (1) increasing the inflow of foreign investment by optimizing the investment environment, (2) supporting the development of foreign-invested enterprises by strengthening investment services, and (3) improving the quality of foreign investment by guiding the direction of investment.

1. Increasing the inflow of foreign investment by optimizing the investment environment
   This section clarifies that they will thoroughly implement the "Negative List for Foreign Investment," which lists areas where foreign companies are restricted or prohibited from investing, treat Chinese and foreign companies equally in areas not on the negative list, implement high standards for domestic treatment after entry, and specify that foreign companies will enjoy equal treatment with Chinese companies in bidding, government procurement, etc. It also plans to develop international industrial investment cooperation activities and strengthen dialogue and exchange with foreign-

[17] Communist Party of China News Network Website (http://cpc.people.com.cn/20th/n1/2022/1026/c448334-32551867.html)
[18] National Development and Reform Commission website (https://www.ndrc.gov.cn/xxgk/zcfb/tz/202210/t20221025_1339087.html?code=&state=123)

invested companies, chambers of commerce and industry, and international organizations.

2. Supporting the development of foreign-invested enterprises by strengthening investment services
   After ensuring that measures are taken against the COVID-19, the policy is to improve convenience for foreign company managers, technicians, and their families in entering and exiting the country, as well as to strengthen the security and facilitation of cargo transport and logistics. It also encourages foreign-invested enterprises to reinvest their profits and strengthens financial and import/export support for foreign-invested enterprises.

3. Improving the quality of foreign investment by guiding the direction of investment
   This section states that it will support the innovation and development of foreign investment, encourage the establishment of central research and development bases for foreign investment, and enhance openness and cooperation in science and technology. It will also accelerate green, low-carbon, and advanced foreign investment, induce active participation in moving from peak carbon emissions to carbon neutrality, and focus on encouraging multinationals in the manufacturing sector to relocate to the Midwest and Northeast.

(2) Notice on Strengthening Industrial Economic Promotion by Establishing Trends for Recovery and Favorable Change

On November 29, the Ministry of Industry and Information Technology, the National Development and Reform Commission, and the State-owned Assets Supervision and Administration Commission released the "Notice on Strengthening Industrial Economic Promotion by Establishing Trends for Recovery and Favorable Change."[19] In order to operate the industrial economy within reasonable limits in the fourth quarter of 2022, maintain the basic stability of manufacturing industry proportions, and build a solid foundation for accelerating the promotion of new-type industrialization in 2023, the Notice put forward 17 policy measures to (1) strengthen the foundations for the recovery and stability of the industrial economy, (2) reinforce the stable development of key industries, (3) promote cooperative development of the industrial economies of each region, and (4) achieve sustained improvements to corporate vitality.

In relation to industrial chains and supply chains, item (1) (strengthen the foundations for the recovery and stability of the industrial economy) mentioned "improving the resilience and safety level of industrial chains and supply chains." The policy states that it will establish normalized and stabilized industrial chain and supply chain coordination mechanisms to respond to major contingencies; focus on key regions, industries, and enterprises; strengthen interregional and upstream/downstream cooperation; and ensure stable production for key enterprises and stable and smooth distribution in key industrial chains and supply chains.

It also plans to implement industrial infrastructure restructuring projects; strengthen supply guarantees and joint stockpiling of critical raw materials, software, and parts; promote the popularization and application of automotive chips, technological R&D, and production capacity improvements; and further

[19] Ministry of Industry and Information Technology website (https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2022/art_a2ce1eab5087427593a184d8263c6d82.html)

develop supply routes. In addition, it will fully demonstrate the role of inter-sectoral coordination mechanisms for coal, electricity, oil, and gas transportation security operations; establish emergency energy supply security measures; guide the optimization of orderly electricity usage measures in local areas; guarantee electricity and coal supply security during peak periods; and meet the reasonable energy demands of industrial development.

1.6 In Conclusion

In anticipation of a prolonged confrontation between the US and China, the Chinese government is promoting the restructuring of industrial and supply chains, focusing on trade and industrial policies, in order to prepare for decoupling risks. On the trade front, however, it is expected that establishing economic frameworks involving China, such as FTAs, will take some time. In addition, in terms of industry, the disadvantage of being dependent on foreign countries for advanced components and core technologies is not something that can be overcome in a short period of time. In light of this situation, China is expected to continue to launch a variety of policies, although the effectiveness of some of the policy measures is still unknown.

In any case, decoupling between the US and China is likely to be a constraint on the business operations of foreign-affiliated firms, including Japanese firms. In particular, the trend toward the restructuring of China's industrial and supply chains is expected to have a major impact.

(Written December 5, 2022)

2 Analysis of the Success or Failure of China's Semiconductor Industry Policies

2.1 Concerns

Since the beginning of the 21st century, China has positioned the semiconductor industry as the one that will support future economic development and national competitiveness, and has made various policy interventions to that end. The culminating policy is Made in China 2025,[20] released in May 2015. Among the strategic industries of "Made in China 2025," which includes 10 sectors, the most important sector is the semiconductor industry, with the goal of increasing semiconductor self-sufficiency to 70% by 2025.

However, the US Trump administration, which took office in 2017, initiated semiconductor trade sanctions against China regarding. First ZTE in April 2018, then five Chinese companies including supercomputer maker Sugon in 2019, followed by a total of 115 Chinese companies including Huawei affiliates and China's largest semiconductor maker SMIC in 2020, and by November 2021, the National Supercomputing Centre in Shenzhen[21] and 42 companies, including semiconductor design firm Goke Microelectronics,[22] were included on the entity list[23] and barred from purchasing US components. The Biden administration, which took office after a change of US administrations in 2021, not only inherited the previous administration's restrictions on exports of advanced semiconductor manufacturing equipment to China, but also urged its allies to adopt similar regulations.

Meanwhile, to counter the US's restrictive semiconductor measures against China, the semiconductor industry was designated as an important industry for development in the "14th Five-Year Plan for National Economic and Social Development and Outline of Long-Term Goals up to 2035"[24] approved at the National People's Congress held in March 2021. In order to achieve the goal of fostering the industry, forms of government involvement have been used to promote the development of the semiconductor industry, such as tax incentives, the establishment of public enterprises, public capital participation in the companies involved, the establishment of a national fund, and the leadership of government leaders. The question and concern of this paper is whether this government involvement in fostering the semiconductor industry has a chance of success.

20 Made in China 2025 http://www.gov.cn/zhuanti/2016/MadeinChina2025-plan/mobile.htm

21 National Supercomputing Centre in Shenzhen: http://www.nsccsz.cn/

22 Goke Microelectronics Co. http://www.gokemicro.com/

23 The Entity List is a trade restriction list published by the US Department of Commerce Bureau of Industry and Security (BIS), which lists certain foreign persons, entities or governments. If you wish to export or transfer certain items, such as certain US technology, to entities on the Entity List, you must apply to BIS for a permit.

24 新 华 社 北 京 3 月 12 日 电 (2021): Zhonghua renmin renmin guo jingjiang jiaoxiang yuansheng fenxiang fenxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang jiaoxiang, State Council, http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm

2.2 Chinese Government Involvement in Semiconductor Industry Development

2.2.1 Background of Chinese Government Involvement in Semiconductor Industry Development

The main background involved in the Chinese government's development of the semiconductor industry is the country's low level of self-sufficiency in semiconductors. China's semiconductor self-sufficiency ratio is the percentage of semiconductors "produced in China" of the total semiconductors supplied to meet China's overall demand. While many Chinese industrial product markets are currently in a state of oversupply (in excess of self-sufficiency) and are struggling with how to reduce excess supply capacity, the semiconductor market is suffering from a supply shortage. To begin with, since semiconductors are used in a variety of applications, it is not easy to obtain accurate information on the semiconductors actually used each year, and there is no data applicable to "country-of-production standards" for semiconductor products.[25] The reason for this is obvious. When a single semiconductor chip is produced, the main production processes [circuit design - front-end production - back-end production - inspection] are completed at the offices and factories of companies located in each country. Thus, it is difficult to ascertain the volume of semiconductor production as a statistical indicator on producer country standards.

Here, we ascertain China's semiconductor self-sufficiency rate in 2021 based on data from IC Insights,[26] a US research firm. According to IC Insights, semiconductor production in China in 2021 was $31.2 billion, accounting for 16.7% (self-sufficiency ratio) of the size of semiconductor demand in China ($186.5 billion). Of the $31.2 billion manufactured domestically, local companies headquartered in China produced approximately 39%, or $12.3 billion worth of semiconductor products. The remaining approximately 61% would have been produced by foreign companies with production plants in China. In other words, the remaining $155.3 billion worth of demand for these products that Chinese semiconductor market in 2021 could not meet, would have been sourced from countries and regions other than China. In 2021, the total global semiconductor market size was US$510.5 billion, with the Chinese market accounting for 36.5% of the global total. The share of the global market for production by Chinese semiconductor companies (including foreign-invested companies) was 6.1%, and only 2.4% for local Chinese companies.

While the above data is for reference only, the data itself indicates a difficult self-sufficiency situation for Chinese semiconductors. Naturally, the Chinese government is well aware of the above situation and has taken steps to increase its self-sufficiency in semiconductors. As a result, the State Council has included numerical targets for semiconductor self-sufficiency (20% by 2020, 70% by 2025, etc.) in "Made in China 2025," and the degree to which these targets have been achieved has become a guide in discussions over

[25] It was Shioji and Tanaka (2020) who raised the issue of "producer country standards" as a concept. Today, the production of many industrial products is not necessarily limited to one country. Since not only the production of product components and finished products, but also the process of manufacturing a single product is often done multilaterally, and it is difficult to calculate the statistics of a single "country" as a "country of production," "manufacturer standards" are sometimes used instead of "country-of-production standards." Semiconductors are a prime example.

[26] "China-based IC production to represent 21.2% of mainland China IC market in 2026." Note that IC Insights ceased operations on December 30, 2022 and can be viewed at TechInsights https ://www.techinsights.com/ja

economic security and other issues. In addition, the tightening of trade restrictions on semiconductors against China since Biden took office as US president in 2021 has been greatly alarming to the Chinese government. As a result, the Chinese government has become increasingly involved in fostering the semiconductor industry.

2.2.2 Current Status of Chinese Government Involvement in the Semiconductor Industry

The key term in this paper, "government involvement," refers to government intervention in the allocation of various resources involved in economic activities. Government involvement includes industrial policy, government regulations and licenses related to industrial resource allocation, establishment of state-owned enterprises, public capital participation in specific industrial sectors, establishment of specific technology development projects, and subsidies. In fact, government involvement in China's semiconductor industry is by no means a recent phenomenon; it has existed almost since the founding of the country (Sono, 2020). Table 2-1 shows details of major government involvement in the semiconductor industry since the reform and opening-up period.

Table 2-1: Major government involvement in the semiconductor industry since the reform and opening-up period

Time	Government Involvement Policies and Regulations	Government Involvement Details and Goals
1980s	The 863 Project	Positioning the semiconductor industry as a pillar industry
1990s	"908 Project," 909 Project	Cultivation of state-owned capital IDMs, such as Huacheng Electronics and Huahong Microelectronics
2000	State Council "Item 18 Writings" (Notice)	By 2010, establishing a major production base for semiconductors
2004	Guidelines for the Priority Development of Immediate High-Tech Industry Priority Areas	Emergence of foundries such as SMIC
2008	The 11th Five-Year Special Development Plan for the Integrated Circuit Industry	Continued increase in 200 mm plants
2014	National IC Industry Development Promotion Guidelines	Establishment of a national IC industry investment fund
2015	Made in China 2025	Becoming a "semiconductor industry powerhouse"
2020	State Council's "Several Policies to Promote the High-Quality Development of the Integrated Circuit Industry and Software Industry in the New Era"	Industry preferential treatment in terms of fiscal and taxation, investment and financing, and research and development

Source: Created by the author

According to this report, the methods of government involvement in the semiconductor industry during the reform period include "notices," "guidelines," "policies," and "plans," some of which would correspond to former Japanese industrial policies and state-led "projects." In particular, in the latter case, there are many examples of state-owned enterprises being established with state funds. The following is an overview of government involvement in the semiconductor industry during the reform period.

First, in the 1980s, the then Ministry of Electronics Industry of the central government proposed the "531 Development Strategy (5 micron promotion, 3 micron development, 1 micron breakthrough)"[27] for semiconductor technologies in 1986, and the National Planning Commission and the then Ministry of Machinery and Electronics Industry adopted the Semiconductor Development Strategy in 1989.[28] Next, in the 1990s, the Chinese government sought to achieve 6-inch wafers and 0.8–1.0 microns in a state-led technology development association called the "908 Project"[29] (1990–95), and 8-inch wafers and 0.5–0.35 microns in a second state-level technology development association endeavor called the "909 Project"[30] (1996–2000). During this period, the goal was to develop vertically integrated semiconductor manufacturing companies (integrated device manufacturers or IDMs), and particular emphasis was placed on supporting six companies, including the state-owned Huajing Electronics and the joint venture Hua Hong NEC.

In the next phase, from the 2000s onward, the government's inability to close the gap with the world's most advanced technologies led to a shift in its traditional emphasis on IDMs and a shift toward the development of semiconductor fabless companies and contract manufacturing foundries. In this context, foundry companies such as SMIC and HiSilicon were established. Then, to close the gap with the rest of the world, in 2000 the State Council issued "Certain Policies to Promote the High-Quality Development of the Integrated Circuit Industry and the Software Industry"[31] ("Item 18"[32]), which strongly promoted the development of the semiconductor industry from various aspects, including taxation, investment, import and export, human resources, intellectual property, purchasing, and foreign currency (Sono, 2000; Koezuka, 2011).

Then, in the 2010s, as China became the world's manufacturing center, demand for semiconductors, which are essential for IT products and electronic and electrical products, greatly exceeded domestic supply capacity. In order to improve semiconductor self-sufficiency, the Chinese government enacted the

[27] China Machine and Electronic Industry Yearbook Committee (1986): China. China Yearbook of Machine and Electronic Industry 1986, Machine Tool Industry Publishing House

[28] China Machine and Electronic Industry Yearbook Committee (1989): China. China Yearbook of Machine and Electronic Industry 1989, Machine Tool Industry Publishing House

[29] China Machine and Electronic Industry Yearbook Committee (1990): China. China Yearbook of Machine and Electronic Industry 1990, Machine Tool Industry Publishing House

[30] China Machine Tool and Electronic Industry Yearbook Committee (1996): China Machine Tool and Electronic Industry Yearbook Committee (1996). China Yearbook of Machine and Electronic Industry 1996, Machine Tool Industry Publishing House

[31] State Council (2000): State Council 关于印发鼓励软件产业和集成电路产业发展若干政策的通知 , 国发 (2000) Vol. 18, http://www.gov.cn/gongbao/content/2000/content_60310.htm

[32] In October 2005, the State Council promulgated a government notice, "Item 18," which had a major impact on China's semiconductor industry. Since then, the industry has been eagerly awaiting new support measures from the government, and relevant government departments and commissions have repeatedly mentioned new support measures. Specifically, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the State Administration of Customs, and the State Administration of Taxation announced 94 semiconductor manufacturing companies in the "First Round of State-Promoted Integrated Circuit Enterprises." These companies will benefit from preferential policies from the government, including research and development funding, tax incentives, human resource training, and loans. The long-awaited support policy for China's semiconductor industry finally began to show some real progress.

"National IC Industry Development Promotion Guidelines"[33] and established the "National IC Investment Fund" in June 2014, which aims to promote semiconductors. Based on this national investment fund, China decided to build major semiconductor plants in the country.

The state-owned company Yangtze Memory invested $24 billion in the spring of 2016 to build a huge production plant (Yunoue, 2019). Furthermore, the "Made in China 2025" plan formulated in 2015 now aims to achieve 40% semiconductor self-sufficiency by 2020 and 70% by 2025.

Ongoing government involvement is centered on the State Council's August 2020 release of "Several Policies to Promote the High-Quality Development of the Integrated Circuit Industry and Software Industry in the New Era."[34] The policy sets forth a plan to accelerate the advanced development of the semiconductor industry by establishing support measures in eight areas: taxation, investment and financing, research and development, imports and exports, human resources, intellectual property rights, market applications, and international cooperation. Taking tax support measures as an example, "semiconductor production enterprises with a circuit line width of 28nm or less, have been promoted by the state, and have been in operation for 15 years or more will be exempt from corporate income tax for 10 years from the year they turn a profit."

For example, the preferential import/export policy states that "enterprises producing logic circuits and memories with a circuit line width of 65nm or less and special process semiconductors with a circuit line width of 250nm or less are exempted from customs duties on imports of raw materials, consumables, clean room construction materials, related systems and integrated circuit production equipment components for their own production. It is rare for the State Council to stipulate such detailed preferential policies, and this shows the seriousness of the central government's involvement in the semiconductor industry.

A document summarizing the Chinese government's involvement in the semiconductor industry during the reform period from a different perspective is presented in TableTable 2-1. According to this, the Chinese government's involvement varies from period to period, but it can be roughly divided into the following three phases: (1980-90s, a period of deep involvement; 2000~10s, a period of light involvement; and the present, another period of deep involvement). At this time, the Chinese government's involvement in the semiconductor industry is broad in scope and represents the deepest and most intense involvement in history. Whether or not China's semiconductor industry can achieve self-sufficiency as expected and gain a strong competitive advantage with such deep government involvement, this issue will be analyzed below using the author's analytical methods.

[33] State Council (2014): National Development Strategy of Integrated Electric Circuit Industry, http://www.cac.gov.cn/2014-06/26/c_1111325916.htm

[34] State Council (2020): Notice on Some Several Policies to Promote the High-Quality Development of the Integrated Circuit Industry and Software Industry in the New Era, 国发 (2020) Vol. 8, http://www.gov.cn/zhengce/content/2020-08/04/content_5532370.htm

Table 2-1: Methods of Government Involvement in the Semiconductor Industry during the Reform and Opening-Up Era

	Establishment of Public Enterprises	Public Capital Fund	Tax Reduction or Exemption	State Project	Public Capital Participation	Financial Benefits
1980s	○			○		
1990s	○		○	○	○	
2000s			○			
2010s		○	○		○	○
2020s	○	○	○		○	○

Source: Created by the author

2.3 An Analysis of the Success or Failure of the Chinese Semiconductor Industry

2.3.1 Analytical Framework -- Observations based on Four Conditions and 16 Elements

When considering whether the Chinese government's involvement in the semiconductor industry is a policy expectation, we should start with the question of defining the necessary conditions for a country's industrial development. While there is probably no general theory in conventional industrial development theory that is common to all industrial development, Porter's "diamond" model, well known around the world, is one of the few attempts to take on the challenge (Porter, 1992). Porter's hypothesis in the diamond model is that a particular country can have a competitive advantage in one industry but not in another. In other words, the idea is that innovation will only occur in certain industries in a given country and not in others.

In the diamond model, Porter states that a country's competitive advantage consists of four factors: (1) a strong corporate strategy and competitive conditions, (2) primary factor conditions, (3) demand conditions, and (4) related industries and supporting organizations. If all four are positive, domestic firms can continue to grow and evolve, and if these four are combined with opportunities and the role of government, industrial agglomeration will occur, according to the report. While Porter's diamond model, which describes a country's potential for industrial development, is now widely accepted, the semiconductor industry is an industry with considerable specificity. Looking at the history of the global semiconductor industry, it is clear that it has certain characteristics that do not exist in other industries - intervention and protection by national governments, severe intra-industry changes, and strong ties to international politics - and these characteristics must be taken into account.

While accepting Porter's hypothesis as an idea, this paper emphasizes the unique industrial characteristics of the semiconductor industry and argues that a unique perspective is needed in analyzing the industry. Specifically, there are four sets of conditions - industry conditions, market conditions, division of labor conditions, and policy conditions - that have a significant influence on the development of today's semiconductor industry. The components of these four conditions are as follows.

First, the industrial conditions essential for the development of the semiconductor industry are considered to be four elements - capital, human capital, manufacturing equipment, and supporting industries. The semiconductor industry is not only an equipment industry that requires a huge investment of capital, but also an advanced high-tech field, so highly skilled technical personnel and a well-developed supporting industry are essential. The above four elements are the minimum for industrial development.

Next, market conditions include four elements - market demand, industry organization, market supply, and the market entry environment. Since semiconductors are originally intermediate goods, the behavior of the companies that produce and consume them has a significant impact on the development of the industry.

The third set, division of labor conditions, has four elements - intellectual property (IP), design (fabless), manufacturing (foundry), and management know-how. The global semiconductor industry has undergone revolutionary changes in the way it operates, and the former IDM production style of vertical integration, in which one company handles the entire semiconductor production process (design, manufacturing, assembly, and testing), has come to an end. Instead, each process involved in semiconductor production has become independent, resulting in a pattern of horizontal division of labor. How a country's semiconductor industry develops will largely determine how it is involved in this intra-industry division of labor.

Finally, as is widely known, the semiconductor industry to date has never been an industry that developed spontaneously or according to the principles of free market competition. Behind this industry, there is always the shadow of the government. The fourth item, policy conditions, is considered to have four elements: industry-related laws and regulations, government intervention, support for the private sector, and support for technological development.

This paper analyzes each of the above four conditions, which have a significant influence on the development of China's semiconductor industry, in light of the industry in that country. Furthermore, each of the above four conditions contains four elements, making a total of 16 elements, and the analysis of these 16 elements is the core substance of this paper.

The above analysis method for the 16 factors is based on the author's own quantitative evaluation of each element. Specifically, a 5-point evaluation is made upon close examination of the content and current status of each element. This 5-point evaluation is divided into five ranks: "strong," "relatively strong," "intermediate," "relatively weak," and "weak" for the content of each element, with 5, 4, 3, 2, and 1 points for each rank, respectively. For example, a score of 5 is given if there are ample funds for industrial investment in the "industrial conditions" element of "funds." In the opposite case, the score is 1 point. For intermediate status between the two, the score shall be evaluated as 3.

2.3.2 Analysis Results

Due to the space constraints of this paper, a detailed explanation of the scoring content will be omitted,[35] but the results of the scoring based on the above analytical framework are shown in Figure 2-1 and Figure 2-2.

[35] See Sono (2020) for the ranking rationale and a detailed explanation.

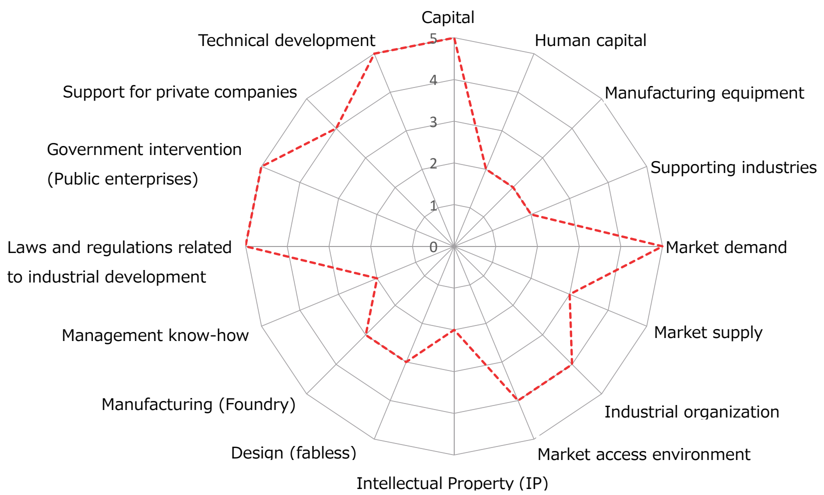


Figure 2-1: Distribution of the Strengths and Weaknesses of Various Elements Related to the Development of China's Semiconductor Industry

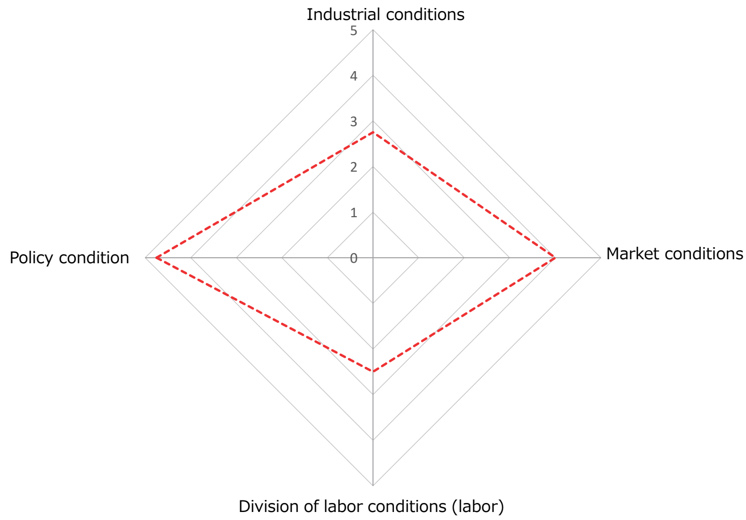


Figure 2-2: Distribution of Strengths and Weaknesses of Four Conditions for Semiconductor Development in China

Figure 2-1is a chart of the distribution of ranks for the 16 elements that have a significant impact on the development of China's semiconductor industry discussed in this paper. There were five "strong" and four "relatively strong" factors related to the development of China's semiconductor industry in this figure that is, those assigned scores of 5 and 4, respectively.

(1) Strong Elements in China's Semiconductor Industry Development

First, the "capital" element will be an extremely strong driving force in the development of China's semiconductor industry. The semiconductor industry, nicknamed the "money-grubbing industry," is a field where nothing can be said without funding. China already has ample funds for investment, having left behind the days when it suffered at the whims of huge investment funds. This huge source of investment capital is an important objective condition that guarantees the future development of the semiconductor industry.

Second, the "market demand" element is a strong driving force behind the development of China's semiconductor industry. China has been the world's largest semiconductor consumer market since 2005

($510.5 billion worldwide in 2021, of which the Chinese market was $186.5 billion). Currently, China's semiconductor market size accounts for more than one-third of the world's total. Furthermore, the Chinese semiconductor market has the largest application area in the world, and its demand is bound to grow in the future. Moreover, the supply of semiconductor products made domestically in China cannot keep up with these huge market demands. Therefore, the incentives for capital investment and technology development are quite strong on the semiconductor supply side. Above all, this favorable market demand structure will strongly push the further development of the Chinese semiconductor industry.

The remaining three "strong" elements are concentrated within the policy conditions (laws and regulations related to industry development, government intervention [public enterprises], and support for technological development). Looking at the world today, it is no exaggeration to say that no other government in the world is as enthusiastic about fostering its own semiconductor industry as the Chinese government. Thus, the current intensifying conflict between the US and China will, in turn, stimulate the Chinese government and spur industrial development even further. Currently, the US government has broadened the scope and strengthened the content of its sanctions against Chinese semiconductor companies, but the more the US imposes sanctions, the more the Chinese government is bound to become even more involved in fostering the semiconductor industry.

(2) Weak elements in the development of China's semiconductor industry

On the other hand, looking at the "weak" and "relatively weak" elements related to the development of China's semiconductor industry, no elements were given a score of 1, but five were given a score of 2. Many of these elements are essential for the future development of the Chinese semiconductor industry.

First, an extremely important element that was given two points is "manufacturing equipment" in the category of "industrial conditions," which is a fatal weakness of the Chinese semiconductor industry as an equipment industry. China now has no shortage of funds to invest in the semiconductor industry, but the problem is the manufacturing equipment itself, which is essential to the semiconductor industry as an equipment industry. In other words, semiconductor factories are being built at a rapid pace in the country, but China is deeply dependent on Japan, the US, and Europe for advanced manufacturing equipment. The most important of the many types of manufacturing equipment is exposure apparatus, and Dutch company ASML dominates the market with an 86.9% share. In addition, Japan's Tokyo Electron Limited (TEL) dominates the market for coater/developers (which apply photoresist and develop it after exposure) with an 84.8% share (Yunoue, 2018).

If the US–China conflict leads to the US imposing an embargo of US equipment on China, and the US then pressures the Netherlands and Japan to impose joint sanctions against China, China could lose its ability to purchase almost all manufacturing equipment from the US and Japan, except for exposure equipment.

The next two "relatively weak" elements were "support industries" and "human capital" under the "industrial conditions" category. These two elements cannot be secured overnight. In the semiconductor front-end manufacturing process, a wide variety of materials are used, including cleaning solutions and material gases for the film formation process, photoresist (photosensitive material) and photomasks for the exposure process, and etching gases for the etching process. The current share of Japanese manufacturers in global semiconductor production is less than 10%, but the share of Japanese companies in these materials reaches 50%. Related industries, especially manufacturing materials, are similar to manufacturing equipment and require long-term technological accumulation and research and development. For example, for silicon wafers, the most important semiconductor material, China is still not even at 5% self-sufficiency within the country and is largely dependent on Japan. It will take some time to reach the current level of Japan.

And the cultivation of "human capital" also takes a long time. When the supply of experienced personnel could no longer keep up with demand, Chinese firms began to target industry-ready talent from overseas. While China has recently been trying to acquire engineers from South Korea and Japan to address its talent shortage, the greatest success has probably been in Taiwan, where they share a common language and culture.

Third, the other two elements are "intellectual assets (IP)" and "management know-how" in the "division of labor conditions" category. The common denominator of these two elements is that they are cumulative over time. In other words, the longer the history of the semiconductor industry, the stronger they become. The global market for the former semiconductor intellectual assets reached US$3.75 billion in 2017, the majority of which is held by Japanese, US, and European companies. In the case of "management know-how," some Chinese firms (such as SMIC) have reached a high level, but overall, the level remains low.

(3) Composition of the Strengths and Weaknesses of the "Four Conditions" for the Development of China's Semiconductor Industry

In this section, we look at the potential for the development of China's semiconductor industry based on the distribution of its strengths and weaknesses among the "four conditions" set forth in this paper. Figure 2-2 is a distribution chart of the "four conditions" calculated based on the scores of the 16 elements. This figure shows the composition of the "four conditions" in order from "strong" to "weak": policy conditions, then market conditions, followed by division of labor conditions, then finally industry conditions.

First, the "policy conditions," which were given the highest score, have been explained above. In short, the goal of the "Made in China 2025" plan formulated by the Chinese government in 2015 was to achieve 40% semiconductor self-sufficiency by 2020 and 70% by 2025. To achieve this, the Chinese government has set up a massive investment fund (National Integrated Circuit Industry Investment Fund) for the semiconductor industry. The fund is investing in local companies with the aim of fostering a complete supply chain within the country, from semiconductor design to manufacturing, testing and packaging. On the policy front, against a backdrop of conflict between the US and China, the Chinese government decided that in 2020 it would exempt from corporate income tax companies that design semiconductors and other products that are essential for semiconductor products to be incorporated into telecommunications equipment.[36] According to a public notice from the Development and Reform Commission, the Ministry of Finance, and other government organizations,[37] for semiconductor design companies and software

[36] State Council (2020): Notice on Some Several Policies to Promote the High-Quality Development of the Integrated Circuit Industry and Software Industry in the New Era, 国发 (2020) Vol. 8, http://www.gov.cn/zhengce/content/2020-08/04/content_5532370.htm

development companies, the corporate income tax rate of 25% would be exempted for one to two years and halved from the third to the fifth year. In short, the Chinese government is in a position to provide all-out support, direct and indirect, for the development of the semiconductor industry.

Next, market conditions are the second strongest after the policy conditions mentioned above. In particular, the huge level of demand in the Chinese market, which accounts for one-third of the world market, is a driving force behind the development of the Chinese semiconductor industry, and is a market that foreign semiconductor companies cannot ignore. The experience in the industrial development process of semiconductors is that market demand drove the semiconductor industry in each country and region.

However, there are also two conditions that are unfavorable to the future development of the Chinese semiconductor industry: division of labor conditions and industrial conditions. These conditions could slow or impede the development of the Chinese semiconductor industry. Industrial conditions are quite unbalanced, because even though the "capital" element is strong, the "human capital," "manufacturing equipment," and "supporting industries" elements are generally weak. This composition may well explain why Chinese companies have been trying to acquire foreign semiconductor companies with huge amounts of money. In other words, Chinese firms have often used strategies to cover up for their competitive disadvantages in industries such as "human capital," "manufacturing equipment," and "supporting industries" by taking advantage of their strong financial position. This strategy has been partially successful in the past, but since the outbreak of the conflict between the US and China, US government sanctions have gradually made this strategy untenable. The results suggest that the future development of the Chinese semiconductor industry may be difficult. Inferior division of labor conditions is another major negative point. This condition of industrial development is not only technological in nature, but also has the characteristic of "accumulation over time," making it difficult to catch up in a short period of time.

2.4 Conclusion

This paper explores the industrial development potential of China's semiconductor industry by analyzing the factors that are essential to its industrial development. In closing is a summary of the findings from previous analyses.

First, the development structure of China's semiconductor industry in terms of the 16 elements involved in the industry's development is as follows. Looking at all 16 elements, the distribution includes eight strong (labeled "strong" and "relatively strong"), five weak (labeled "weak" and "relatively weak"), and three intermediate (labeled "intermediate") elements. Comparing simple numbers alone, we can conclude that the strong elements account for a little more than half of the total, and thus the development potential of

[37] National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Finance, General Administration of Maritime Affairs (2021): Notice of the Five Departments of the State Development and Reform Commission and Other Agencies' Requests for the Establishment of a Tax Refund Policy for Collective Electric Road Enterprises, Projects, and Software Enterprises, State Administration of Taxation, http://www.chinatax.gov.cn/chinatax/n810341/n810825/c101434/c5162974/ content.html

China's semiconductor industry is high.

Second, the above optimistic conclusion by no means implies that the Chinese semiconductor industry will develop smoothly. This is because there are "weak" and "relatively weak" factors involved in the development of the Chinese semiconductor industry, and many of these factors are related to technology and are essential for the future development of the Chinese semiconductor industry. In particular, in the case of the semiconductor industry, a typically technology-intensive field, it is difficult to develop an industry without both hard technology (equipment and materials) and soft technology (design, IP, manufacturing know-how, production management, and engineers). Moreover, these elements cannot be secured overnight, but rather accumulate over time, making it difficult to catch up in a short period of time.

Third, the "four conditions" for industrial development are countervailing, with two strong conditions and two weak conditions. "Policy conditions" and "market conditions" are strong and drive industrial development. In other words, there is a clear commitment on the part of the Chinese government to provide all-out direct and indirect support for the development of its own semiconductor industry, and at the same time, the enormous market demand in China, which accounts for half of the world market, is a driving force behind the development of the semiconductor industry.

Fourth, the two weak conditions for the future development of the Chinese semiconductor industry, "division of labor conditions" and "industrial conditions," may slow or hinder the development of the Chinese semiconductor industry. These two conditions for industrial development are not only technological in nature, but also have characteristics that accumulate over time, making it difficult to catch up in a short period of time.

As is widely known, today's semiconductor industry has transformed itself into a field with a distinctive international division of labor. Once a vertically integrated industry with everything from design to assembly completed within a country, each process in the industry is now a single industry in each country or region with a horizontal division of labor. As a result, the importance of the international division of labor and cooperation in the development of the semiconductor industry is growing. However, the current intensifying conflict between the US and China poses a threat not only to the Chinese semiconductor industry, but also to the development of this industry worldwide. We will have to keep a close eye on the direction in which China will guide its semiconductor industry in the future.

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3 The Actual Situation and Direction of Intelligent Manufacturing in China: Policy Development, Role Models (Case Studies), and Implications

3.1 Introduction Awareness of the Issue and Aims of this Report

Ten years have passed since Industry 4.0 efforts began globally, and although the principles of Industry 4.0 and digital transformation have become quite widespread in the manufacturing industries of Japan, the US, and Europe, some have argued that they may not be linked to the productivity gains and enhanced competitiveness that were expected. In 2015, China, which had been slow to develop its manufacturing sector, launched an industrial policy called "Made in China 2025" in order to become a "manufacturing powerhouse." "Made in China 2025" is a two-pronged strategy that aims to strengthen the foundations of manufacturing, including parts, materials, manufacturing facilities, and technologies, and to establish smart manufacturing (called "intelligent manufacturing" in China) that leverages digital technology. In the overall policy arrangement, the central project of the "manufacturing powerhouse" is to promote the transformation, optimization, and upgrading of industrial technology, with intelligent manufacturing as the main orientation. China's policy priority on smart manufacturing is presumably due to its estimation that digital technology will give it an advantage over the physically-based technology of manufacturing, and that it has the potential to compete with Japan, the US, and Europe in manufacturing in the future. Is China's intelligent manufacturing policy really progressing as it should?

This report is an attempt to research the policy development, actual conditions and issues of initiatives, and advanced cases related to intelligent manufacturing in China, with the aim of providing insights, and obtaining implications for Japan.

3.2 A Macro Assessment of Intelligent Manufacturing Policy Development and Manufacturing Industry Development

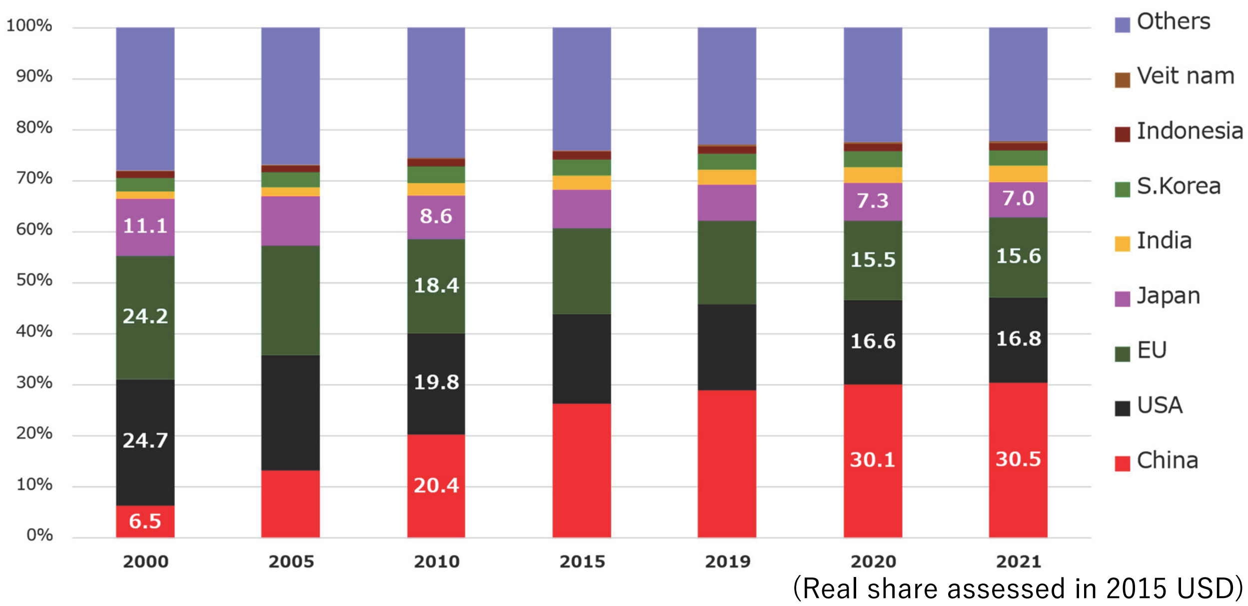
The "Made in China 2025" flag may have been lowered due to US–China conflict, but it has led to implementation plans such as the "Intelligent Manufacturing Plan" and the "Industrial Internet of Things (IIoT) Development Action Plan," and has been transformed into a series of sector-specific policies such as the Semiconductor Industry Promotion Policy, Robot Industry Development Policy, and Medical Equipment Industry Development Policy.

This paper will begin by summarizing the policy developments related to the intelligent manufacturing.

3.2.1 "Made in China 2025" Derailed by US–China Conflict

China began to be called the "world's factory" around 2010, when China's new membership in the WTO led to an influx of direct foreign investment and a reversal in the value added in the manufacturing sector between the US and China (Figure 3-1). The financial crisis around 2008 triggered the full-scale launch of the Advanced Manufacturing policy in the US under the Obama administration. In Germany, Industrie 4.0 was proposed in 2011 and approved as an industrial policy in 2012. In Japan, the "New Robot Strategy"[38] was enacted in January 2015.

Spurred on by policy developments in Japan, the US, and Germany related to the promotion of next-generation manufacturing, China launched its "Made in China 2025" policy in 2015 after a series of strategic response studies by think tanks in 2013. The Trump administration, which came to power after the Obama administration, inherited the Obama administration's policy of restoring manufacturing, but became increasingly concerned about "Made in China 2025" policy developments, and launched one counter-policy after another against China, from trade disputes to technology regulations.



Source: Calculated and prepared by author based on UNIDO database

Figure 3-1: Share of Major Countries/Regions in Global Manufacturing Value Added

It is believed that the US is moving toward a policy of opposition to China because it is concerned that "Made in China 2025," which also sets forth a policy of military-civilian integration, poses a security threat and that it will cede control of advanced technology to Chinese companies equipped with next-generation technology.

China, wishing to avoid a decisive confrontation with the US, has been forced to go quiet about "Made in China 2025." Since late 2018, the term "Made in China 2025" has not been seen in Chinese policy texts.

[38] https://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/robot_honbun_150210.pdf

3.2.2 The 13.5 Intelligent Manufacturing Plan and the 14.5 Intelligent Manufacturing Development Plan

Advanced nations and regions such as Japan, the US and Europe went through a gradual process of establishing production infrastructure and automating and computerizing their production systems at every level, and have reached the stage of promoting smart manufacturing. In contrast, China, having not been through the process of upgrading (automating, computerizing) its production bases and systems, needed to simultaneously move forward with the traditional processes of upgrading, automation, and informatization of its manufacturing industry. Therefore, China's policies, management strategies, and methodologies for smart manufacturing will naturally require different mechanisms than those of Japan, the US, and Europe.

China also had a sense of crisis that if it followed the process of manufacturing improvements of the developed countries - physical production infrastructure, automation, information technology, and smart manufacturing - it would forever fall behind those countries. Therefore, the idea that arose was to shorten the development process for smart manufacturing by taking advantage of the country's own strengths, such as internet technology and digital innovation, which are as advanced as those of developed countries.

In fact, after the promulgation of "Made in China 2025" (May 2015), policy guidelines were issued for the "Progress toward Developing Integration between Manufacturing and the Internet" (May 2016) to encourage the integration of internet and manufacturing technologies. Subsequently, apart from the "13th Five-Year Plan," a manufacturing development plan (promulgated in December 2016) was set and dedicated to smart manufacturing; this was called the "Intelligent Manufacturing Development Plan" (2016–2020). The main contents of this "Intelligent Manufacturing Development Plan," summarized in Table 3-1, centered on the development of smart manufacturing infrastructure (hardware, software, standards, etc.) and the promotion of informatization of the manufacturing industry (called "digitized manufacturing" in Chinese).

Table 3-1: Key Targets of the Intelligent Manufacturing Development Plan (2016–2020)

Development goal	(1) By 2020, strengthen the foundation and support capabilities as well as achieve digital manufacturing in priority areas. (2) By 2025, support systems will be established. Key industries will be in the initial stages of transitioning to a new level of expertise.

Key KPIs	• Developed 60 types of technical equipment to satisfy 50% of the domestic market • Development of informatization software, such as CAX, MES, ERP, CRM, etc., constituting 30% of the domestic market • Established or revised over 200 standards on intelligence manufacturing, 100 POC platforms, and 100 public service PF 50 or more. Cultivate 40 IT service vendors with sales of 1 billion yuan (20 billion yen) or more • Over 300 model projects have been promoted, and over 150 excellent projects have been selected from these projects to become role models. Make it look like *KPIs: (1) 20% cost reduction; (2) 20% reduction in product development time; (3) 20% increase in productivity; and (4) 10% reduction in defective product rate; (5) 10% increase in energy use efficiency. • Industrial Internet (IPv6, 4G/5G, WiFi, RFID, related hardware and software) • Encouragement of foreign investment (R&D, human resources training, model factories) in intelligent manufacturing; encouragement of foreign M&A and investment.

Source: Summarized and prepared by the author, based on the Intelligent Manufacturing Development Plan (2016–2020)[39]

Then, in December 2021, coupled with the start of the "14th Five-Year Plan," the "145" Intelligent Manufacturing Development Plan (2021–2025)[40] was enacted. The said plan mainly targets full-scale smart manufacturing, including high-end, intelligent, and green manufacturing infrastructure and systems. Specific goals and established KPIs (Key Performance Indicators) can be summarized as shown in

Table 3-2.

Comparing the goals and KPIs set in the first phase of the "Intelligent Manufacturing Development Plan" (2016–2020) and the second phase of the "145" Intelligent Manufacturing Development Plan (2021–2025), the first phase focused on the infrastructure (hardware, software, standards, etc.) and model development necessary to promote smart manufacturing. The second phase focuses on more advanced technologies, high-end products, maturity assessment, and the spread of smart manufacturing. Externally, while the first phase targeted foreign investment and technology introduction, the second phase aims to send domestically established and matured smart manufacturing-related technologies, products, and systems to overseas markets, along with introducing more advanced technologies.

However, the rationale and estimation methods used were not disclosed for the numerical targets (challenges) indicated by the two smart manufacturing-related plans mentioned above, as they were with the targets set in "Made in China 2025." From a market economy perspective, I believe that apart from qualitative goals, specific KPI indicators are ambitious and "reckless" goals. In addition, China has so far set the challenge of its domestic production rate out of fear of being " 卡脖子 " (bottlenecked) by unilateral sanctions and export restrictions to China, which may be criticized as not consistent with the spirit of the WTO.

39 http://www.gov.cn/xinwen/2016-12/09/content_5145438.htm
40 http://www.gov.cn/zhengce/zhengceku/2021-12/28/content_5664996.htm

Table 3-2: Key Targets of the "145" Intelligent Manufacturing Development Plan (2021–2025)

Development goal	(1) By 2025, larger manufacturers (70%) will be digitized and networked; key businesses of core industries will transition to rudimentary smart manufacturing (2) By 2035, full penetration of digitalization and networking in larger manufacturers; key businesses of core industries will transition to basic smart manufacturing
Specific KPI	• Establish over 500 model factories for smart manufacturing and evaluate its level of maturation • Supply capacity: Market satisfaction rate (equipment 70%, software 50%); foster 150 highly capable IT vendors • Establish more than 200 standards and develop 120 influential industrial Internet platforms • Special Activities: (1) Smart manufacturing technology (Digital Twin, Edge-Computing, SI technology, etc.), (2) " 卡脖子 " (bottleneck) equipment and software, new types of smart manufacturing equipment (5G, Beidou, Ei, Star Internet, cooperative robots, etc.), (3) Industrial software (conventional software, cloud-native software), (4) Standards and international cooperation (Germany, Japan, UK) • Encourage foreign investment (R&D, human resource development, model factories) (continue); utilize One Belt One Road, BRICS, RCEP, etc. Encourage the internationalization of equipment, software, standards, and solutions related to intelligent manufacturing.

Source: Compiled and prepared by the author based on the "145" Intelligent Manufacturing Development Plan (2021–2025)[41]

3.3 Developing a Digital Infrastructure for Manufacturing: IIoT Action Plan

Smart manufacturing as described above can be understood as a futuristic production method or production system brought about by the digital transformation of the manufacturing industry. This smart manufacturing is supported by physical production technology and the industrial internet, which handles data assets. The Industrial Internet is a digital infrastructure with a series of functions such as data acquisition, transmission, storage, and computation in a network for industry. In developed countries such as Japan, the US, and Europe, the Industrial Internet generally refers to the IIoT (Industrial Internet of Things).

Table 3-1 shows that China’s plan for the development of intelligent manufacturing already includes the development of an industrial internet. However, in light of the fact that China has a well-developed internet for consumers but a lagging network infrastructure for industry, it has launched a stand-alone industrial internet action plan.

41 http://www.gov.cn/zhengce/zhengceku/2021-12/28/content_5664996.htm

In November 2017, the Chinese government promulgated a policy guideline, Guiding Opinions on Deepening the "Internet + Advanced Manufacturing Industry" to Develop the Industrial Internet,[42] setting out broad development targets with three checkpoints by 2025, 2035 and around 2050. However, specific initiatives are described in the "Industrial Internet Development Action Plan (2018–2020)" (promulgated in May 2018)[43] and the "Industrial Internet Innovation and Development Action Plan (2021–2023)" (promulgated in December 2020).[44]

According to the abovementioned Guiding Opinions, the goal is to develop an advanced network infrastructure to support a "manufacturing powerhouse" and a "network powerhouse," with infrastructure development basically completed by 2025, and international advanced infrastructure and platforms completed by 2035, reaching a world-leading level around 2050.

The "Industrial Internet Development Action Plan (2018–2020)" action plans were developed to 1) establish a network system (development of a physical network infrastructure, development of a label analysis system for ID data verification/matching, and establishment of data standardization and unified modeling to enable members of the industrial ecosystem to understand each other), 2) establish an industrial internet platform (a place for data aggregation, modeling and analysis, knowledge reuse, and application innovation), and the establishment of an industrial internet safety system. This three-year action plan played a role in laying the groundwork for the industrial internet.

The "Industrial Internet Innovation and Development Action Plan (2021–2023)" further developed the foundation established by the abovementioned three-year actions and shift the emphasis to the utilization and implementation of the industrial internet. Some examples include the digitization of existing facilities (conversion of incompetent facilities to IP; intercommunication between different structures, standards, and protocols; existing internal networks and new networks; integration between IT and OT networks, etc.), integration and flattening of enterprise networks, introduction of Chinese local 5G and development of full 5G connected factories, acceleration of the development of regional-level label analysis centers, construction of industrial data centers (IIDCs) and promotion of data utilization, and promotion of the shift to cloud computing for facilities and business systems.

3.3.1 Development and Challenges of Intelligent Manufacturing

Around seven years have passed since the publication of "Made in China 2025." As noted above, the "Made in China 2025" flag has been lowered, but the core of the policy, including the smart manufacturing described in this paper, has been subdivided and implementation activities have been unfolding. However, the enactment of policies will be nothing but a "storybook" if it does not lead to advancement in the areas covered by the policies (the manufacturing industry in this paper), increased added value, and greater competitiveness. In this sense, policies need to be adjusted flexibly in response to the results of interim and project evaluations and changes in the economic and social environment.

The various action plans mentioned above are evaluated after the fact to a certain extent. In addition, in

[42] http://www.gov.cn/zhengce/content/2017-11/27/content_5242582.htm
[43] http://cppcc.china.com.cn/2018-11/30/content_72932131.htm
[44] http://www.gov.cn/zhengce/zhengceku/2021-01/13/content_5579519.htm

October 2020, China's standardization agency[45] established two national standards for smart manufacturing, the "Intelligent Manufacturing Capability Maturity Model" and the "Intelligent Manufacturing Capability Maturity Assessment Method," which went into effect on May 1, 2021. Self-assessments based on these two criteria have also been conducted. In addition, structural changes in the manufacturing sector have been assessed at the macro level ("Manufacturing Powerhouse Development Index") on an ongoing quantitative basis since 2015. However, while micro-level companies often require quantitative evaluation in terms of return on investment, the effects of smart manufacturing or digital transformation (DX) will be evaluated with a time lag of several years as an upfront investment.

Below, we will examine the status of smart manufacturing development and challenges from the perspective of policy effectiveness and independent assessment of smart manufacturing maturity.

3.3.2 Evaluation of the Intelligent Manufacturing Test Model Project

China's Ministry of Industry and Information Technology selected 305 pilot model projects to test the implementation of intelligent manufacturing over the four years from 2015–2018. The following performance indicators were obtained before and after implementation.[46]

- Production Efficiency Average increase of 37.6%, maximum increase of 200%
- Energy use efficiency: 16.1% increase on average, maximum increase of 25%
- Operating costs: 21.2% reduction on average
- Product development time: reduced by 30.8% on average
- Product defect rate: 25.6% reduction on average

In addition, the 305 test model projects span 92 industries, including process and discrete industries. Project investment, including government subsidies and private investment, amounted to approximately 100 billion yuan (equivalent to about US$15 billion). Incidentally, the outcomes obtained from the project implementation described above have not translated into economic benefits, so a return on investment evaluation is not possible.

In addition, information on whether or not the 2019–2020 Intelligent Manufacturing Pilot Model Project was implemented at the central government level, how many projects were implemented, and how they were evaluated is not publicly available and cannot be evaluated in this paper.

On the other hand, in the second phase of the "145" Intelligent Manufacturing Development Plan (2021–2025), which focuses on the spread of smart manufacturing, model factories (role models for intelligent manufacturing) and excellent use cases for intelligent manufacturing were selected in February 2022 for the year 2021.

In contrast to the first phase project, which was more of a Proof of Concept (PoC), the second phase project was designed to promote the implementation of the intelligent manufacturing system by encouraging horizontal development within the company and the transfer of technology and models to other companies. In addition, the condition for selection is stipulated as "Level 2" or higher in intelligence manufacturing capability maturity level, which is described below. In other words, even though a company

45 State 标准化管理委员会 http://www.sac.gov.cn/
46 http://industry.people.com.cn/n1/2018/1212/c413883-30461080.html

may be a role model, it can be a model case if it has excellent impact on the digital transformation of certain business activities, even if it is not a company-wide transformation.

Since the 2021 project has just started and the maintenance period is stipulated to be two years, it will not be possible to evaluate the project until the end of 2023 at the earliest.

3.3.3 Independent Assessment of Smart Manufacturing Maturity: Intelligent Manufacturing in the Early Stages

The organizations responsible for establishing and implementing the aforementioned smart manufacturing-related standards conducted two independent diagnoses and evaluations through the "Intelligent Manufacturing Diagnostic and Evaluation Public Service Platform" in January 2021 (over 12,000 participating companies) and December 2021 (20,000 participating companies).

China's national standards define five maturity levels, as follows.

Level 1 (Planning Level): The company can plan the foundations and conditions for implementing intelligent manufacturing and process management of core business activities (design, production, logistics, sales, and service).

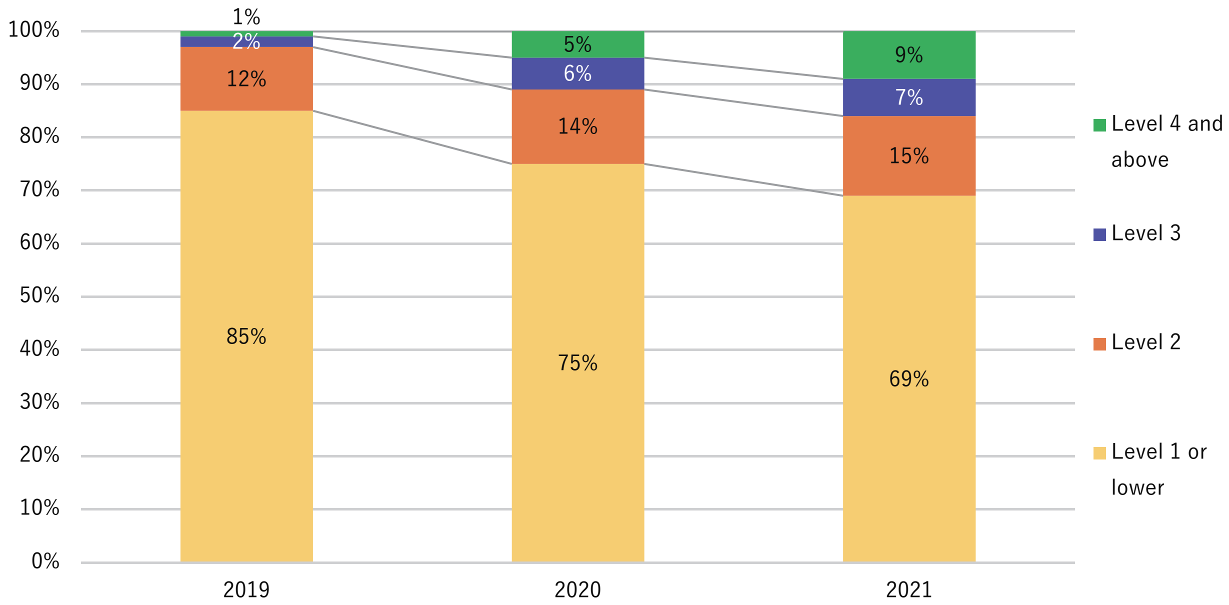
Level 2 (Standard Level): The company uses automation and information technology to modify and standardize core equipment and core business activities, etc., to implement data sharing of individual business activities.

Level 3 (Integration Level): The company provides integration for equipment, systems, etc., to share data between business activities.

Level 4 (Optimization Level): The company performs data mining on personnel, resources, manufacturing, etc. to build knowledge, modeling, etc. to accurately predict and optimize core business activities.

Level 5 (Leader Level): Based on modeling, the company continuously optimizes and innovates its business activities, achieves collaboration in the industrial chain, and at the same time derives new production methods and business models.

The indicators for assessing maturity level consist of four major indicators, 12 medium indicators, and 13 minor indicators (excluding overlap with the medium indicators). Companies are allowed to increase or decrease the number of indicators in their self-assessment according to the characteristics of their operations.



Source: Prepared by the author based on "China Intelligent Manufacturing Development Index Report 2021," China Institute of Electronics Technology Standardization (March 2022).

Figure 3-2: Trends in Results of Independent Assessment of China's Intelligent Manufacturing Capability Maturity Level

The results of the most recent three-year independent assessment of the maturity level of the intelligence manufacturing capacity are as shown in Figure 3-2. The number of companies (in 2021, "Level 1 or below" + "Level 2") whose intelligent manufacturing remains at the planning level or only applies to individual business activities has reached 84% of the total (about 20,000 companies). In China, smart manufacturing efforts are underway, but are still in the early stages. According to data from Japan's Ministry of Economy, Trade and Industry, about 95% (in 2020) of companies, not just those in the manufacturing industry, have not started or are only implementing in one sector, similar to China's 89% (in 2020, Level 2 or below).[47]

3.3.4 Challenges in Promoting Intelligent Manufacturing

As mentioned earlier, nearly seven years have already passed since the enactment of "Made in China 2025," with intelligent manufacturing at its core, but it has not yet reached its ideals. While industry's understanding has progressed, and it has implemented a number of government-led model cases, efforts (implementation) in the manufacturing industry as a whole are still in the early stages.

So, why is it that companies understand the utility of intelligent manufacturing, but are hesitant to actually invest in and implement it? In the author's view, the following are the challenges in China, and the challenges they share with the rest of the world.

Challenges in Promoting Intelligent Manufacturing in China

1) First, there is an imbalance between external and internal DX. Areas of digitization that Chinese companies are focusing on are customer engagement, consumer and customer data-driven DX, and

[47] Ministry of Economy, Trade and Industry (December 2020) "DX Report 2 (Interim Summary)"

externally driven digitization, such as an emphasis on e-commerce (EC).[48] Despite the government's emphasis, digitization of production facilities will likely be an afterthought. In China, it can be said that there is no choice but to respond to the current situation where consumers are becoming increasingly digitalized.

2) It is difficult to expect investment returns. Chinese company managers tend to expect short-term earnings rather than long-term management, and SMEs are especially hesitant to invest if they cannot recover their investment in three to four years.[49] In fact, Accenture, one of the world's leading consulting firms, also noted from its survey of local companies that the difficulty of securing ongoing investment in digital transformation is one of the three major challenges for Chinese companies, since digital transformation investments are long-term, systemic efforts that do not immediately generate revenue.[50]
3) There are no organizations within companies that are tasked with the strategic planning and promotion of intelligent manufacturing. This work is handled on a case-by-case basis. Similarly, the Accenture survey mentioned above also cites the lack of strategy by Chinese companies in digital transformation as one of the three major challenges.
4) There are not enough of the human resources needed for intelligent manufacturing. For example, there is not enough talent to create algorithms that fit companies' business. This is also one of the three major challenges that the above Accenture study identified: the lack of talent in Chinese companies with regards to digital transformation.
5) The majority of equipment such as smart machining tools related to intelligent manufacturing and software such as MES (Manufacturing Execution Systems) for factory systems and ERP (Enterprise Resource Planning) for enterprise systems are dependent on foreign capital and are difficult to attain for companies with low profit margins to begin with. This would be a challenge that falls into the same category as 2) lack of profitability.
6) Promotion of intelligent manufacturing requires organizational restructuring, but is often met with resistance from traditional management.

The above 1) and 2) are Chinese issues, while items 3) through 6) are common globally.

3.4 Case Examples of Chinese Intelligent Manufacturing Role Model Companies Evaluated by the World Economic Forum

When conducting case studies of intelligent manufacturing role models, as mentioned above, the Chinese government selected companies that were at Level 2 or above in their intelligent manufacturing capability maturity level. Furthermore, detailed data, such as selected use cases and impact data were not published, so there is a lack of information. Another aspect is the difficulty of international comparisons based on uniform standards.

48 Prophet (2019) "The Next Chapter of Digital Transformation in China."
49 Huang, Pei (2019) "Seven Challenges and Six Measures to Promote Intelligent Manufacturing!"
50 Accenture (2021) "China Digital Transformation Index 2021."

Fortunately, the World Economic Forum (WEF) has been focusing on the transformation of the manufacturing industry through next-generation digital technologies (Fourth Industrial Revolution technologies) since the 2010s. In light of the situation in which DX in the manufacturing industry has not progressed well, starting in 2018, the Global Lighthouse Network,[51] which selects the world's leading DX companies, was been established in collaboration with McKinsey & Company (USA) to publish global role models (case studies) of manufacturing DX on a global scale. As of January 2023, 132 Global Lighthouse locations (companies) have been certified from more than 1,000 candidates in the global manufacturing industry.

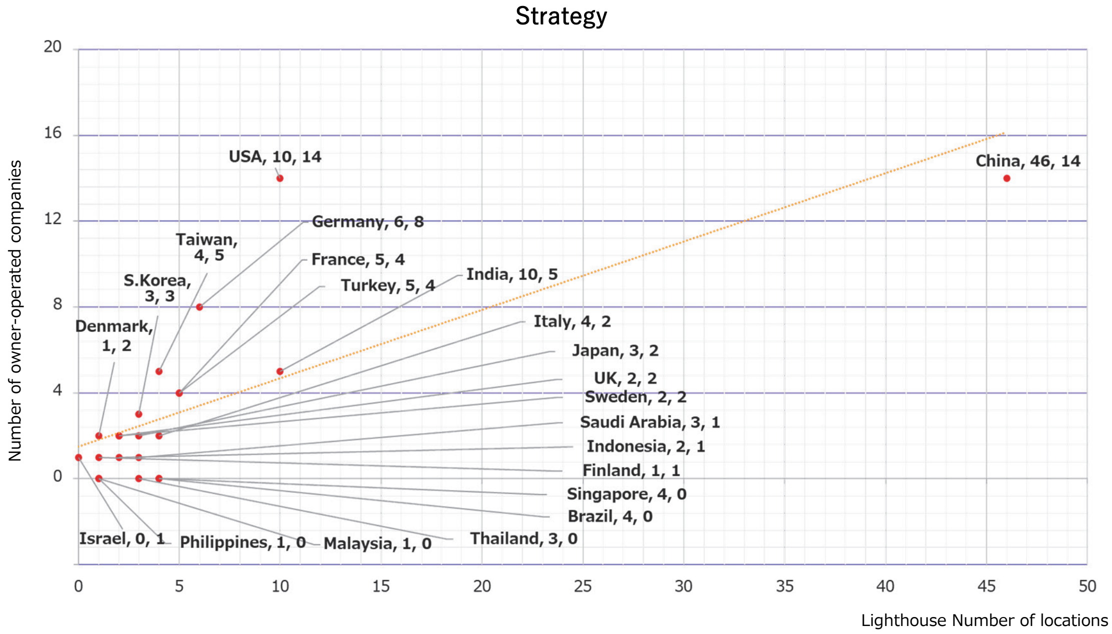
Below is a case study of a Chinese company selected as a WEF Global Lighthouse.

3.4.1 Positioning of Chinese Companies as WEF Lighthouses

As noted above, as of January 2023, there were 132 lighthouses evaluated by the WEF. Figure 3-3 shows that there are 46 light houses (companies) operating in China, with 14 of these being owner-operated companies (with one to several locations). In terms of the number of owner-operated firms, China was tied with 14 US firms. Incidentally, the number of locations in Japan is three (companies) and the number of lighthouse owner companies is two.

Of the 46 light houses in China, 26 were established by local Chinese companies, while the rest were established by foreign companies, including Taiwanese companies. It is particularly important to emphasize that Western multinationals have a global presence, compared to Chinese lighthouse owner-operated companies, which basically stop at establishing domestic bases in China. This is probably because the global expansion of Chinese-owned companies is still in its early stages. However, the fact that Western multinationals are developing advanced intelligent manufacturing bases in China can be understood as a model case for Chinese companies to study in a positive way and encourage the spread of this technology in China.

[51] https://jp.weforum.org/projects/global_lighthouse_network



Source: WEF (January 2023)

Figure 3-3: Number of WEF Lighthouse owner companies and locations in major countries and regions

3.4.2 Example of a lighthouse in China (in a factory): CATL Aims for "Extreme Manufacturing"

The WEF certifies both digital transformation (four-wall factory lighthouses) types within company factories, which correspond to so-called smart factories, and end-to-end (E2E) types of lighthouses that reach the entire value chain, as it were, arriving at customers and users. While most of the factory lighthouses were of the in-factory type at the start of the 2018 certification period, the number of E2E types has been increasing in recent years.

In addition, as mentioned above, many companies are still stuck in PoC and unable to scale up. In this sense, the initiatives of the world's top EV battery manufacturer CATL (Contemporary Amperex Technology Co., Limited), chosen as a WEF Lighthouse, are a great reference point.

CATL's approach to smart manufacturing was an orthodox three-step approach.[52]

First, there was a phase (2011–2013) in which they began to automate processes. Through this phase, CATL was able to rapidly increase its level of automation, including equipment automation, production line automation, logistics automation, and warehouse automation, while accumulating expertise in manufacturing process improvement and forming an ecosystem with its supplier equipment manufacturers.

Next was the automation and digitalization phase (2014–2017). SAP's ERP (Enterprise Resource Planning: a system common to all departments), CRM (Customer Relationship Management), SRM (Supplier Relationship Management), PLM (Product Lifecycle Management), and other information systems were

[52] High Tech (2021) "CATL 如何让智能制造落地 ?"

introduced all at the same time. During this phase, CATL also began building a big data platform, building IIoT systems, and deploying a hybrid cloud. They promoted informatization and the use of next-generation digital technology in parallel.

The third phase is the "smart" phase (2017-present). During this phase, the company began work on data management analysis, including data management, data applications, data analysis, and starting in on the real optimization of the production line, which played a major role in the production process.

CAL was recognized by the Ministry of Industry and Information Technology of China as a model enterprise for intelligent manufacturing in 2019 for the above efforts, and in 2021 it was recognized as a national "Next Generation Digital Technology and Manufacturing Industry Integration Development Model" policy project.

On the other hand, what was noteworthy about CATL's efforts in smart manufacturing was the concept of "extreme manufacturing" in 2020. This was an effort to improve the defect rate of car batteries from ppm (parts per million) to ppb (parts per billion) and to bring safety performance from 6 sigma to closer to 9 sigma. In addition, CATL's sustainability efforts did not stop at improving productivity and quality, but also included the creation of a resource and energy management platform that includes such areas as the mining of raw materials, manufacturing, materials, and recycling related to batteries.

The WEF greatly appreciated CATL's performance, citing both productivity and sustainability, and awarded it the honor of Global Lighthouse (manufacturing site location: Ningde, Fujian Province) in September 2021. The WEF highly praised the company: "Faced with increasing complexity and high quality in its manufacturing processes, CATL leveraged AI, advanced analytics and edge/cloud computing to achieve a defect rate of 1 in 1 billion, and a rate of 1.7 seconds per cell in three years, while increasing labor productivity by 75% and reducing energy consumption by 10%."[53]

Of course, CATL's performance on smart manufacturing does not stop with the above WEF assessment. For example, WEF-accredited lighthouses have created roughly 20–40 use cases, but the performance of the top five cases is publicly available (Table 3-3). The top 5 use cases for CATL are as follows.

Table 3-3: Overview of CATL's Top 5 Use Cases

	Use case	Impact (KPI)	Quantitative evaluation
1	AI-based process control	Labor productivity	75% improvement
2	AI-based optical inspection	Defect rate of 1 in 1 billion	80% reduction
3	Big data/AI-enabled product design and testing	R&D Cycle	50% reduction
4	Digital tracking	Manpower for screening tests	80% reduction
5	Aggregation of real data from sensors via IIoT for energy, emissions, waste, and water management	Annual energy consumption	10% reduction

Source: Prepared by the author based on WEF (September 2021)

[53] WEF (September 2021) "Global Lighthouse Network: Unlocking Sustainability Through 4IR"

CATL's efforts continue. A second lighthouse (in Yibin, Sichuan Province) was certified by the WEF in October 2022. The WEF assessed, "To keep pace with significant business growth and higher quality and sustainability expectations, CATL has further deployed in-depth AI, IIoT, and flexible automation at the plant it built in Yibin, in addition to the Lighthouse Digital Initiative at its Ningde headquarters, to increase line speed by 17%, reduce yield losses by 14%, and achieve zero carbon emissions." CATL's approach to smart manufacturing has entered a new phase.

Currently, CATL has established 13 production sites worldwide, including sites in Germany and Hungary, and is looking to build on the experience of the first lighthouse mentioned above to expand horizontally to other sites and scale up. Such a large scale-up is consistent with the purpose of the WEF's Global Lighthouse initiative.

3.4.3 China Lighthouse Case Study (E2E): Alibaba Aiming to Establish a C2M Manufacturing Model

As mentioned earlier, the areas of digitization that Chinese companies, especially consumer-facing companies, focus on are characterized as customer engagement and DX driven by consumer and customer data. As it stands, E2E lighthouses make up the majority of global lighthouses in China. For example, home appliance makers Haier and Midea have six and five certified lighthouses, respectively, along with US-based P&G and UK-based Unilever, both general consumer goods manufacturers, with six each.

This section will present a case study of Alibaba, an e-commerce platform IT vendor that aims to create a new manufacturing business model (C2M) that connects consumers and manufacturing sites from a consumer-driven perspective by leveraging its superior know-how in consumer insights. In September 2020, Alibaba's new manufacturing base was also recognized by the WEF as a Global Lighthouse. The WEF said in assessing the plant, "By combining powerful digital technology with consumer insights, Alibaba's pilot XUNXI factory (Hangzhou, Zhejiang Province) has brought to life a new, fully digital manufacturing model. This enables E2E on-demand production based on consumer needs, allowing small companies to compete in the rapidly changing fashion and apparel market by reducing delivery times by 75% and the need to hold inventory by 30%. It also reduces water consumption by 50%."

Figure 3-4 is a conceptual summary of the functions of the XUNXI system. Fundamentally, the system is designed to 1) help SMEs better understand customer preferences for fashion trends and stay competitive in the fast-paced fashion and apparel market through consumer intelligence that leverages Alibaba's high-level digital technology and consumer insights from various platforms across the Alibaba ecosystem, 2) conduct product development that is informed by development needs, supply chain conditions, and manufacturing schedules, while optimized design leverages an extensive libraries of patterns, AI maximizes durability, and products are optimized to suit manufacturing resources regarding employee capabilities and machine availability, and 3) in the manufacturing phase, facilitate the ability to produce smaller quantities and at the same time strategically utilize operators and resources through auto-configuration and risk assessment using digital simulation.

Consumer Intelligence

The preferences expressed by consumers on social media, processed by sophisticated analytical algorithms are used in product development and manufacturing.
Provide input to the process

Product Development

Tailored development of products that effectively match customer preferences

Automated development platform

Development needs based on customer demand, supply chain purchasing, and manufacturing schedules

Optimized product design

Related patterns recommended directly based on extensive libraries. Durability of the final design guaranteed by computer vision AI

Customized product requirements

Product requirements that match employee skill levels, machine availability, and craftsmanship requirements

Manufacture

Immediate and small lot production with fast and flexible manufacturer

Auto-automated product configuration

Operator skills matrix, resource availability, digital production simulation, and potential risks
Strategies for the management of the asset based on evaluation

Dynamic line balancing

Real-time workstation load balancing based on resident production data and simulation

Online quality inspection

Online quality inspection system for instant detection and control of quality problems

Source: Prepared by the author based on WEF (September 2020)

Figure 3-4: Conceptual diagram of Alibaba's case example concerning agility and customer centricity

To make the XUNXI system work and achieve the objectives of intelligent manufacturing, Alibaba also employs a number of use cases. The published top five use cases, the KPIs to be set and the quantitative evaluation are as seen in Table 3-4.

Table 3-4: Summary of TOP 5 Use Cases for Alibaba (XUNXI)

	Use case	Impact (KPI)	Quantitative evaluation
1	Market forecasting and demand forecasting	Sales rate	40% increase
2	AI-supported product design and testing	Product development lead time	66% reduction
3	Optimized production planning based on high-level analysis	Production lead time	75% advance
4	E2E automated internal logistics	Warehouse worker efficiency	300% improvement

5	Flexible manufacturing with digital support	Lowest volume of Smallest order volume compared to industry average relative to industry average	98% reduction

Source: Prepared by the author according to WEF (September 2020)

XUNXI's model factory, Xiniu Zhizao, began operations in September 2020. The company has already started providing services to more than 200 emerging brands, with a minimum order of 100 and delivery time of seven days. Alibaba aims to provide cloud production capabilities that offer on-demand production infrastructure to third parties, the same as ordinary cloud services.[54] In addition, as of February 2022, Xiniu Zhizao has already developed cooperative relationships with more than 300 companies.[55] The Chinese government has also selected the XUNXI plant, which has become a lighthouse, as a model for E2E-type intelligent manufacturing for its popularization project.

3.5 Summary and Recommendations: Characteristics from the Perspective of Chinese Lighthouse, and Implications for Japanese Companies

The 22 Chinese lighthouses accredited by the aforementioned WEF have the following overarching characteristics.

(1) Expanding range of industries, but none related to pharmaceuticals

Chinese lighthouse industries include home appliances, electronics, industrial machinery, steel, IT, consumer goods, and EV batteries. However, no pharmaceutical companies are included.

(2) Horizontal deployment of proven effective cases within the company

Leading companies are not stopping at making individual sites smarter, but are scaling up the effects by horizontally deploying proven use cases and know-how. For example, SANY, which is also continuously certified as a lighthouse, has been horizontally deploying innovative and standardized technological solutions in more than 20 plants.

(3) Currently limited to China, with plans to expand horizontally to overseas locations

Many Chinese lighthouse owners limit themselves to China. However, some owners, like CATL, are scaling up to overseas locations.

(4) Provision of own best practice know-how as a service to external parties

Case study examples Alibaba (one lighthouse) and Midea (five lighthouses), as well as Haier (six) and SANY (two) have established technology transfer subsidiaries or centers to provide know-how

[54] https://www.xiniuim.com/home
[55] http://m.ccidnet.com/pcarticle/10581947

and solutions to external parties. This is useful to break out of the PoC trap in promoting intelligent manufacturing.

As discussed above, China is aiming to become a "manufacturing powerhouse" by swiftly enacting a series of industrial policies, such as "Made in China 2025," with intelligent manufacturing at their core. This has been stimulated by industrial upgrading and the digital transformation initiatives (e.g., Industry 4.0) in the manufacturing industry in the West. On the other hand, with the spread of the internet, the internet industry and digital innovation are advancing rapidly, and the country has also set its sights on becoming an "internet powerhouse." Intelligent manufacturing is a field that embodies the "manufacturing powerhouse" and "network powerhouse" concepts. However, government-led industrial policies have not been as effective as expected, and intelligent manufacturing is still in its infancy.

On the other hand, some leading manufacturing companies are exploring and boldly taking up the challenge of intelligent manufacturing. The aforementioned WEF-accredited lighthouses are representative and will set the direction of China's intelligent manufacturing. In addition, the activities of these local centers and foreign-funded centers are intermingling, creating the ecosystem that is necessary for the promotion of intelligent manufacturing in China.

Japanese manufacturers are considered to be more advanced than their Chinese counterparts in terms of sophistication of production systems, especially in streamlining production processes, automating processes, and informatizing business management. However, some aspects of the digitalization of society, especially digital consumption, may be lagging behind that of China. Therefore, productivity inside the companies is quite advanced, and the degree of pressure from the consumption side is considered weaker than in China. There is also the aspect that the return on investment of digital transformation is difficult to gauge in the early stages, and there is a strong possibility that PoC fatigue has set in. The effect of the recent depreciation of the yen may further dilute the incentive to promote smart manufacturing.

The implications for the Japanese manufacturing industry based on an analysis of China's lighthouses are as follows: (1) companies with advanced DX should promote horizontal development at their own manufacturing bases, including overseas bases, and (2) advanced companies should participate in the WEF's global lighthouse ecosystem to develop their own know-how into globally applicable use cases or technology solutions, and then provide them as services to other companies. If (1) and (2) can bring out the scaling-up and network effects of smart manufacturing, this will accelerate the spread of manufacturing DX in Japan. We have high expectations for the future.

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4 China's Automotive Industry Becoming a "Manufacturing Powerhouse"

4.1 Introduction

"Made in China 2025," promulgated in 2015, was positioned as an action plan for a manufacturing powerhouse strategy for the following decade. In this context, the gap between developed countries and China's manufacturing sector is still large, and this particular sector in China is "large but not strong." China's automotive industry was a perfect example of an industry that was large but not strong. In terms of numbers of automobiles produced, China overtook the US in 2008 and Japan in 2009 to become the world's top producer, and although production has declined somewhat since reaching 29.02 million vehicles per year in 2017, production in 2021 (26.08 million vehicles) was far ahead of the US (9.17 million vehicles) and Japan (7.85 million vehicles). However, when it comes to export volume, this number hovered at around 1 million units per year from 2012 to 2020. Imports were also around 1 million units per year, so net exports minus imports were negligible. The "Medium- and Long-Term Development Plan for the Automotive Industry" promulgated by the Chinese government in 2017[56] also notes that "the situation of a large but not strong automotive industry remains serious."

In 2021, however, the number of automobiles exported quickly expanded to 2.14 million units. Another 2.1 million units were exported in the January-September period of 2022, and if this momentum continues through the end of the year, it is likely to exceed 3 million units in 2022. This would still trail Japan (4.82 million units exported in 2019) and France (5.61 million units), but surpass South Korea (2.4 million units) and Spain (2.31 million units), and approach the level of Germany (3.7 million units) and the United States (3.19 million units).[57] As far as exports are concerned, China seems to have made a leap forward to become an automotive industry powerhouse in one fell swoop. This paper will analyze how such a leap became possible.

First, Section 4.2 analyzes data on auto exports and traces export efforts since the 2000s. Section 4.3 then clarifies the inner workings of the auto export leap after 2021. The leap forward in 2021 occurred as China's automotive industry seized the tailwind of the global shift to electric vehicles (EV), building on the export efforts made since the 2000s.

Section 4.4 will take stock of the current situation in which China's automotive industry has gained a competitive edge in EVs and briefly summarize why.

Section 4.5 will discuss the current status of self-driving vehicles, which is likely to increase the competitiveness of China's automotive industry in the future.

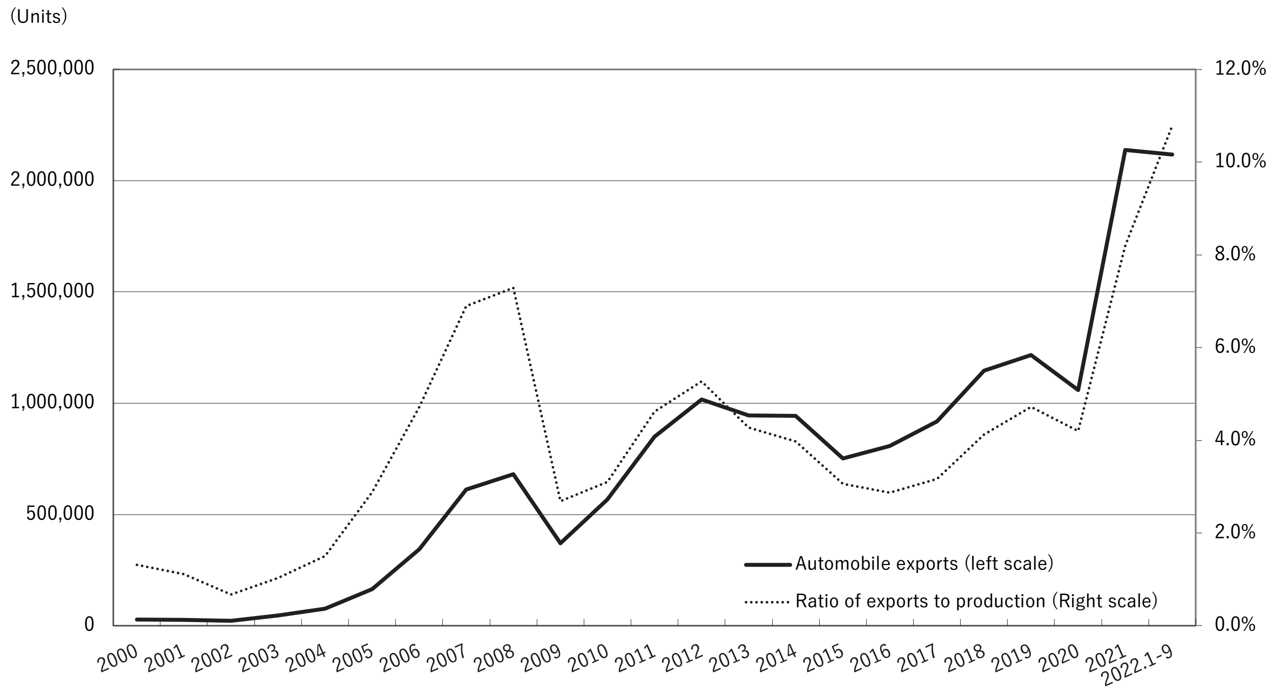
[56] 汽车产业中长期发展规划 ; http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5600356/content.html

[57] Export figures for each country are based on information from the Japan Automobile Manufacturers Association (JAMA) website. Although 2020 figures are also available, the same year saw a drop in exports due to the global COVID-19 pandemic, so comparisons were made with 2019 figures.

4.2 Rapid Increase in Automobile Exports

4.2.1 Background

Until it joined the World Trade Organization (WTO) in 2001, China protected its domestic automotive industry with import volume restrictions and import tariffs of over 80% on passenger cars. The competitiveness of China's automotive industry was weak, and it was only exporting trucks and other vehicles to developing countries at a scale of about 10,000 to 27,000 units per year. It was thought that the poor competitiveness of the automotive industry would be severely damaged by WTO membership (Lee et al., 2000), but when all was said and done, automotive production increased more than fourfold between 2000 and 2007. More surprisingly, automobile exports began to grow in 2003 (Figure 4-1). Exports grew from 26,000 units in 2001 to 612,000 units in 2007 and 681,000 units in 2008, accounting for 6.9% and 7.3% of domestic production, respectively. The increase in exports during this period will be referred to in this paper as the first export boom.



Source: China Automotive Industry Yearbook, annual editions, China Association of Automobile Manufacturers

Figure 4-1: China's Automobile Exports

This boom was driven by Chery and Geely, two emerging automakers at the time. Until then, the Chinese automotive industry was dominated by state-owned enterprises such as FAW, Dongfeng Motor, and SAIC, as well as joint ventures established by these and foreign automakers such as Volkswagen (VW), Citroen, and GM. The Chinese government strongly urged joint venture manufacturers to produce parts domestically in order to boost the level of foreign investment in the country's automotive industry. With industrial infrastructure not yet in place and the scale of the automotive industry still quite small, if they were to try to unreasonably increase the rate of domestic production of parts, the production cost of domestic parts would be higher than that of imported parts, and the cars assembled from them would not be affordable enough for export.[58] Therefore, the government attempted to develop the automotive industry by authorizing a limited number of passenger car joint ventures between foreign and state-owned manufacturers, and by robustly fostering these joint ventures. This severely restricted new entrants into passenger car production, and even manufacturers such as Toyota, Nissan, and Ford were not allowed to enter the market in the 1990s. Amid such strict regulations, there were several emerging manufacturers that entered passenger car production through the "back door," so to speak, and one of them was Chery Automobile. The company was founded in 1997 by eight people from Anhui Province who had worked for FAW (Marukawa, 2008). At that time, the Anhui Provincial Government, Wuhu Municipal Government, and others invested in the company, so it is considered a local state-owned enterprise, but in reality it is closer to being privately owned.[59] Chery established a production system by purchasing equipment from Ford's used engine plants, and in order to obtain a license to produce passenger cars, Chery transferred 20% of its shares to SAIC Motor in 2001 at no cost. In other words, the company thought that if it became an affiliate of SAIC Motor, which holds a license to produce passenger cars, the license granted to it by SAIC Motor would be extended to it as an affiliate. In order to create its own original passenger cars, Chery hired a number of foreign automotive engineers, including a Japanese automotive industry alumnus as plant manager, and actively incorporated foreign intellectual resources by commissioning engine design to the Austrian firm AVL and car body design to the Italian firm Pininfarina. Since the start of production in 2000, the company's production volume rose to 100,000 units in 2003 and 310,000 units in 2006, making it a major player in the Chinese passenger car market.

The other emerging manufacturer is Geely Automobile, a privately owned company that began producing passenger cars in 1998, but in order to obtain approval for production, established a joint venture with a state-owned company in Sichuan Province that has a license to produce small buses. As a result, Geely's early vehicles were nominally considered "small buses" despite their passenger car-like appearance (Hyakumoto, 2007). Geely also quickly established a production structure by purchasing engines from a Toyota joint venture, recruiting an alumnus of the Daewoo Motor Company in South Korea to head its design institute, and actively incorporating overseas intellectual resources.

New automakers thus entered the market through the "back door" and obtained official production approval by accumulating production results, but it was not easy to secure sales destinations. In the case of joint ventures between state-owned enterprises and foreign manufacturers, a certain amount of sales can be secured through public sector demand, such as cabs in large cities and official cars for bureaucrats. However, since Chery and Geely are based in the medium-sized cities of Wuhu in Anhui Province and Ningbo in Zhejiang Province, respectively, the local market size is also limited. Therefore, from a very early stage, emerging manufacturers began to export automobiles overseas.

[58] However, the Chinese government also encouraged foreign manufacturers to establish export-only factories. Honda Automobile (China), established by Honda Motor Co. in September 2003, was allowed to be majority-owned (65%) by the foreign capital side (Honda) on the condition that all vehicles produced be exported, and was not required to produce any parts domestically.

[59] As of September 2022, Chery Automobile (Chery Holdings) is owned 27.7% by Wuhu Construction Investment, which is under the Wuhu municipal government; 25.6% by Ruichuan Investment, which is controlled by Chairman Yun Tongyue; and 19.9% by LuxShare, a manufacturer that supplies parts to Apple.

Starting with the export of 100 passenger cars to Syria in 2002, Chery established a knockdown production facility in Iran in 2003 and exported knockdown parts there to be assembled and sold locally. In 2006, the company also established a knockdown production facility in Kaliningrad, Russia, with the cooperation of Avtotor, and began exports to Russia. In 2007, the company exported 120,000 passenger cars, or 31% of its production.

Geely, on the other hand, has also been increasing exports since 2004, when Chairman Li Shu-fu launched a grand goal of exporting two-thirds of its automobile production by 2015. In addition to Syria, other export destinations include Ukraine, Russia, and Venezuela. In 2007, the company exported 29,067 units, or 14% of its production.

Other manufacturers that exported a large number of vehicles as of 2007 were Honda Automobile (China), which has a plant dedicated to exports (see Note 2), with 43,124 units; Hafei, a new manufacturer in the aviation industry, with 34,569 units; and Great Wall Motor, a privately owned SUV manufacturer, with 28,519 units. In other words, exports at that time were not handled by mainstream state-owned manufacturers such as FAW, Dongfeng Motor, and Changan Automobile or their joint ventures with foreign capital, but by many outsiders in the automobile industry.

Emerging manufacturers targeted export destinations outside the developed countries of the automotive industry, such as Europe, the US, Japan, and South Korea, with exports to Russia, Syria, and Ukraine in particular during the first export boom in 2007-08 (Table 4-1). All of these markets have weak foundations for their own automakers and seem to be fertile ground for foreign automakers.

Table 4-1: Major Automotive Export Destinations (2006–12)

(Units)

Counter for years	2006	2007	2008	2009	2010	2011	2012
Russia	38,051	107,791	85,241	*6,985*	*31,017*	*70,837*	*88,536*
Syria	51,662	52,629	32,267	25,157	*32,718*	*25,134*	*668*
Ukraine	10,119	47,091	60,287	*5,167*	*4,877*	*24,263*	*30,542*
South Africa	*6,158*	39,752	25,305	*5,524*	*16,928*	*16,720*	*19,130*
Vietnam	14,491	35,846	52,851	30,732	*30,669*	*21,518*	*13,931*
Algeria	20,201	34,223	44,946	41,407	*43,541*	*80,392*	*148,600*
Iran	10,606	30,675	34,253	13,931	*24,446*	*42,134*	*72,711*
Venezuela	*7,867*	27,029	*11,478*	*1,062*	*339*	*12,679*	*32,097*
Colombia	*7,763*	*14,762*	*10,850*	*3,222*	*12,052*	*23,045*	*31,235*
Egypt	*5,977*	*11,523*	*22,116*	22,336	*28,345*	*26,377*	*34,557*
Chile	*2,366*	*8,732*	*23,924*	*8,929*	*30,492*	*53,250*	*62,437*
Iraq	13,618	*6,836*	*9,157*	19,448	*22,868*	*36,885*	*89,975*
Peru	*598*	*2,640*	*10,611*	*7,716*	*18,536*	*30,275*	*36,803*
Brazil	*91*	*1,401*	*3,202*	*4,141*	*24,804*	*102,622*	*20,959*

Source: *China Automotive Industry Yearbook*, various years; italicized text from UN Comtrade.

UN Comtrade data excludes 870310 from the total of HS8702, 8703, 8704, and 8705. Although the data from the *China Automotive Industry Yearbook* and UN Comtrade generally agree, there are discrepancies of a few hundred units. In this table, the former is used when the former figure is available, and the latter is used when it is not.

As shown in Figure 4-1, automobile exports expanded very rapidly until 2007, but reached a plateau in 2008 and dropped to nearly half of the previous year's level in 2009. In this year, the wave of the global economic recession spread to China's auto export destinations, and in Russia, auto sales fell to less than half of the previous year's level. The number of automobiles exported from China to Russia fell sharply in 2009, down 90% from the previous year. Additionally, exports to Ukraine and Venezuela were also down 90% (Table 4-1).

The sharp decline in exports to Russia may be due in part to the negative growth of the Russian economy in 2009, but it is also said to be due to policy changes by the Russian government and bad publicity about Chinese cars. In 2008, the Russian government tightened model certification for imported vehicles and increased tariffs on knockdown parts (China Automotive Technology Research Center, 2009). In addition, a Russian automobile magazine reported that Chery's passenger cars received the worst scores in crash tests. These reports are also said to have been prompted by local manufacturers in Russia (21st Century Economic Report, August 6, 2008; December 15, 2010). Therefore, Chery decided to shift its export focus to Egypt, Brazil, Algeria, and other countries where local manufacturers are even weaker than in Russia.

4.3 Surge in Exports in Recent Years

After falling in 2009 due to the Lehman shock, China's automobile exports have been recovering rapidly since 2010, exceeding 1 million units for the first time in 2012. In addition to the recovery of exports to Russia, it has gained new import markets in South American countries such as Brazil, Peru, Chile, and Colombia, and Middle Eastern and North African countries such as Algeria, Egypt, Iraq, and Iran (Table 4-1). Emerging manufacturers such as Chery, Geely, and Great Wall Motor led the export expansion.

Table 4-2 summarizes information on export destinations for 2017 and beyond. In addition to the markets that Chinese manufacturers have traditionally cultivated, such as South America, the Middle East/North Africa, and Russia, they have added Bangladesh, India, Mexico, and the Philippines to the list of major export destinations. Furthermore, in 2021, we notice expanded exports to developed countries such as Belgium, the United Kingdom, and the United States. On the other hand, there have been instances of sharp declines in exports to countries that were once major export destinations, such as 665 units to Algeria and 3,089 units to Iran in 2021.

Table 4-2: Major Automotive Export Destinations (2017–21)

(Units)

Counter for years	2017	2018	2019	2020	2021
Chile	62,089	75,177	76,682	56,601	191,249
Saudi Arabia	8,661	20,793	57,790	97,768	132,997
Russia	32,197	18,783	39,304	42,707	122,826
Belgium	11,049	5,615	1,376	18,736	111,712
Mexico	59,866	109,572	113,127	34,782	93,853
Egypt	20,803	43,667	36,466	60,682	87,880
Bangladesh		104,741	146,262	79,793	86,465
United Kingdom		14,224	18,850	26,120	81,169
Philippines	25,483	26,004	42,967	31,431	60,692
Peru	32,581	31,588	41,602	28,415	59,179
India		45,420	83,144	49,515	55,396
America	53,284	67,483	40,017	39,887	54,476
Tai (species of reddish-brown Pacific sea bream, Pagrus major)		1,979	5,801	4,112	48,752
Vietnam	55,192	36,639	35,093	33,904	48,511
Brazil	10,994	21,444	28,042	25,112	47,640
Ecuador	26,231	37,142	34,721	19,200	45,157
Germany		3,975	6,044	12,977	38,162
Belarus		7,562	22,318	20,438	34,104
South Africa	9,100	13,113	16,644	13,815	30,927
Iran	250,324	193,185	2,006	1,841	3,089

Source: China Automobile Dealers Association, "China Automotive Export Analysis 2021," *China Automotive Industry Yearbook* for 2017

Looking at China's auto exports by country, there are many ups and downs. This suggests that in each country's market, Chinese manufacturers' automobiles are marginal, with purchases when the economy improves and extremely low sales when the economy worsens. However, exports have continued to be relatively constant in seven countries: Russia, Chile, Mexico, Bangladesh, Peru, Egypt, and the Philippines.

For example, in Chile, which had the highest export volume in 2021, Chery ranked fifth in sales by brand in 2021, after Chevrolet, Suzuki, Hyundai, and Nissan; MG (SAIC Motor's brand) ranked eighth; Changan Automobile ranked 11th; and Jianghuai Automobile (JAC) ranked 11th. Chinese manufacturers have a particular presence in SUVs, with Chery in first place with a 13.6% market share and MG in third place with 8.2% (Okado, 2022).

On the other hand, in Russia, where Chinese automakers have already made efforts to expand sales for more than 15 years, the top spots achieved in the passenger car sales rankings for 2021 were Haval (Great Wall Motor's SUV) in 11th position (2.4% share) and Chery in 12th (2.4% share) and Geely is in a lowly 15th position. The combined share of all Chinese manufacturers is 7.5%, which is less than that of Lada (22% share), Kia (13% share), Hyundai (11% share), and Renault (9% share), which occupy the top positions (JETRO, 2022).

However, the outbreak of the Russian-Ukrainian war in February 2022 seems to have been an unexpected tailwind for Chinese manufacturers. In addition to Renault Russia, Renault held a 68% stake in AvtoVAZ, which produces the Lada, but withdrew from both in May by selling their shares to Russian companies. Toyota and Nissan were also forced to withdraw from the market because they could no longer produce locally. On the other hand, Chinese manufacturers continued to produce and export after the war started, and their market share increased, reaching a total of 21% in June 2022.

Great Wall Motor is making a full-scale effort, including a $500 million investment to establish a plant in Russia's Tula Oblast in 2019 through sole investment. Until then, Chinese automakers' overseas expansion had been limited to the level of exports or knockdown production, but Great Wall Motor's Tula plant was a full-scale local production facility with pressing, welding, painting, and assembly processes (Economic Information Daily, June 12, 2019; PC Auto, 2022, April 13[60]). While the increase in market share in 2022 does not indicate an increase in the competitiveness of Chinese manufacturers, it was made possible because Chinese manufacturers have been steadily gaining ground in the Russian market.

Looking at exports by auto manufacturers in 2021, SAIC Motor had the highest volume with 598,000 units, followed by Chery with 269,000 units, Changan Automobile with 159,000 units, Dongfeng Motor with 154,000 units, Great Wall Motor with 143,000 units, and Geely with 115,000 units. However, the figures for SAIC Motor, Changan Automobile, and Dongfeng Motor represent each group's total exports, which include those of joint ventures with foreign companies. For example, in the case of SAIC Motor, it includes not only SAIC Motor Corporation, which produces the MG brand, but also SAIC-GM and SAIC-GM-Wuling, which are joint ventures with GM, and SAIC-VW, which is a joint venture with Volkswagen. Thus, when comparing the number of exports by a single firm, it appears that Chery was still the top exporter.

Noteworthy in the export of automobiles in 2021 was the sharp increase in the export of electric vehicles (EVs), from 224,000 units in the previous year to 588,000 units. Electric vehicles are a powerful weapon for Chinese manufacturers to cut into markets in countries where Western, Japanese, and South Korean automakers have established roots. As mentioned above, exports to countries such as Belgium, the United Kingdom, Germany, and Thailand grew significantly in 2021, with EVs being the mainstay of exports to these countries, accounting for 96% of exports to Belgium, 70% to the United Kingdom, 76% to Germany, and 83% to Thailand. Exports to Japan also grew significantly from 996 units in 2020 to 11,688 units in 2021, of which EVs accounted for 95%. EVs also accounted for 96% of exports to Bangladesh and 89% of exports to India.

A certain percentage of EV exports from China are believed to be made by foreign manufacturers. Sebastian and Chimits (2022), based on European car sales data, estimate that 49% of Chinese EVs sold in Europe from January 2021 to March 2022 were from Tesla Shanghai, 14% were built by European automakers in China and 35% were European brands owned by Chinese companies such as Volvo and MG, while only 2% were purely Chinese-brand vehicles. In Southeast Asia, on the other hand, most Chinese-made EVs are likely to be Chinese-brand vehicles. For example, regarding Thailand, SAIC Motor and Great Wall Motor started exporting EVs in 2021, with the two companies accounting for 70% of the Thai EV market. The two companies plan to begin local production in Thailand in 2022 and 2023 (Nihon Keizai Shimbun, March 26, 2022; Nikkei Business, October 18, 2021). Hozon Auto, which began producing EVs in 2018, also built a plant in Nanning with an annual production capacity of 100,000 units for export to Thailand and other Southeast Asian countries.

This concludes the detailed look at the situation from the first export boom in 2007–2008 to the second

[60] https://www.pcauto.com.cn/jxwd/2987/29875791.html

export boom starting in 2021. Chinese automakers have focused on developing markets that are not well penetrated by existing manufacturers in developed countries. As a result, the market for Chinese manufacturers has expanded throughout the non-developed world. However, in 2021, as the shift to EVs continues in Europe, the US, and China, Chinese-made EVs are expanding their market to developed countries as well. This suggests that Chinese-made EVs are becoming competitive enough to rank among advanced domestic EVs.

4.4 Competitiveness of China's EV Industry

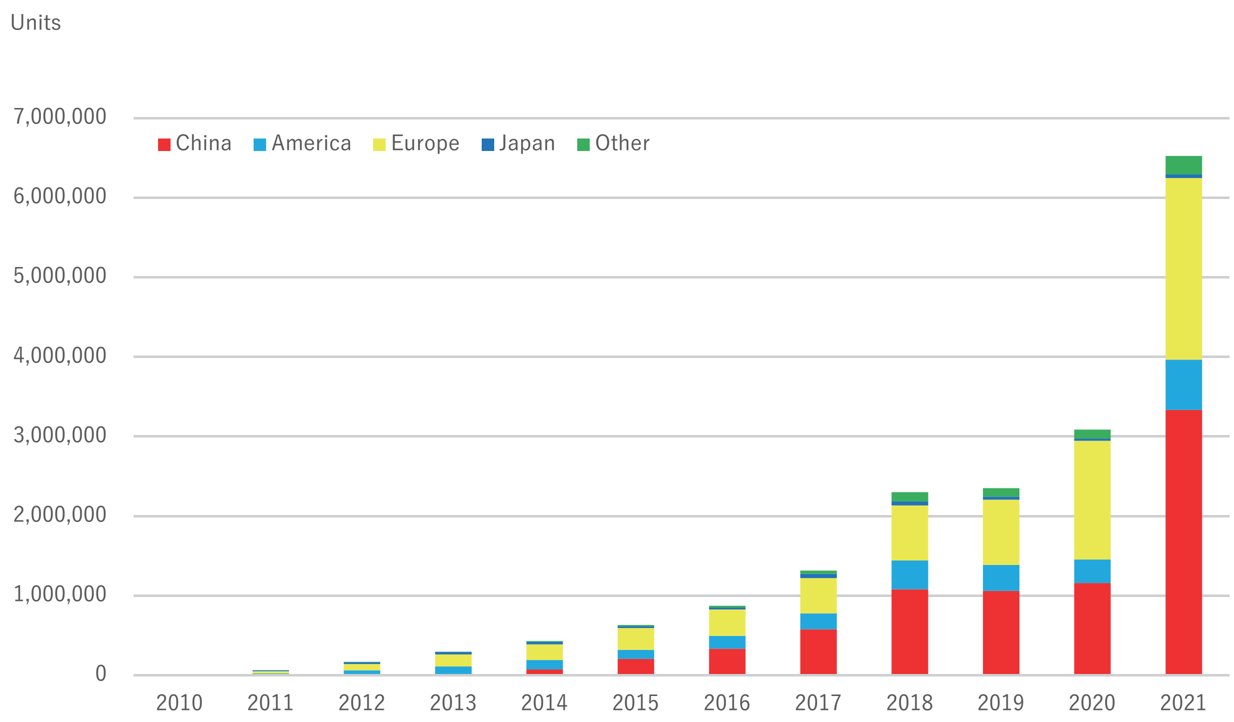
As China's EV industry becomes more competitive, the global EV shift is expected to increase China's position in the global automotive industry. Why has China's EV industry become more competitive?

4.4.1 Production and Market Size

The primary reason for this would be the scale of domestic production and sales. In 2021, China produced 3.54 million units and shipped 3.52 million units of EVs (the sum of BEVs [battery electric vehicles], PHEVs [plug-in hybrid electric vehicles], and FCVs [fuel cell vehicles], all called "new energy vehicles" in China).[61] Figure 4-2 shows global EV passenger car sales figures compiled by the International Energy Agency, with China accounting for 51% of the global total at 3.33 million units.[62] This chart shows that China is driving the expansion of global EV sales, but at the same time, Europe will see a 53% year-on-year increase to 2.28 million units in 2021, and the United States will see a 114% year-on-year increase to 630,000 units, indicating that the global shift toward EVs is progressing. However, only Japan has not yet been swept up, with sales stagnating at around 30,000~50,000 units per year from 2017 to 2021. Since automobile production processes involve high fixed costs, such as body stamping, it is considered economical to have an annual production capacity of about 100,000 units at a single plant. In other words, with an annual production of 3.5 million units, 35 automakers with economically sized plants could coexist, but with an annual production of 50,000 units, not a single automaker would be viable.

[61] As noted above, China exported 588,000 EVs in 2021, so it is likely that exports are included in the number of units shipped.

[62] In Figure 4 1, only EV passenger cars are included, as data for EV commercial vehicles (trucks and buses) are not available for some countries. According to the IEA, China's EV sales, including commercial vehicles, were 3.43 million units in 2021.



Source: Prepared by the author based on IEA and Global EV Outlook 2022 database

Figure 4-2: Global EV Passenger Car Sales

4.4.2 Intense Competition

A second reason for the increased competitiveness of China's EV industry is the competition among numerous manufacturers for the domestic EV market. In addition to foreign companies such as Tesla Shanghai, SAIC-GM Automobile, and FAW-VW, state-owned manufacturers such as SAIC Motor, Guangzhou Automobile, and Changan Automobile, as well as emerging EV manufacturers, there were 24 manufacturers that produced more than 20,000 EVs in 2021. Eight of the Chinese manufacturers were among the top 20 global EV manufacturers in 2021. Besides these, Volvo, of which Geely is a major shareholder, was also in the top 20 (Table 4-3). BYD, which was second in the world in 2021, produced 640,000 EVs in the first half of 2022, making it the world's top EV producer. The company will cease production of gasoline engine vehicles in March 2022 and is focusing on EVs (including PHEVs). Since Changan Automobile, the 20th largest automaker, sold less than 100,000 units, it can be said that the manufacturers in the top 20 are already in a position to produce on an economic scale. With only one Japanese manufacturer in the top 20, Toyota, the Japanese have missed the trend of the shift to EVs.

In addition to the eight companies in the top 20, other Chinese manufacturers that are likely to exceed 100,000 units per year in the near future include Nio (93,000 units in 2021), Li Auto (90,000 units in 2021), Geely (81,000 units in 2021), and Hozon Auto (70,000 units in 2021). There are a number of companies in China that have no track record of producing gasoline engine vehicles and were established from the beginning as specialist EV manufacturers, and these are known as "new auto-making powerhouses."

Around 2014, numerous entrepreneurs in China began convincing venture capitalists to launch EV ventures. At one time, as many as 300 ventures were said to be planning to enter the EV market (Economic Information Daily, February 22, 2021). Many of these EV ventures did not start production, but a few went public after venture capital investment. Among them, Xiaopeng Motors, which ranked 19th in the world in terms of EV sales in 2021, Nio Automobile, and Li Auto are all listed in the United States (New York or NASDAQ) and Hong Kong, and are regarded as representatives of the new auto-making powerhouses. However, all three companies have yet to achieve a profit in a single year, and in the first half of 2022, their losses were even larger than in the previous year due to stagnant sales caused by the Shanghai lockdown and soaring battery material prices (21st Century Economic Report, September 9, 2022). Following these top three companies are Leapmotor, which is scheduled to list its shares in Hong Kong in September 2022, and Hozon Auto, which is developing EVs under the NETA brand.

The Chinese government did not initially welcome the emergence of these new EV manufacturers. In 2016, the government introduced regulations requiring a license to produce EVs, in an attempt to put a stop to new entrants. Therefore, emerging EV makers, like Chery and Geely had done previously, sought to enter the market through alliances with existing automakers that were qualified to produce cars. Nio Automobile outsourced the assembly of EVs to Jianghuai Automobile (JAC), a commercial vehicle manufacturer; Xiaopeng Motors to Haima, a passenger car manufacturer; and Leapmotor to Hangzhou Changjiang Passenger Vehicles. The government officially approved such consignment production in 2019 and set the criteria for granting licenses to EV manufacturers at a cumulative sales volume of 30,000 units and sales value of 3 billion yuan (Tang, 2019).

Table 4-3: Global EV Sales by Maker

Manufacturer	Units
Tesla	9,36,172
BYD	5,93,878
SAIC-GM-Wuling Automobile	4,56,123
VW	3,19,735
BMW	2,76,037
Mercedes	2,28,144
Shanghai Automobile	2,26,963
Volvo	1,89,115
Audi	1,71,371
Hyundai	1,59,343
Kia	1,58,134
Great Wall Motor	1,37,366
Renault	1,36,750
Guangzhou Automobile	1,25,263
Peugeot	1,25,263
Toyota	1,16,029
Ford	1,11,879
Chery Automobile	99,109
Xiaopeng	98,698
Changan Automobile	97,911
Other	17,31,984
Total amount	64,95,388

Source: Pontes, 2022.[63]

In a fiercely competitive environment, each manufacturer approaches the market with a different strategy. While Tesla specializes in luxury vehicles priced at more than 290,000 yuan, SAIC-GM has launched an extremely low-priced model priced at 33,000 yuan per vehicle. BYD also offers a wide range of vehicle models from 70,000 yuan to 230,000 yuan. Among new EV makers, Nio Automobile's cheapest model is a luxury car priced at 328,000 yuan, while Hozon Auto has a mass-market line starting at around 80,000 yuan. Thus, China's EV industry as a whole offers a diverse range of EVs in various price ranges. This diversity will also be an advantage in capturing markets in other countries.

4.4.3 EV Industry Development Policy

A third reason for the increased competitiveness of China's EV industry is the preferential treatment for EV purchases and protection policies for domestic manufacturers. Subsidies for EVs have been available since the early 2010s, and as of 2013 there were three levels of subsidies: 60,000 yuan, 50,000 yuan, and 35,000 yuan, depending on cruising range (Fourin China Research Department, 2016). In July 2019, the government announced plans to reduce the level of subsidies and eliminate them at the end of 2020, which led to a sharp decline in EV sales in the second half of 2019. Therefore, in April 2020, it was announced that the subsidy elimination date would be extended to the end of 2022, and then further extended to the end of 2023. The subsidies would offer discounts on the purchase of EVs, but would only be paid to domestic EV manufacturers, so imported EVs would not be eligible for the subsidies. Therefore, the purchase subsidy was a powerful protection measure for domestically produced EVs.

The government also introduced regulations on EV batteries in 2015, stipulating that only EVs powered by batteries from companies on the government's list of battery manufacturers can receive subsidies. While a list of 57 companies was published in 2015–16, no leading Japanese or South Korean storage battery manufacturers such as Panasonic, Samsung SDI, SKI, or LG Chemical were listed among them (Tang, 2019; 21st Century Economic Report, June 28, 2019; "Train Man," June 27, 2019[64]).

Although this regulation was repealed as of June 2019, Chinese battery manufacturers made great strides between 2015 and 2019, when this regulation was in place, and it truly functioned as an industry growth protection policy. Furthermore, Western commentators believe that the reason for the rapid growth of China's EV industry is largely due to its fostering policies (Sebastian and Chimits, 2022; Graham et al., 2021), therefore suggesting that Western countries will adopt countermeasures such as antidumping duties. Indeed, the policy of only subsidizing domestically produced EVs that use batteries from domestic manufacturers is contrary to the GATT/WTO's main principle of non-discrimination between domestic and foreign manufacturers. However, since China is already ending its policy of protecting this nascent industry, the time is already ripe to adopt countermeasures. Also, as a matter of fact, it would be one-sided to attribute the reason for growth to protection policies alone, given that protection policies would have come up empty without the active participation of a large number of companies in the EV industry, as discussed in the previous section.

[63] José Pontes (2022): Top 20 Electric Cars In The World - March 2022 (Charts), https://cleantechnica.com/2022/05/02/top-20-electric- cars-in-the-world-march-2022-charts/

[64] https://www.pcauto.com.cn/hj/article/245178.html

4.4.4 Competition among EV Component Manufacturers

A fourth reason for the increased competitiveness of China's EV industry is the intense competition that is also developing among EV's key component manufacturers. The key components of EVs include the onboard battery, drive motor, battery management system (BMS), and power control unit (PCU), etc. Chinese EV manufacturers often compete with multiple suppliers for procurement of these key components.

A typical example is batteries. Chinese battery manufacturer Contemporary Amperex Technology Limited (CATL) grew rapidly during the period when the Chinese government was excluding Japanese and South Korean manufacturers from the passenger car automotive battery market. The company has been the world's top seller of automotive batteries since 2017. As of January-September 2022, it has a 35.1% global market share, far ahead of rivals such as LG Energy (14.1%), BYD (12.8%), and Panasonic (8.1%).[65] CATL is a big fish in a small pond in China, but Chinese EV manufacturers often increase the number of battery suppliers to two or more as production increases to avoid becoming too dependent on CATL.[66] For example, SAIC-GM-Wuling's Hongguang mini EV, which became China's top selling model in 2021, is powered by batteries from a number of battery manufacturers, including CATL, Guangzhou Great Power, and Gotion (21st Century Economic Report, August 10, 2021).

Note that South Korean manufacturers such as LG Chemical and Samsung SDI were excluded from the Chinese market for automotive batteries for passenger cars in 2015, but they continued to expand their sales channels to Chinese commercial vehicle manufacturers (Fourin China Research Department, 2016), and SKI and LG Chemical continued their aggressive stance by establishing new plants in China in 2018 (Tang, 2019). When the regulation was lifted in 2019, China's automotive battery industry saw open competition between numerous Chinese manufacturers and South Korean and other manufacturers. For example, Tesla's Shanghai plant, which began operations in 2020, sources batteries from Panasonic, Contemporary Amperex Technology Limited (CATL), and LG Chemical.

CATL has a very open sales policy and supplies a wide range of batteries to Chinese state-owned manufacturers, emerging private manufacturers, and foreign manufacturers. CATL supplied batteries for more than 1,200 of the 2,400 or so EVs approved by China's Ministry of Industry and Information Technology by the first half of 2021.[67] On the other hand, Panasonic, from Japan, has a sales policy that is the exact opposite of this. The company has stated that it only supplies batteries to the "world's top class" and in fact only sells batteries to Tesla, Toyota, and some Honda models.[68] Indeed, it is a characteristic of the Japanese automotive industry that automakers and parts suppliers work together in close relationships to improve quality and reduce costs. However, in the current age of aggressive competition

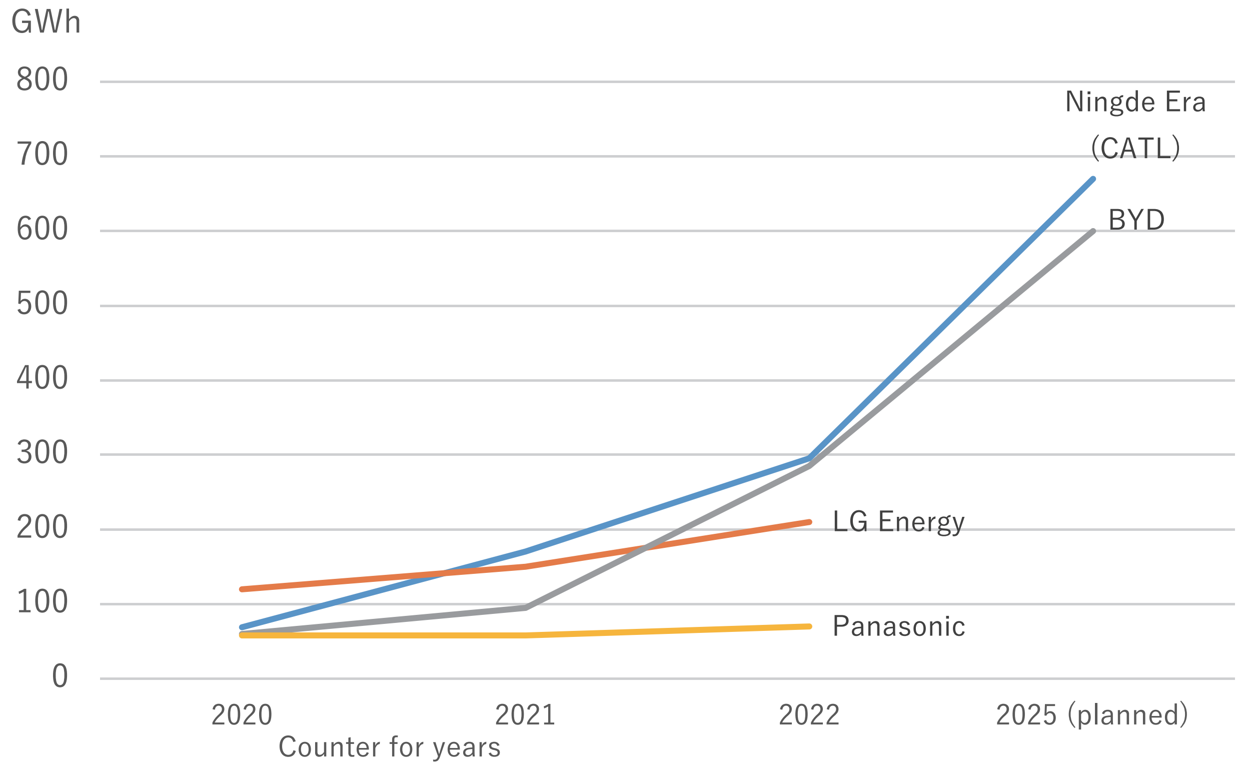
[65] Based on the SNE Research website (https://www.sneresearch.com/kr/home/). Viewed November 8, 2022.

[66] Note that even when creating production systems for internal combustion engine vehicles, Chinese automakers tended to secure their independence with respect to suppliers by procuring key components from multiple suppliers (Marukawa, 2013).

[67] Contemporary Amperex Technology Limited New Energy Technology Corporation, "2021 Semi-Annual Report."

[68] "China's Rising Star That Overtook Panasonic," *Nikkei Business*, June 11, 2018;
China Industrial Secs, "Contemporary Amperex Technology Limited Research Report," March 2022.
https://baijiahao.baidu.com/s?id=1726240185356298144&wfr=spider&for =pc

in the EV industry, where it is difficult to predict which EV makers will survive, it is a very risky bet to deal only with a very limited number of EV makers and not to seize business opportunities beyond these. In fact, since losing its global leadership position to CATL in 2017, Panasonic's share of the automotive battery market has been declining (Figure 4-3).



Source: Kenmin Kim, "Post-COVID-19, Digital Transformation, and the Green Revolution for a New Era," 21st *Century Economic Report*.

Figure 4-3: Production Capacity (GWh) of Major Automotive Battery Manufacturers

In June 2022, Panasonic announced a plan to expand EV battery production capacity to three to four times the current level, mainly in North America, by FY2028 (Sankei Shimbun, June 2, 2022). However, it is still around 240 GWh, which is less than half of the production capacity planned by CATL and BYD for 2025. In addition, China's top three automotive battery makers, CALB, SVOLT, and Gotion High-Tech,[69] are planning production capacities of 500 GWh, 600 GWh, and 300 GWh in 2025, respectively, and if sales expand as planned, Panasonic will fall from its current 2022 4th place in the world to 8th place or lower.

[69] As of January-September 2022, China Aviation Lithium Battery (CALB), Fengchao Energy Science and Technology (SVOLT), and Gotion High-Tech had global market shares of 4.0%, 1.3%, and 2.9%, and ranking 7th, 10th, and 8th in the world, respectively.

4.4.5 Potential for Automotive Production System Transformation

Having pointed out the four reasons for the increased competitiveness of China's EV industry above, this section will point out a shift in the production system that may further increase the production efficiency of the Chinese EV industry in the future. It is well known that China has an overwhelming share of the global market for the production of PCs and smartphones, and consignment manufacturing, known as OEM and ODM, is widely used for such IT products. The division of labor between brand-name manufacturers devoted to the development and sale of products and software, and EMS (electronic manufacturing services) companies devoted to production in China, has largely eliminated Japanese electronics manufacturers that had focused on increasing production efficiency and vertical integration of development, production, and sales.

On the other hand, consignment production is also used in some parts of the automotive industry, but it is not mainstream. For automobiles with complex mechanical structures, there is often a need for coordination between production and design, and if both are handled by different companies, smooth coordination may be hindered. However, while the mechanical structure of EVs is much simpler than that of conventional vehicles, the addition of functions such as automatic driving and internet connectivity, which will be discussed in the next section, will place a greater emphasis on software development and other aspects. These changes could alter the structure of the automobile production system. On the one hand, IT companies may become more deeply involved in the development of automobiles, while on the other hand, production may increasingly be outsourced to specialized companies.

In fact, there are signs that such a division of labor is forming. BAIC BluePark, established in 2018 with investment from Beijing Electric Vehicles and others and responsible for the Beijing Electric Group's EV business, outsources EV production to Aiya, a joint venture established by the company and Magna International. Magna, headquartered in Canada, is a global auto parts manufacturer, and its subsidiary Magna Steyr is contracted to produce some Mercedes-Benz and BMW models. BAIC BluePark's 2022 Arcfox Alpha S is touted as HI (Huawei Inside) with full cooperation from Huawei for its self-driving features and smart cockpit.

LuxShare, which started out as a manufacturer of connectors and also does contract manufacturing of PCs and smartphones, acquired 20% of Chery Automobile's shares in February 2022. In the future, the company aims to become an ODM manufacturer of EVs through cooperation with Chery. LuxShare has been producing connectors, wire harnesses, and other products for automakers, but now the company intends to seize the opportunity of the EV shift to produce and develop automobiles (Economic Information Daily, August 12, 2022; 21st Century Economic Report, February 15, 2022).

IAT Automobile Tech (IAT), an independent automotive engineering firm that has been contracted by numerous automakers to design their vehicles, also purchased Tianjin Bogun, a Tianjin-based automaker, in 2022. Tianjin Bogun originally bought a passenger car plant that produced Daihatsu cars under license, but went bankrupt in 2020. With this acquisition, IAT now has an automotive plant and a production license, and is aiming to transform itself into an ODM manufacturer that not only designs but also produces vehicles in the future.

It remains to be seen whether these OEM and ODM production systems for EVs will be successful and how far they will spread, but given the trend of shifting the emphasis of product development to software and simplifying the mechanical structure of EVs, a certain degree of expansion can be expected.

4.5 Expansion of Automated Driving

In China, advanced automated driving is being prepared for practical application on a fairly wide scale in the near future. The Chinese government's basic strategy for automated driving is summarized in the Intelligent Vehicle Innovation and Development Strategy,[70] which was jointly promulgated by 11 departments, including the National Development and Reform Commission, in February 2020. Among its goals are to create conditions that will make automated driving socially feasible by 2025, including automated vehicle technology, industrial ecosystems, infrastructure, regulations and standards, product certification systems, and network safety. The company states that by establishing such a system, "highly automated driving" will be commercialized by 2025.

The "highly automated driving" referred to here is considered to be Level 4 of the six categories (Level 0 to 5) of automated driving in the national standards for automated driving (GB/T40429-2021) that came into effect in March 2022, meaning "under set conditions, the system performs all driving operations and automatically selects the least risk." The term "set conditions" refers to conditions such as constant availability of 4G and 5G wireless communications.

Among Chinese companies, internet giant Baidu was one of the earliest companies to work on automated driving. In 2017, the company formed a strategic partnership with Beijing Automotive and has continued to experiment with automated driving in Yizhuang, an industrial park in Beijing. In June 2021, BAIC BluePark unveiled the Apollo Moon, a Level 4 self-driving car based on the Arcfox Alpha T EV discussed in 4.4.5. The Apollo Moon is characterized by a production cost of 480,000 yuan. This vehicle can withstand five years of use, which means the cost per month is 8,000 yuan. This is lower than the monthly income of cab drivers in many cities. In other words, operating the Apollo Moon as an unmanned cab for five years would save enough labor costs to recover the cost of the vehicle.[71] Baidu plans to deploy 3,000 driverless cabs ("robotaxis") in 30 cities by 2023, and self-driving is moving from the experimental stage to the stage of being used in commercial businesses. According to a person who actually rode in a "robotaxi" in Yizhuang, Beijing, even though it is called a cab, it has a designated stop, and when the passenger enters the desired section of the route into his/her smartphone, the car will automatically drive them to the designated stop. In addition, robotaxis will have a safety officer on board at all times to handle any emergencies.

Baidu also established a joint venture with passenger car maker Geely to create a manufacturer specializing in self-driving EVs called Jidu Auto in 2021. Jidu Auto accepted reservations for its first model, the ROBO-01, in October 2022, limited to 1,000 units at a price of 399,800 yuan. ROBO-01 claims "automatic operation from (departure) point to (arrival) point," but does not clarify which of the six categories of automatic operation this falls under. Perhaps it is difficult to say at what level because conditions vary

[70] https://www.ndrc.gov.cn/xxgk/zcfb/tz/202002/P020200224573058971435.pdf
[71] Coldzelin, "Baidu 极狐共创 Apollo Moon: three years fall ground 1,000 units," Photon Star Ball, June 17, 2021.

from city to city. Jidu Auto aims to be ready to ship 800,000 self-driving cars (which the company calls "car robots") per year by 2028, and unlike the Apollo Moon, it is intended for sale to ordinary car users (21st Century Economic Report, August 10, 2022). In addition, in July 2022, Baidu announced the Apollo RT6, which is capable of Level 4 automatic driving, costs 250,000 yuan, and will be used in "Apollo Go," a self-driving online reservation car service operated by Baidu (21st Century Economic Report, August 16, 2022). However, there is little information on this "Apollo RT6" and it is not clear which automaker produced it.

Also in August 2022, the Avatr 11, produced by Changan Automobile, with Huawei responsible for the development of the automatic driving and smart cockpit, and Contemporary Amperex Technology Limited providing the batteries, was launched at a starting price of 349,900 yuan. This one states that automated driving is possible only in areas where national laws allow it and where detailed maps have been published.

Huawei has launched EVs called the HI (Huawei inside) versions of BAIC BluePark's Arcfox Alpha S and Changan Automobile's Avatr 11, as mentioned above, as well as of Aion, a specialist EV manufacturer in the Guangzhou Automobile Group, respectively. In the HI version of the EVs, Huawei is collectively responsible for the HarmonyOS that operates the cockpit, the computing platform for automated driving, and sensors such as laser radar. Huawei is thus collecting driving data from multiple EV manufacturers and using artificial intelligence (AI) to learn from this data and continually update the software to improve the quality of automated driving (21st Century Economic Report, August 16, 2022).

In this way, Huawei is aiming to become like Microsoft in the PC industry, taking on a cross-functional role in software, key components, and sensors related to automated driving and cockpits. However, some EV manufacturers are opposed to this strategy, claiming that it will destroy their source of added value. Nio and Xiaopeng, the new auto-making powerhouses, do not rely on major IT companies such as Huawei and Baidu, and intend to develop software on their own.

Like Nio and Xiaopeng, major smartphone maker Xiaomi is also aiming to mass-produce self-driving EVs solely through independent development. In March 2021, Xiaomi announced plans to enter the automobile market, and in November of the same year began construction of a plant in Yizhuang, Beijing, with an annual production capacity of 300,000 units. Mass production is expected to begin in 2024.

In China, 53.3% of all new cars sold in 2021 were network-capable and had achieved level 2 or higher self-driving (partially self-driving). The number of new cars sold with this function (which automatically controls the vertical or horizontal movement of a vehicle and can detect and respond to related targets and incidents) accounted for 43% of the world's new car sales (21st Century Economic Report, August 10, 2022).

As the number of vehicles with automated driving functions increases in this way, the legal treatment of these vehicles becomes an issue. When riding in a vehicle with advanced automated driving features, is it permissible under traffic laws to ride without any occupants in the driver's seat? Also, if an automated vehicle were to cause an accident under such conditions, who would be held criminally, civilly, and administratively responsible for the accident? Until these points are clarified, even if a car has advanced automated driving capabilities, it will not be legally allowed to do more than assist the driver's movements.

In April 2022, the Beijing municipal government established rules for unmanned driving tests in the city's experimental areas. This allowed Yizhuang, where robotaxis and other automated driving experiments have been conducted, to be driven automatically with a safety officer sitting in the passenger seat rather than in the driver's seat. Also in August, the "Regulations of Shenzhen Special Economic Zone on the Administration of Intelligent Connected Vehicles"[72] went into effect in Shenzhen. The ordinance is the first local law in the nation to authorize automated vehicles to drive on the road with no safety personnel seated in either the driver's seat or the passenger seat. However, this is only the case for Level 5 fully automated vehicles, and the city's traffic police will determine the extent to which unmanned driving is allowed. In the case of Level 3 and Level 4 automated vehicles, the driver must be in the driver's seat, and the driver is responsible for any violations of traffic laws. On the other hand, if a Level 5 unmanned vehicle commits a traffic violation, the owner and manager are liable (21st Century Economic Report, August 9, 2022).

Thus, at the local level, legislation to accept automated driving has begun to be developed. However, at the national level, road and traffic laws that accept automated vehicles are not yet in place. By 2025, self-driving cars, in which major IT companies such as Huawei, Baidu, and Xiaomi were deeply involved in the development, should be ready for mass production, but by that time, it will be necessary to establish regulations and other acceptance measures on a national level.

4.6 Summary

Finally, while summarizing the main points of this paper, this section will provide some additional information on the impact on Japan.

China's automobile exports are increasing at a rate such that it will surpass 3 million units by 2022, reaching a level comparable to that of the US and Germany, the leading countries in the automotive industry. The main factor that has led to the increase in exports has been the development of emerging markets by Chinese manufacturers over the past 15 years. In addition, the recent global shift to EVs has led to the export of Chinese EVs to developed countries and Southeast Asia as well. China's EV production reached 3.54 million units in 2021 and more than 6.5 million units in 2022, which alone puts it on par with the automotive industry powerhouses. The competitiveness of Chinese EVs has not been simply boosted by the government's policy of fostering EVs, but is a combination of the size of the domestic market, fierce competition among manufacturers, and the competitiveness of manufacturers of key components such as onboard batteries. Furthermore, the division of labor between manufacturers specializing in vehicle design and sales, and companies contracted to manufacture vehicles, and the emergence of IT companies responsible for automated driving software across the board are gradually forming a structure familiar from the IT equipment industry, such as smartphones and PCs, in EVs as well. If this division of labor, which is very different from that of the Japanese automotive industry, were to spread widely, the Japanese automotive industry would be isolated and could even become even more isolated, as has happened with the mobile phone industry.

The Japanese automotive industry spearheaded the global shift to EVs in 2009–2010 with the mass

[72] http://www.szrd.gov.cn/rdlv/chwgg/content/post_826149.html

production of Mitsubishi Motors' i-MiEV and Nissan's LEAF, the world's first EVs. However, despite subsidies for EV purchases and other policies, EV sales in the Japanese market have been slow to pick up, so that Japan now trails China not only in EV production, but also in the number of companies participating in EVs and the variety of EVs on the market. Panasonic, once the world leader in automotive batteries, has been overtaken by latecomer Chinese manufacturers due to its reluctance to promote sales, and the Japanese EV industry as a whole is not internationally competitive. Chinese-made EVs are already gradually entering the Japanese market, and EV imports from China are likely to expand further in the future.

Major IT companies such as Baidu and Huawei play a major role in the development of self-driving cars in China. From 2023 onward, if communications conditions are met, vehicles capable of advanced Level 4 self-driving will be marketed in the Chinese market at relatively affordable prices. However, whether or not they will actually sell depends in part on the development of social systems that accept self-driving cars, such as laws and regulations, and we cannot necessarily be optimistic about this. The day is not far off when most cars sold in China will be equipped with Level 2 or higher self-driving functions. If Japanese automakers operating in the Chinese market do not improve their automated driving technology in light of such a situation, it will be difficult for them to survive in the Chinese market. As for the possibility of Chinese-made self-driving cars being exported outside of China, such as to Japan, it is still unlikely for anything more advanced than driving assistance functions up to Level 2. In order to realize automated driving in other countries, it is necessary to repeat long-term experiments based on the road conditions and road laws of each country, and it is unlikely that Chinese automakers will devote that much energy to overseas markets.

The recent massive export of automobiles from China should serve as an opportunity to wake up from the delusion that "Japan's automotive industry is the best in the world and China is a backward country." The COVID-19 pandemic has made it difficult to see cutting-edge developments taking place in the Chinese automotive industry, such as automated driving, but we need to keep a close watch on these developments.

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5 Trade investment, Catch-Up and Industrial Policy in China's Robotics Industry

5.1 Awareness of the Issues and Purpose of this Paper

China is the world's largest market for industrial robots. According to the International Federation of Robotics (IFR), about 47% of the global market is destined for China (IFR, 2022). Against the backdrop of labor shortages due to an aging population and rising wages, China's industrial robot market has expanded rapidly since 2013. In 2016, the number of industrial robots in operation in China surpassed Japan to become the greatest in the world, and furthermore, the number of industrial robots in operation in 2019 reached approximately 783,000, more than double the number of robots in operation in second-place Japan (approximately 355,000) (IFR, 2020). It is not yet fully clear to what extent highly internationally competitive Japanese firms in this field are participating in the Chinese market through trade and investment, whether Chinese firms are catching up to Japanese firms, and what role Chinese government industrial policy is playing.

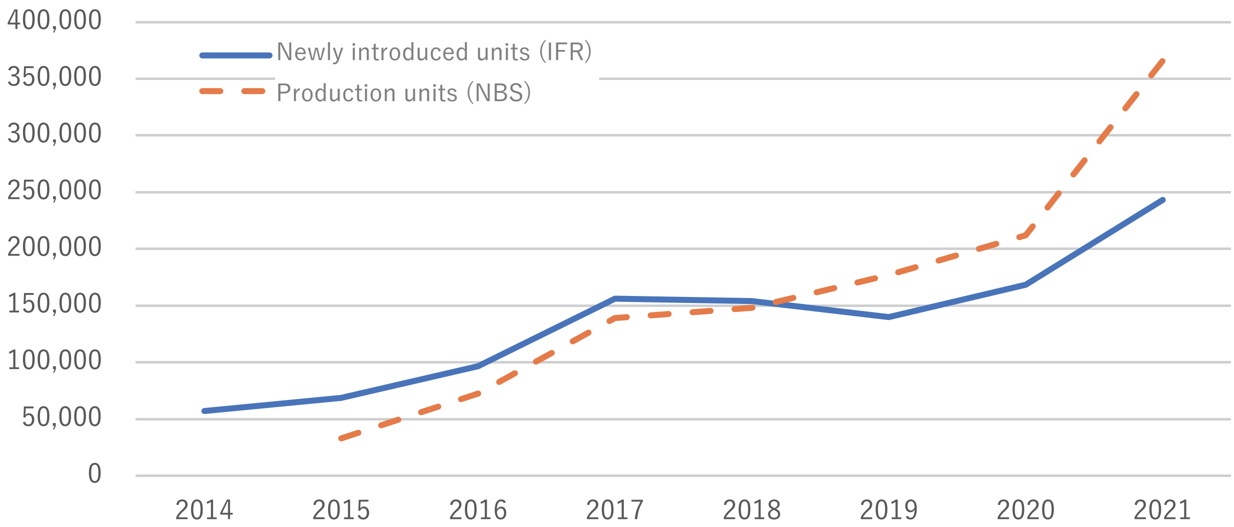
Focusing on industrial robots, this paper uses industry and company data to provide observations on trade investment, Chinese firm catch-up, and industrial policy in China's robotics industry, and discusses the current status and issues in industrial development. The main results of the analysis are as follows. First, China's industrial robot market has expanded rapidly in recent years, and the ratio of robots installed at the manufacturing industry and firm level is approaching that of developed countries. However, the domestic production ratio of robots is still low, and the introduction of robots relies heavily on imports and local production by foreign firms. Second, in recent years, Chinese companies (Siasun Robotics,[73] Shanghai STEP Electric,[74] Estun Automation,[75] and EFORT Intelligent Equipment[76]) have been catching up with Japanese companies (FANUC Corporation and Yaskawa Electric Corporation) with high growth rates in sales and capital investment and increased research and development (R&D) investment. However, Chinese companies (especially state-owned enterprises) have low profit margins on sales, and their labor productivity in 2020 will be only about 30% of that of Japanese companies. Third, subsidies to Chinese companies have increased rapidly in recent years, taking various forms ranging from R&D subsidies to value-added tax refunds, and are expected to have some effect on the development and production of industrial robots. The Chinese government's development plan for the robotics industry sets a high target of 70% market share for independent brands and domestically produced core components by 2025, but currently only about 25% of the market is accounted for, and the target is not expected to be reached by 2025.

[73] Siasun Robotics & Automation Co., Ltd.
[74] Shanghai STEP Electric Corporation
[75] Nanjing Estun Automation
[76] EFORT Intelligent Equipment

5.2 Industrial Robot Markets and Trade Investment

5.2.1 Production and Installation of Industrial Robots

Figure 5-1 shows the annual production and installation of industrial robots in China. According to IFR (2022), the number of new robot installations in China in 2021 reached a record high of 268,000 units, a 51% increase over 2020 and about 2.8 times more than in 2016 (97,000 units).[77] According to China's National Bureau of Statistics (NBS),[78] industrial robot production increased 19.7% year-on-year in 2020 and 72.6% year-on-year in 2021. This is due, again, to the growing introduction of industrial robots and automation technology due to labor shortages and rising labor costs in China. In addition, the spread of COVID-19 infections beginning in 2020 is thought to have further accelerated the introduction of industrial robots.



Source: Compiled by the author based on the National Bureau of Statistics (NBS), China's National Economic and Social Development Statistics Bulletin, various years,[79] and IFR World Robotics, various years[80]

Figure 5-1: China's Industrial Robotics Market

In terms of the ratio of robots installed in the manufacturing industry (the number of robots per 10,000 employees), China ranked fifth in the world in 2021, with 322 robots installed, more than the 274 robots installed in the United States and well above the global average of 141 robots (IFR, 2022). However, China is still low compared to first-place South Korea (1,000 units), second-place Singapore (670 units), third-place Japan (399 units) and fourth-place Germany (397 units). This means that there is still significant room for the introduction of robots and automation in China. Looking at the introduction of robots for each type of manufacturing industry, the automotive and electronics industries have the largest number of new installations (42% of the total) and operating units (74% of the total) in 2019, which is similar to developed

77 https://ifr.org/downloads/press2018/2022_WR_extended_version.pdf
78 National Bureau of Statistics (NBS), China National Economic and Social Development Statistics Bulletin, various years
79 中华人民共和国 2021 年国民经济和社会发展统计公报 _ 数据快递 _ 中国政府网 (www.gov.cn)
80 International Federation of Robotics (ifr.org)

countries. Of course, some companies in the same industry have introduced robots, while others have not. According to the China Enterprise-Employee Survey, of 1,882 companies, only 2% had robots in place in 2008, but this figure reached 7% in 2013 and 13% in 2017. Although only a few firms have adopted robots, the percentage of firms that have is steadily increasing (Cheng et al., 2018).

5.2.2 Trade and Direct Investment in Industrial Robots

The introduction of robots in Chinese companies relies heavily on imports and local production by Chinese subsidiaries of multinationals. Approximately 71% of new robots introduced in China in 2019 were sourced from foreign suppliers (foreign firms and foreign-invested companies in China) (IFR, 2020). Recent trends in robot imports in China are shown in Table 5-1. Import value and volume have been increasing every year since 2015 and are expanding significantly, reaching approximately $1.5 billion in import value and 110,000 imported units in 2021. China's robot imports are heavily dependent on Japan. In 2021, Japan accounted for 74% of China's imports in value terms and 84% in volume terms. Due to the high dependence on Japan, in recent years there has not been a significant difference between the overall import price and the price of imports from Japan. These results are generally consistent with firm-level robot adoption figures. In addition, Cheng et al. (2018) confirm that the import value of industrial robots account for 49% of total installation value.

Table 5-1: China's Robot Imports

	Value (USD 1,000)	Volume (Units)	Price (USD 1,000/ unit)	Japan's share (value)	Japan's share (volume)	Price in Japan (USD 1,000/unit)
2015	804,834	46,819	17	57%	79%.	12
2016	875,522	52,200	17	62%	75%	14
2017	1,326,503	84,226	16	61%.	77%	12
2018	1,144,285	100,349	11	63%.	57%	13
2019	989,855	60,723	16	61%.	77%	13
2020	1,042,448	76,342	14	71%	83%	12
2021	1,535,467	114,698	13	74%.	84%	12

Note: The HS code for industrial robots is 847950. Source:
Prepared by the author based on Global Trade Atlas and the S&P Global database[81]

Interestingly, at the same time that China's robot imports are expanding, China's robot exports have also been growing rapidly in recent years (Table 5-2). Export value (and number of units exported) increased from $140 million (11,000 units) in 2015 to $340 million (55,000 units) in 2021. However, the average price of imports is $13,000 while the average price of exports is only $6,000 (both in 2021), suggesting that China is importing higher-end products while exporting lower-end products. In addition, the value and volume of exports to Japan are quite small. Japanese companies produce many industrial products in China and re-import the final goods back to Japan, but this appears to be different for industrial robots.

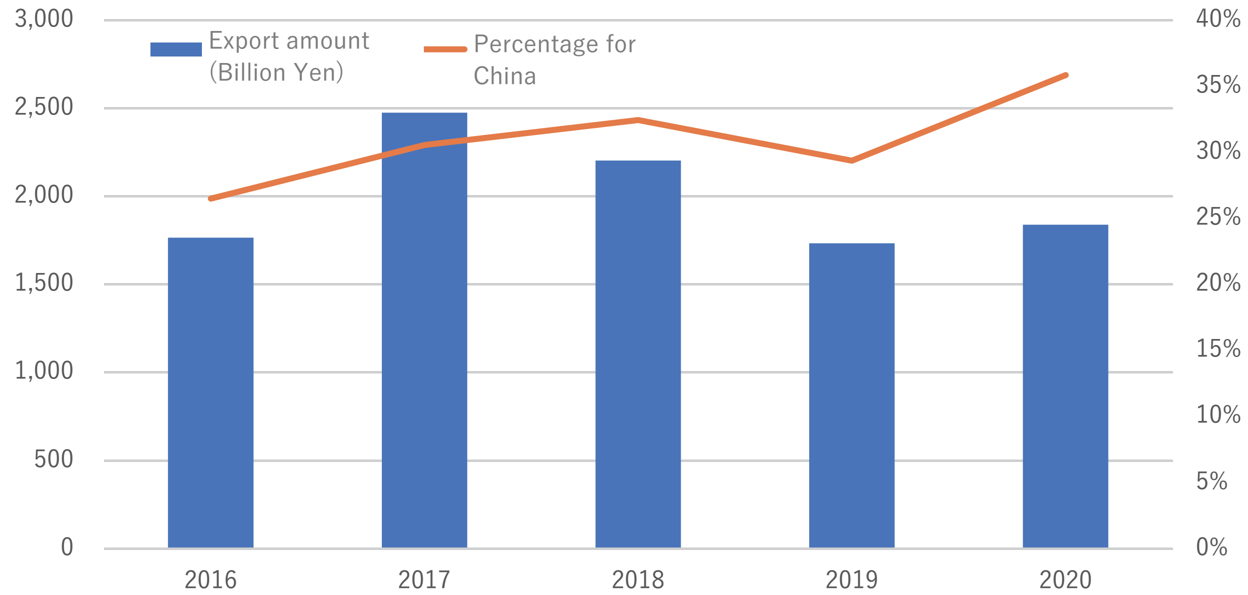
[81] International Import Export Trade Data Global Trade Atlas ¦ S&P Global (spglobal.com)

Table 5-2: China's Robot Exports

	Value (USD 1,000)	Volume (Units)	Price (USD 1,000/ unit)	Japan's share (value)	Japan's share (volume)	Price in Japan (USD 1,000/unit)
2015	144,449	11,807	12	6%	5% (of the total)	14
2016	155,929	44,211	4	4%	10% (%)	2
2017	208,517	28,300	7	3%	2%	13
2018	264,879	60,506	4	5% (of the total)	5% (of the total)	4
2019	240,355	105,604	2	5% (of the total)	5% (of the total)	2
2020	243,486	80,944	3	7%	3%	7
2021	342,087	55,466	6	6%	7%	5

Note: The HS code for industrial robots is 847950. Source: Prepared by the author based on Global Trade Atlas and the S&P Global database

From the Japanese side, China is the most important market for industrial robots. First, China is Japan's largest export destination for industrial robots. Figure 5-2 shows Japan's total industrial robot exports and the share of exports to China in this total. Japan's total exports are valued at approximately JPY200 billion per year, with the share for China expanding from 27% in 2016 to 36% in 2020. In addition, according to Ministry of Finance trade statistics, in terms of volume, Japan exported 54,545 robots to China in 2020, which is equivalent to 43% of all Japanese-made industrial robot exports. However, the unit price of robots exported to China is lower than those exported to the US and other developed countries. A simple calculation based on export value and export volume shows that the unit price of robots bound for China is only about 0.65 if the unit price of robots bound for the US is 1, suggesting that China is importing relatively low-end industrial robots from Japan.



Note: The HS code for industrial robots is 847950. Source: Prepared by the author based on Ministry of Finance Trade Statistics[82]

Figure 5-2: Japan's Robot Exports

In recent years, Japanese companies have also expanded their direct investment in China. FANUC, which has the largest share of China's industrial robot market, was reportedly set to invest a record JPY26 billion in 2021 to expand the size of its Shanghai robot factory by multiple of five.[83] According to FANUC FY2021 financial documentation,[84] capital expenditures increased by JPY22.5 billion over FY2020, and sales in the Chinese market account for 31.3% of total company sales. FANUC's Beijing subsidiary manufactures and sells computer numerical controls (CNCs), and its Shanghai subsidiary develops, manufactures, and sells robot systems. Yaskawa Electric Corporation, with bases in Shanghai, Beijing, Shenyang, Changzhou, and other cities, is engaged in the business of manufacturing and selling inverters, servos, controllers, and robot systems, and produces 18,000 industrial robots annually in Jiangsu Province. In June 2022, the new plant of Yaskawa (Changzhou) Machinery & Electric Integrated Systems began operations, supplying main components such as mounted substrates and electronic units. In addition, FANUC formed an industrial robot joint venture with Chinese consumer electronics giant Midea Group, and Yaskawa Electric did the same with Chinese steelmaker Shougang Group. These ventures are expected to significantly increase China's industrial robot production capacity, while at the same time transferring technology through joint ventures.

In order to acquire more advanced technologies, Chinese companies are aggressively pursuing outward mergers and acquisitions, and the field of industrial robots is no exception. In 2016, Midea acquired German robotics giant KUKA. This has given Chinese companies highly accurate industrial robot technology that automatically optimizes tasks through the power of software and networks, and sensor technology that monitors the surroundings to prevent accidents. KUKA's share of sales in the Chinese

[82] Trade Statistics of Japan (customs.go.jp)
[83] FANUC to expand robot factory in China, investing 26 billion yen: Nihon Keizai Shimbun (nikkei.com)
[84] https://www.fanuc.co.jp/ja/ir/announce/pdf/2022/reference202203.pdf

market grew from about 15% in 2016 to 25% in 2017 after the acquisition.[85] On the production side, a new site was established in Shunde District, Foshan, Guangdong Province, making it the third KUKA robot manufacturing plant, after the Germany and Shanghai plants, to begin operations at the end of 2019.

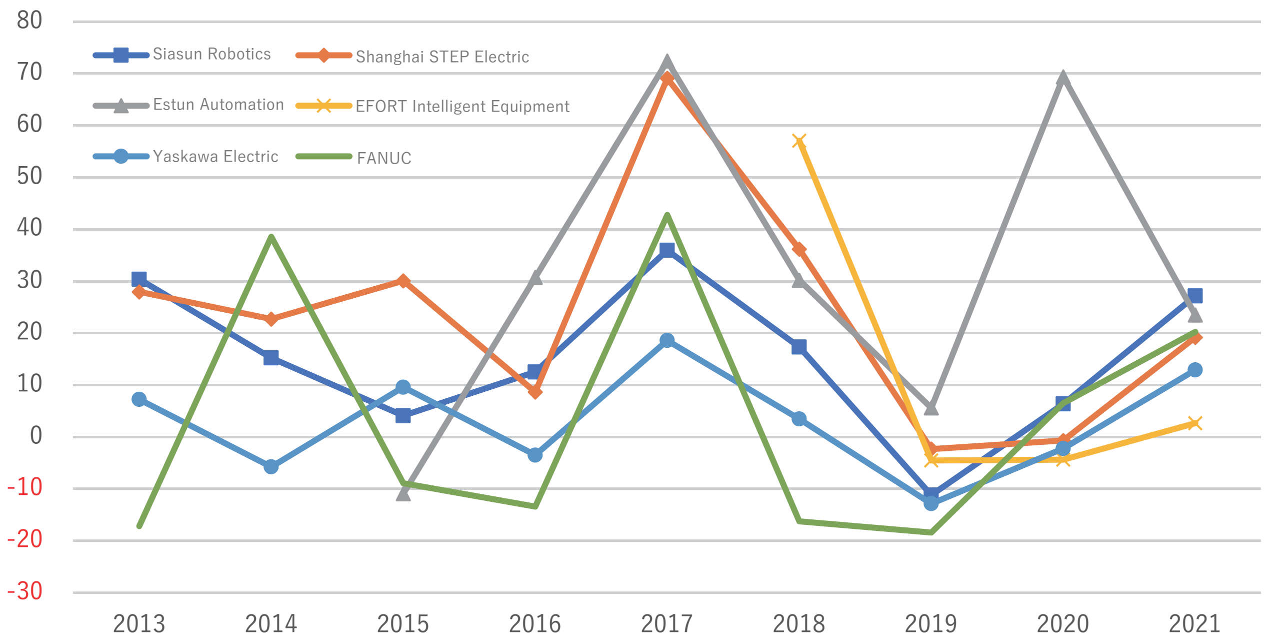
5.3 Chinese Companies Catching Up

Since the 2000s, as China's economy has grown, Chinese firms' productivity has increased and they have been catching up with Japanese firms. The catch-up of Chinese listed firms vis-à-vis Japanese listed firms is mainly led by the high-tech industry, and catching up with cutting-edge firms is found to be the most important factor in raising the TFP level of Chinese firms (Miyagawa et al., 2019). Focusing on industrial robot-related patent applications, it has been pointed out that the number of patent applications filed by Chinese firms is increasing and that their technology is approaching that of Japanese firms, while also accumulating technology through differentiation (Kimura et al., 2022).

This paper focuses on six Japanese and Chinese robot manufacturers that produced more than 2,000 industrial robots in 2018, and examines whether Chinese companies are catching up based on financial data from these listed companies. The six companies are Yaskawa Electric and FANUC (Japan), and Siasun Robotics, Shanghai STEP Electric, Estun Automation, and EFORT Intelligent Equipment (China). Of the Chinese companies, Siasun Robotics is a start-up company originating from the Shenyang Institute of Automation of the Chinese Academy of Sciences, and EFORT Intelligent Equipment is a company managed under the State-owned Assets Supervision and Administration Commission of the Wuhu Municipal Government of Anhui Province, and was listed in 2020. The remaining two Chinese firms are private companies. Each set of company data was obtained from the Orbis database.[86] This section provides a comparative analysis of each firm's sales growth rate, fixed asset growth rate, research and development (R&D) intensity, labor productivity, and return on sales from 2012 to 2021. As for KUKA, it was world-class company to begin with, and data is lacking, so it is not included in this analysis.

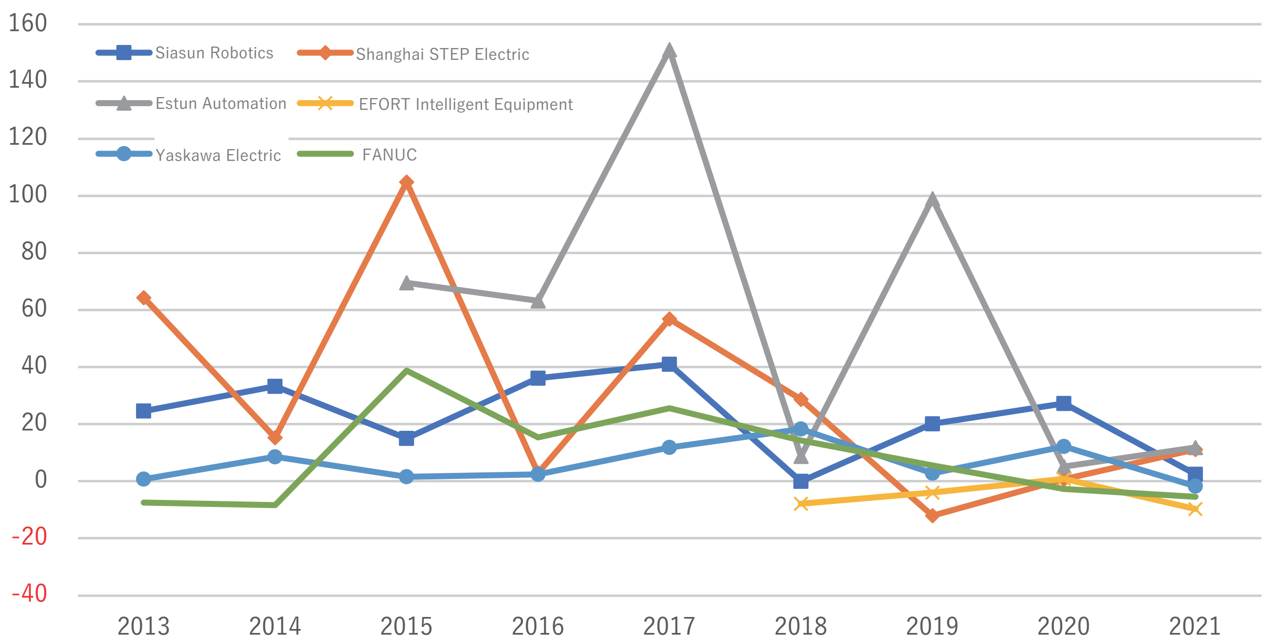
First, Chinese firms have higher sales growth rates (Figure 5-3) and fixed asset growth rates (Figure 5-4) in recent years than Japanese firms. In terms of sales growth, Siasun Robotics, Shanghai STEP Electric, and Estun Automation are particularly high. The average sales growth rates for the five-year period from 2017–2021 were 15% for Siasun Robotics, 24% for Shanghai STEP Electric, 40% for Estun Automation, 13% for EFORT Intelligent Equipment, 4% for Yaskawa Electric, and 7% for FANUC. In terms of fixed asset growth, Siasun Robotics, Shanghai STEP Electric, and Estun Automation are particularly high. The average sales growth rates for the 5-year period 2017–2021 were 18% for Siasun Robotics, 17% for Shanghai STEP Electric, 55% for Estun Automation, −5% for EFORT Intelligent Equipment, 9% for Yaskawa Electric, and 7% for FANUC. This can be understood as being caused by the rapidly expanding Chinese market.

[85] KUKA's Robots Gain Presence in China | Robot Insight | Rentec Insight | ORIX Rentec Corporation (orixrentec.jp)
[86] https://www.bvdinfo.com/ja-jp/our-products/data/international/orbis



Source: Prepared by the author based on the Orbis database

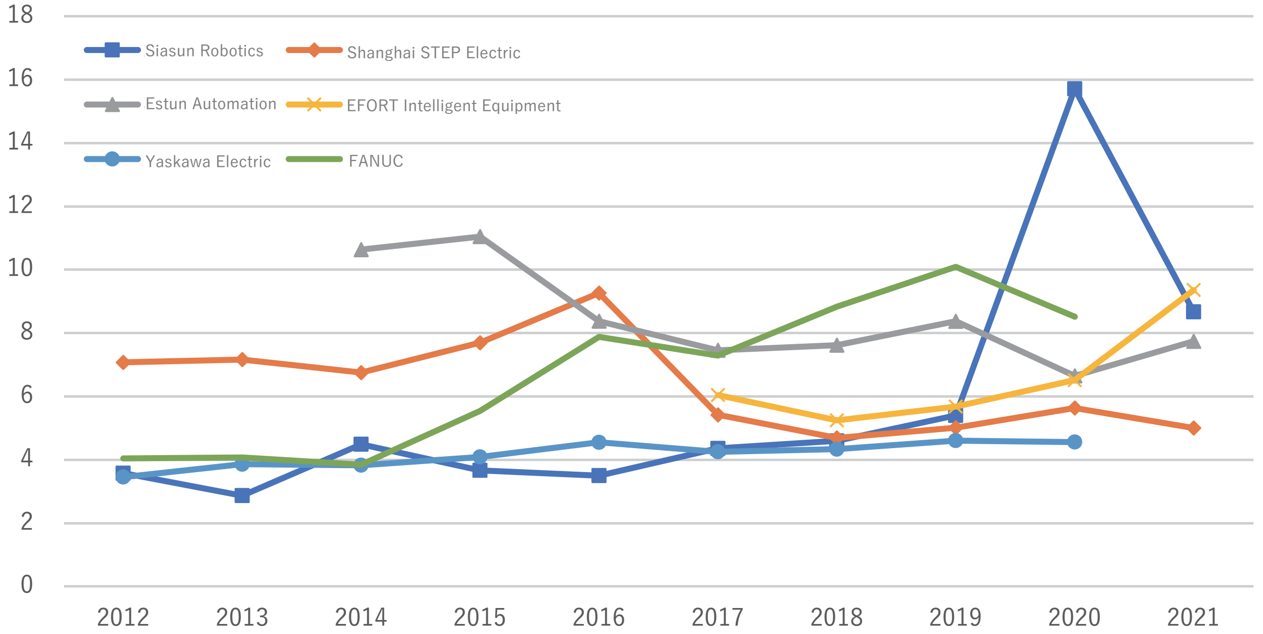
Figure 5-3: Sales Growth Rate (%)



Source: Prepared by the author based on the Orbis database

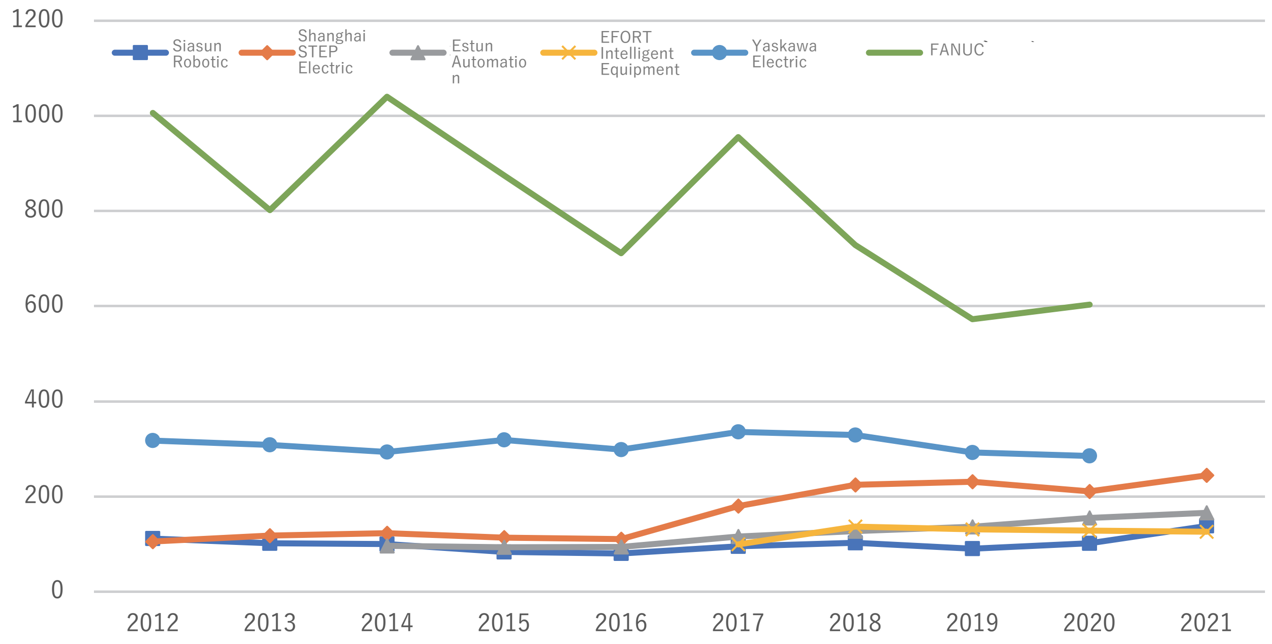
Figure 5-4: Fixed Assets Growth Rate (%)

Second, in recent years, the R&D intensity of Chinese firms has increased and reached a level almost equal to that of Japanese firms (Figure 5-5). The average R&D intensity for the 5-year period 2017–2021 was 8% for Siasun Robotics, 5% for Shanghai STEP Electric, 8% for Estun Automation, 7% for EFORT Intelligent Equipment, 4% for Yaskawa Electric, and 9% for FANUC (average for the 4-year period 2017–2020 for the two Japanese firms). On the other hand, labor productivity (sales/employees) of Chinese firms has been increasing very slowly in recent years, and still remains at a low level compared to Japanese firms (Figure 5-6). The average labor productivity (USD 1,000/capita) for the 5-year period 2017–2021 was 106 for Siasun Robotics, 218 for Shanghai STEP Electric, 140 for Estun Automation, 124 for EFORT Intelligent Equipment, 311 for Yaskawa Electric, and 715 for FANUC (average for the 4-year period 2017–2020 for the two Japanese firms). It is interesting to note that the state-owned enterprises Siasun Robotics and EFORT Intelligent Equipment have the lowest productivity. As of 2020, the labor productivity of Chinese firms was only 52% of Yaskawa Electric, 25% of FANUC, and about 30% of the average of the two Japanese firms.



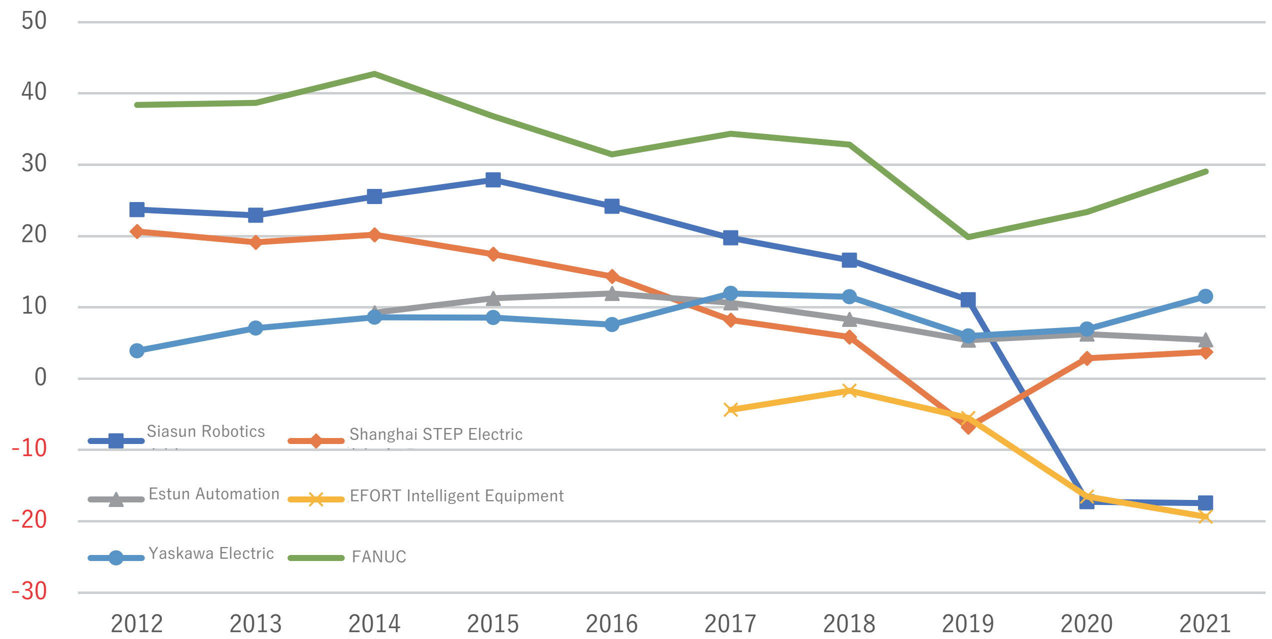
Source: Prepared by the author based on the Orbis database.

Figure 5-5: R&D Intensity (%)



Source: Prepared by the author based on the Orbis database.

Figure 5-6: Labor Productivity (USD 1,000/capita)



Source: Prepared by the author based on the Orbis database.

Figure 5-7: Ratio of Current Profits to Net Sales (%)

Finally, the return on sales of Chinese firms is considerably lower than that of Japanese firms, as is productivity (Figure 5-7). The average return on sales for the 5-year period 2017–2021 was only 3% for Siasun Robotics and Shanghai STEP Electric, 7% for Estun Automation and − 9% for EFORT Intelligent Equipment, compared to 10% for Yaskawa Electric and 28% for FANUC. Again, state-owned enterprises Siasun Robotics and EFORT Intelligent Equipment had the lowest return on sales as well as the lowest productivity. The profit margin of these two companies was more than − 17% for the second consecutive year in the COVID-19 pandemic.

Results shown in Figure 5-3 through Figure 5-7 collectively indicate that Chinese firms (especially state-owned enterprises) are still at low levels of productivity and return on sales compared to their Japanese counterparts, although in recent years Chinese firms have been catching up to their Japanese counterparts with high growth rates in sales and capital investment, and increasing R&D intensity and productivity.

5.4 Robotics Industrial Policy

5.4.1 Industrial Policy Goals and Outcomes

The Chinese government is actively using industrial policy to promote the development, production, and introduction of industrial robots. There have been three main industrial policies in recent years; in chronological order: the industrial policy "Made in China 2025" launched in 2015, the Robotics Industry Development Plan (2016–2020) in 2016[87] and the "145" Robotics Industry Development Plan announced at the end of December 2021.[88] Of course, these policies have been implemented consistently. The vision of these industrial policies is that by 2025, China will become the world's base for robot technology innovation and will have a cluster of advanced manufacturing and applications, and by 2035, its robotics industry will reach the world's top level of competence. In this section, we attempt to examine the problems of industrial policy while summarizing the goals and achievements of these industrial policies.

First, Table 5-3 summarizes targets and outcomes related to the number of industrial robots produced, operating revenues, and the ratio of robots installed in manufacturing industries. With regard to production volume and operating revenue, "Made in China 2025" and the 2016 Robotics Industry Development Plan specify that 100,000 industrial robots would be produced annually by 2020, and the "145" Robotics Industry Development Plan specifies an average annual growth rate of at least 20% in operating revenue by 2025. In practice, the production volume for 2020 was 212,000 units, more than double the target. In addition, since the sales growth rate (2017–2021 average) of four Chinese companies, including Siasun Robotics mentioned in Section 2, was about 23%, the 2025 target is expected to be achieved if the current situation continues. With regard to the ratio of robots in the manufacturing industry, "Made in China 2025" and the 2016 Robotics Industry Development Plan set a goal of achieving a ratio of 150 robots per 10,000 manufacturing employees by 2020, but by 2019 the ratio had reached 187 robots per million employees, achieving the goal ahead of schedule. According to the "145" Robotics Industry Development

[87] Ministry of Industry and Information Technology, National Development and Reform Commission, and Ministry of Finance (2016): 机器人产业发展规划（2016−2020）

[88] Ministry of Industry and Information Technology, National Development and Reform Commission, Ministry of Science and Technology, Ministry of Public Security, Ministry of Civil Affairs, Ministry of Housing and Urban Development, Ministry of Agriculture and Rural Areas, National Health and Welfare Commission, Ministry of Emergency Management, People's Bank of China, State Administration of Market Supervision and Control, China Banking Insurance Supervision and Control Commission, China Securities Supervision and Control Commission, National Defense Science and Technology Administration, State Migrant Safety Inspection Bureau (2021): China Banking and Insurance Regulatory Commission Notice of the "145" Robotics Industry Development Plan, Ministry of Economy, Trade and Industry (工信部联规 [2021], Vol. 206), 10p.

Plan, the target for the adoption ratio in 2025 is more than double that of 2020 (246 robots per 10,000 people). In practice, the growth rate of the adoption ratio from 2015 to 2020 was about 37%, which is expected to be achieved by 2023.

Table 5-3: Industrial Policy Goals and Outcomes (1)

	Production volume and operating revenue		Ratio of robots installed in the manufacturing industry (units/10,000 people)	
Year	Target	Outcome	Target	Outcome
2013				30
2015		32,000 units		51
2017		139,000 units		68
2019		177,000 units		187
2020	100,000 units	212,000 units, 100 billion yuan	150	246
2025	"145" target: Average annual growth rate of operating revenue 20% or more [Reference] Average growth rate of 2017–2021 sales of four companies, including Siasun Robotics, was about 23%		"145" target: more than double 2020 [Reference] Growth rate of introduction ratio from 2015–2020: 37%, expected to be achieved by 2023	

Source: Actual production volume and operating revenues are based on NBS, and actual installation ratio is based on IFR.

Prepared by the author based on various sources

Next, the domestic market share and leading company-related targets and results for independent brands and domestically produced core components are summarized at Table 5-4. As for the domestic market share of independent brands and domestic core components, according to "Made in China 2025" and the 2016 Robotics Industry Development Plan, the goal is very high, reaching 50% by 2020 and 70% by 2025. However, looking at the results for the period from 2015–2020, the domestic market share remained in the 20% range, showing no significant growth. The "145" Robot Industry Development Plan no longer sets a 70% goal, but instead sets goals for breakthroughs in core robot technologies, components, and high-end products, and for raising the performance of finished-product indicators and core components to the level of international advanced technology. Presumably, the goal of 50-70% domestic market share is almost impossible to achieve, so they have changed to a more realistic, albeit more ambiguous, goal. As for leading companies, the target was for three internationally competitive companies with annual production of 10,000 units or more and sales of 10 billion yuan by 2020, and for one or two companies to be among the world's top five by 2025. However, since this too will probably not be achieved, the goal under the "145" plan seems to have been changed to include a few internationally competitive companies and a number of little giant companies with innovation potential.

Table 5-4: Industrial Policy Goals and Outcomes (2)

	Domestic market share of independent brands		Domestic market share of core components produced in Japan		Leading companies	
	Target	Outcome	Target	Outcome	Target	Outcome
2015		29.4%				
2017		22.3%				
2019		28.7%		22~30% (2018)		
2020	100,000 units, 50%	45,000 units, 26.7%	50%	27%	Three internationally competitive companies with annual production of 10,000 units or more and sales of 10 billion yuan	
2025	"Made in China 2025" target: 70% for both "145" target: breakthrough in robot core technologies and components and high-end products; performance of finished-product indicators and core components at the international advanced level.				Made in China 2025: One to two companies in the world's top five "145" target: several internationally competitive companies and many little giant companies with innovation potential	

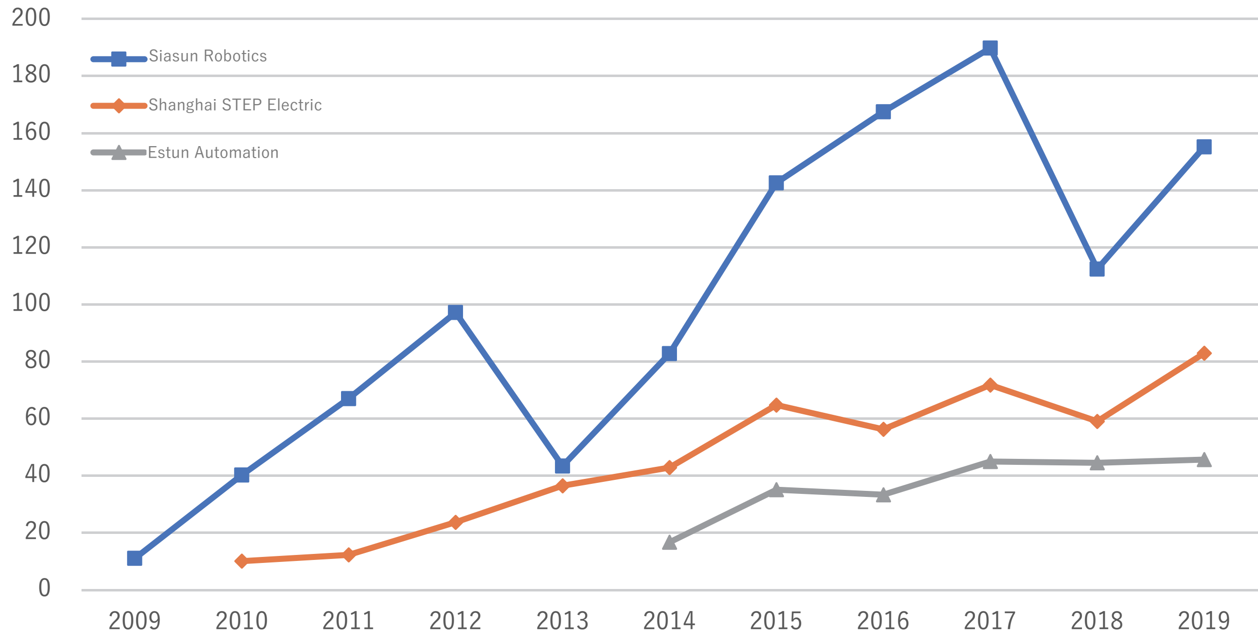
Source: Domestic market share results are based on IFR. Prepared by the author based on various sources

5.4.2 Industrial Subsidies

To achieve its industrial policy goals, the Chinese government is mobilizing a variety of policy instruments. For example, the number and value of industrial subsidies in China have increased rapidly in recent years, with 97% of listed manufacturing companies receiving at least one subsidy in 2019, and the average subsidy intensity reaching 1.8%. It is important to note that there are more subsidies for innovation activities such as R&D and patents than for employment and trade investment. As for the effects of subsidies, estimates show that companies receiving subsidies related to "Made in China 2025" have increased their R&D investment by 14.9% and the number of patent applications by 18.3% (and registrations by 24.9%) since 2015, compared to companies not receiving subsidies (Zhang, 2021a). These results suggest that industrial policies and subsidies such as "Made in China 2025" have had a certain effect on the expansion of innovation activities of Chinese companies in recent years.

This section focuses on industrial subsidies for industrial robots. A subsidy is a direct, gratuitous offer of property, including cash, by the central or local government to an enterprise. For listed companies, government subsidies have been recorded in accordance with the Corporate Accounting Standards since the 2006 revision of the same. The author estimates that the number of subsidies for robot R&D and implementation for Chinese listed companies increased from 47 in 2015 to 139 in 2019, and the total amount of subsidies increased from 4.6 billion yuan in 2015 to 15.4 billion yuan in 2019 (Zhang, 2021b). In addition, according to Chenget al. (2018) and Cheng et al. (2019), the subsidies (both total, innovation-related subsidies, and machinery and equipment-related subsidies) are more than three times higher for firms with robots compared to firms without robots, and many companies received subsidies for the introduction of robots.

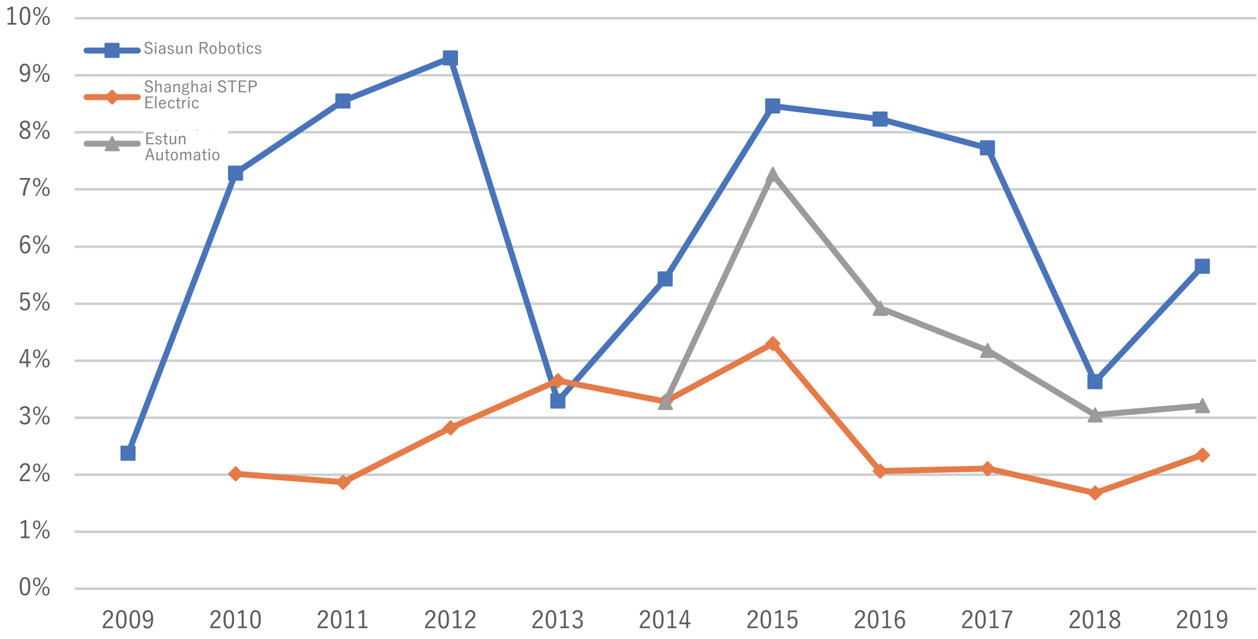
Of course, robot-related subsidies are provided directly to companies that develop and produce robots as well as to companies that install robots. Figure 5-8 and Figure 5-9 show the subsidy amounts and subsidy aggregates for Siasun Robotics, Shanghai STEP Electric, and Estun Automation. In recent years, the amount of subsidies has been on the rise, especially for the state-owned company Siasun Robotics. Subsidy intensity (subsidies/sales) is not on an upward trend; in 2015, it reached about 8% for Siasun Robotics, 4% for Shanghai STEP Electric, and 7% for Estun Automation, but by 2019, the intensity has decreased slightly, with about 6% for Siasun Robotics, 2% for Shanghai STEP Electric, and 3% for Estun Automation.



Note: No data available for EFORT Intelligent Equipment because it will be listed in 2020. Source: Prepared by the author based on the WIND database[89]

Figure 5-8: Subsidies to Industrial Robot Manufacturers (1 million yuan)

[89] https://www.wind.com.cn/portal/en/EDB/index.html



Note: No data available for EFORT Intelligent Equipment because it will be listed in 2020.

Source: Prepared by the author based on the WIND database

Figure 5-9: Subsidy Intensity for Industrial Robot Manufacturers (Subsidies/Sales)

The grants include a variety of projects (items). In reviewing the subsidies received by Siasun Robotics in 2018–2019, the highest subsidy item in 2018 was a software sales value-added tax refund (24.4 million yuan), the second highest was a subsidy from the Hangzhou Municipal Finance Bureau for setting up factories and other facilities in Hangzhou (20 million yuan), and the third highest was an was for R&D in the core technology of industrial robots and AI (14.7 million yuan). The highest subsidy project in 2019 was R&D and production base subsidies for industrial robots (33 million yuan), the second highest was software sales value-added tax refunds (26.37 million yuan), and the third highest was Industry 4.0 system solution platforms (24 million yuan).[90]

The above discussion does not indicate a causal relationship, but it does suggest that industrial policies, including subsidies, contributed to a certain percentage of the development, manufacturing, and introduction of robots by Chinese firms. Of course, industrial subsidies are not the only means of industrial policy. In the "145" Robotics Industry Development Plan announced in 2021, government support measures focused on fiscal and financial support. Specifically, (1) Strengthen support for robot R&D and applications in national major science and technology projects and key national R&D programs. (2) Exercise the role of government procurement and promote the creation and application of robots, along with improving the insurance compensation system for critical technologies and equipment. (3) Steadily implement tax exemptions for R&D investments. (4) Promote investment by industrial funds, and support stock listings. (5) "Industry fusion yield" (financing for key enterprises and key projects): encourage investment in robotics

[90] All sources are WIND databases.

manufacturers, and guide financial institutions in offering new services such as accounts receivable financing and supply chain financing, in pilot cities. Going forward, we will continue to focus on how the "145" Robotics Industry Development Plan is being implemented in concrete terms and what effects it will have.

5.5 In Conclusion

In recent years, the industrial robot market in China has been expanding rapidly. China's industrial robots rely heavily on imports and local production by foreign firms. Japanese companies are increasing their presence in the Chinese market through trade and investment, and there is ample room for further expansion in the future. At the same time, Chinese robot exports are increasing rapidly, and Chinese companies are actively transferring technology through joint ventures and outward mergers and acquisitions, which shows how this industry is developing.

Chinese firms are playing catch-up with Japanese firms. In terms of sales growth, fixed asset growth, and R&D intensity, Chinese firms have already grown to the same or higher levels as Japanese firms, while labor productivity and return on sales are still low compared to Japanese firms. For Chinese firms, it is imperative to increase productivity and profitability. Chinese firms are not likely to replace Japanese firms in the next three to five years, but in the long run, as in other manufacturing sectors, Chinese firms may catch up with firms in developed countries, including Japanese firms, and become more internationally competitive. Over the past two decades, Chinese companies have become very present in global industries, some of which include steel, shipbuilding, solar panels, and electric vehicles. Of course, behind this is the strong support of the Chinese government.

Since 2015, the Chinese government has implemented the industrial policy "Made in China 2025," the Robotics Industry Development Plan (2016–2020) and the "145" Robotics Industry Development Plan, and has actively supported Chinese companies in areas ranging from R&D and manufacturing to the introduction of robots. It is undeniable that industrial subsidies for this purpose have also had a certain effect. As a result, the number of industrial robots produced and the ratio of industrial robots installed far exceeded the target. However, it has been unable to achieve its target market share for independent brands and domestically produced core components, which is crucial, and the development of leading companies is also proving difficult. Major challenges remain in industrial policy.

Finally, although outside the scope of this paper's analysis, increasing geopolitical risks, such as US–China conflict, and economic and security concerns of various countries over the high-tech industry may have a significant impact on the development of China's robotics industry and trade and investment. We will need to continue to closely monitor how inward-looking policies, such as tighter export and investment restrictions on advanced technologies, components, and equipment, will affect the robotics industry.

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6 Data Protection and Utilization in China—Transitioning Away From "Savage Development"

6.1 Introduction: Is Data the New Oil?

There is a famous phrase: "Data is the oil of the 21st century." An early report was published in 2011, "Personal Data: The Emergence of a New Asset Class."[91] In the context of an era in which the widespread use of smartphones has made it possible to collect vast amounts of personal behavioral data, this term has attracted attention for deciding the direction of next-generation business. A little more than a decade later, the collection and utilization of data is facing barriers as well as progress. Commonly referred to as siloing (fragmentation), it is not easy to put together data that is stored separately. This can be categorized into personal data related to individuals and industrial data held by companies, but social consent has yet to be formed on how to protect privacy and obtain individual consent for the use of personal data. While companies were making progress in using data, another issue was the data holdings of giant IT companies and the lack of data distribution among companies.

The Japanese government proposed "Society 5.0" in 2016. The report envisions a future in which big data and new technologies such as artificial intelligence (AI), robotics, and automated driving will solve a variety of social issues, but one of the challenges facing cyberspace is that various types of data are independent and there is no data infrastructure to link these fields. This challenge is universal, and China is no exception. In recent years, breaking down "information silos" has been a recurring keyword in various administrative reforms, and Chapter 18, Section 1 of the 14th Five-Year Plan ([92]) addresses the establishment of data element markets. A series of related policy regulations have been issued since then.

This paper analyzes China's current state of data utilization and distribution and efforts for the future. It will also depict how China is trying to find a solution to this universal challenge of how to distribute data.

6.2 Use of Data Prior to Regulations

6.2.1 Leading Private Companies

Before tracing current efforts, we will first take a look at how China has promoted the use of data to date. Major private platform companies such as Alibaba Group, a major Chinese e-commerce (EC) company, and Tencent, a major messaging app and game company, have been leading the way.

91 "Personal Data: The Emergence of a New Asset Class," World Economic Forum, February 17, 2011. https://jp.weforum.org/reports/personal-data-emergence-new-asset-class/

92 新华社北京 3 月 12 日电 (2021): National 经济和社会发展第十四个五年规划和 2035 年远景目标纲要 , State Council of the People's Republic of China

"Humanity is moving from Information Technology (IT) to Data Technology (DT)"

Alibaba Group founder Jack Ma (Ma Yun) spoke at the International Conference on Big Data in Beijing in March 2014. Alibaba had been focusing on big data and cloud computing since 2009, five years before the lecture. He was proud of the new financial products that were created as a result.

Alibaba Group is home to the payment application Alipay. Originally an escrow service for secure online shopping,[93] it gradually established itself as a payment and remittance service. Since 2013, it can be used not only for online transactions but also for purchases in physical stores. It is the leading cashless payment service in China and is an innovation from that country, with similar services being used in Japan and other countries around the world. Furthermore, in 2013, a service called Yuebao was introduced. From the user's perspective, it was a dream service, as it could be handled like a savings account at a bank and still provide a much higher yield than a fixed deposit. At its peak, it attracted 1.69 trillion yuan, making it the world's largest MMF in terms of assets under management. As an investment product, there is a certain amount of risk, but it was advertised as being properly controlled by big data. How effective was this big data in risk management? The details of the service design have not been disclosed and are unknown now that the scale of the service has been greatly reduced by the authorities' regulations, which were put in place to reduce the risk of bankruptcy or other crisis. However, the 2015 releases of Zhima Credit and Huabei were truly the crystallization of data utilization.

Zhima Credit is what is called a credit score service, which calculates a score that is used as the basis for credit screening decisions. There are precedents, such as the FICO Score X Data[94] in the US; the credit score concept itself is not new. What was innovative was the calculation method. While existing credit scores were based on occupation, annual income, and loan repayment history, Zhima Credit calculates scores from a wide range of data, including online shopping, mobile payments, online relationships, assets held, and educational background. No human judgment intervenes in these calculations. While it is difficult to determine the availability of loans for informal workers and farmers using existing methods, it is possible to do so using big data on the Internet. Based on Zhima credit, individual users were provided with a line of credit, which could be utilized for Huabei, which converts Alipay payments into monthly installment payments. They could also access Jiebei, a consumer credit loan that users apply for from a smartphone, and for which payments are received immediately. Zhima credit scores were also used not only for financial products related to the Alibaba Group, but also for shared bicycles, appliance and clothing rentals, or free deposit screening for hotel stays, and identity verification for job hunting and matchmaking websites.

This Zhima credit has generated followers in countries around the world, and in Japan, the major messaging application LINE has developed a personal loan service called "LINE Pocket Money." The "LINE Score," a credit rating calculated by big data, is calculated to determine risk. The study reveals that "risk is higher if the number of friends is lower relative to the previous month," "risk is lower if the person

[93] A service in which a trusted "neutral third party" acts as an intermediary between contracting parties to ensure the safety of transactions, such as payment settlements, when goods are bought or sold. In the early days of online shopping, Alipay's ability to secure trust is said to have driven the growth of Chinese EC.

[94] https://www.fico.com/en/products/fico-score-x-data

sends messages in multi-person group chats," and "risk is lower the higher the value of gifts the person gives to friends." Mercari, an app for private sales of used goods, also offers monthly installment payments and consumer finance services, but employs a track record of buying and selling and whether the goods were shipped as promised when selling used goods as part of the financing decision.[95]

Services that allow IT companies to make credit decisions by utilizing their own user data are now commonplace. However, what sets Zhima Credit apart is the fact that it not only uses information obtained from its own services, but also data from related companies. To begin with, Ant Financial, which operates Zhima Credit, is a separate company from Alibaba Group. When Alibaba Group was listed in the US, it had to split off its financial services, which are only allowed for Chinese companies, and the related divisions are independent as separate companies with no direct equity ties. After going independent, Alibaba Group and Ant Financial were still set up to share user data held by each other in accordance with their data cooperation agreement. This agreement was dissolved in 2021 under the guidance of the government.[96] Other features include the collection and utilization of a wide range of data, including usage history of Weibo, a major social networking service in which Alibaba Group has a stake; its retail chains, and affiliated rental services; movie theater and hotel reservation sites; and even public data, such as court blacklists.

Alibaba Group is not alone in sharing data across companies. Major platform companies such as search giants Baidu and Tencent, food delivery giant Meituan, and short video app ByteDance have acquired or invested in an extremely broad range of data. While major US IT companies such as Google, Facebook, and Amazon offer services worldwide, the services they provide and the data they have access to are biased in terms of fields. In contrast, Chinese IT companies have succeeded in acquiring multifaceted data on China's domestic market, although their overseas operations are not as strong. In other words, it can be said that the distribution and utilization of data was realized in an economic sphere centered on certain platform companies.

6.2.2 Repeated "Savage Development" in the Use of Data

In China, there is often a contrast drawn between development that arises out of government plans and mechanisms (Chinese: "ordered development") and untamed development in violation of regulations ("savage growth"), but often the latter gives rise to powerful industries. In mobile phones, regular operators licensed by the government failed to grow, while operators that grew up outside of the industrial policy developed significantly. Taxi apps, which by law should be recognized as "white cabs" (unlicensed cabs), have become an indispensable part of the transportation infrastructure. Rental bicycle programs began as a guerrilla approach of scattering bicycles around the city. Data utilization also began as an example of "savage development."[97] The Chinese government is also taking a different stance, as exemplified by the phrase

[95] "90% of Consumer Finance Applied for via Smartphone Applications; Line also Involved in Payments and Borrowing," Nihon Keizai Shimbun, November 11, 2022. https://www.nikkei.com/article/DGXZQOUB09BC10Z00C22A8000000/

[96] "Ali and Macao stop the "数据共享协议"后会带来哪些影响," 21 Economy Network, July 30, 2022. http://www.21jingji.com/article/20220730/herald/916ea2a797fa0d0ab672e29cb4684f53.html

[97] Savage developments are detailed below. Kota Takaguchi (ed.) (2019), *China Class S and Class B Theory: A Country Where the Developing and the Cutting-Edge are Mixed*, Sakura-sha, p.248.

"wait and see first, manage later," to assess the advantages and disadvantages of innovations that emerge from regulatory gray zones over a certain period of time, rather than abruptly shutting them down. Some businesses were kept alive, such as car-delivery apps and shared bicycles, while others were completely banned, such as P2P finance (person-to-person lending via the internet) and cryptocurrencies. It is fair to say that the use of data by the private sector, in advance of regulations, has been under observation for a certain period of time.

But even if the government had taken a wait-and-see approach, would there have been any outcry from citizens? A statement by Baidu founder Robin Li (Li Yanhong) in March 2018 is instructive in this regard.

When data from different areas are gathered into one, their power grows. However, we are also well aware of privacy and data protection issues. In the past few years, China has become increasingly aware of the importance of these issues, and the relevant authorities have been cracking down more. On the other hand, this is also about how we think. Chinese attitudes toward privacy issues are more open. On the whole, the situation is not very sensitive. If they can obtain convenience, security, or efficiency in exchange for privacy, the Chinese will do so in many situations. Of course we adhere strictly to certain principles. We use data only when it is of benefit to the user and the user consents to its use. We believe this is the basic criterion that separates what we can and cannot do (with data).[98]

While other countries are becoming more cautious of companies' use of data, the report points out that in China, many people are willing to cooperate with the use of data if it provides a high level of convenience. Robin Li's remarks provoked a backlash, with many critics in the comments section of news sites and commentaries in state-owned media such as People's Daily and Xinhua saying that companies should be more careful in handling personal information.[99] On the other hand, there has been no movement to refrain from using IT services out of a sense of caution about data use. If asked whether they want to protect their privacy or not, anyone would say that they do, but on the other hand, the services offered are attractive. From the point of view of someone who is familiar with services in China and abroad, it is often felt that the convenience and accessibility of Chinese services, which consist of extensive data collection, exceeds that of other countries. The setup of enjoying services in exchange for data is common to those of us who use services such as Google and Facebook, but it may be said that the amount of data offered is proportional to the amount of services we get to enjoy.

These exchanges of data provision and convenience extend to a wider area. The most notable of these services are those that utilize blockchain technology. For example, there is a service that registers data on the qualifications, work history, and compensation of pesticide-spraying drone pilots and operators of boom lifts to better calculate insurance premiums and offer financing for equipment purchases and repairs,[100]

[98] Li Hikohong: 很多时候中国人愿意用隐私交换便利性 ," 财新网 , March 26, 2018. Available at: https://economy.caixin.com/2018-03-26/101226645.html

[99] The following article summarizes criticism of Robin Li's remarks by internet users and state-owned media. "Li Hikohong 言论发酵：媒体标题有断章取义之嫌，但百度也非清白之身 ," Sohu, March 28, 2018. https://www.sohu.com/a/226617509_250147

[100] Takeshi Yamaya, "China's Ant Group Leverages Blockchain for Work Truck Leasing Business," ZDNet Japan, December 7, 2022, https://japan.zdnet.com/article/35196983/

and a service that certifies the performance of nanny services.[101] SMEs and sole proprietorships that are not large corporations lack the means to prove their ability and creditworthiness. Using the technical characteristics of the blockchain's tamper-resistance, such businesses also have the advantage of being able to prove their track record and credibility. Therefore, service providers will provide their own data such as sales and work records in order to gain trust.[102]

The data thus gathered will also lead to the development of AI (artificial intelligence), which is expected to play a central role in the industry. Kai-Fu Lee, former Google China President and founder of Sinovation Ventures, one of China's leading venture capital firms for angel investment (investment in the early stages of a business), recognizes that AI development is becoming more favorable for China globally.[103] The development of AI algorithms requires three elements: big data, computing power, and talented people. Therefore, Chinese entrepreneurs in the AI business are in an advantageous position, he said.

This group of entrepreneurs has access to another "natural resource" of the Chinese technology world: an abundance of data. China's data production has already surpassed that of the United States. Not only because of the sheer volume of data, but also because of a technology system unique to China - a parallel universe of products and functions not found anywhere else in the world - the data is tailored to building profitable AI companies.[104]

He argues that the schema of data collection and utilization, formed mainly by IT companies, is a major weapon in the development of AI.

6.2.3 Industrial Data Distribution

The cases we have discussed so far have mainly involved personal data. Although not as numerous as personal data, there are many noteworthy examples of industrial data distribution.

A vivid success story is Cainiao, a logistics solutions company under the Alibaba Group.[105] While Alibaba Group outsourced its logistics to an external company, JD.com (Jingdong), China's second largest e-commerce company, achieved higher quality and speedier logistics standards by conducting logistics in-house. To counteract this, Cainiao was created in 2013 through a joint investment by Alibaba Group and several logistics companies.

[101] "栽诚科技进入母婴行业，打造母婴服务业诚信证明平台," Sohu.net, March 11, 2019. https://www.sohu.com/a/300446042_504894

[102] The People's Bank of China issued a notice banning cryptocurrency trading in September 2021. The broad prohibition on not only domestic transactions in China, but also on overseas exchange mediation and mining, is a clear statement of a total ban on cryptocurrencies that had been in a gray zone for many years. On the other hand, President Xi Jinping has not withdrawn his policy on blockchain, the underlying technology behind cryptocurrencies, as he indicated at a study session of the Politburo of the Communist Party of China in October 2019 that he will continue to emphasize it as an important breakthrough for innovation. While denying the application of cryptocurrency, China's policy trend should be to promote various applications that take advantage of the technology's tamper-proof characteristics.

[103] *See AI World Order: US and China Dominate in a 'Jobless Future'* by Kai-Fu Lee, translated by Motomi Ueno (2022), Nikkei BP, Chapter 1, section "The Age of Data" in the electronic edition.

[104] See Ibid, Section "Chinese Dominance" in Chapter 1 of the electronic version.

[105] Kota Takaguchi, "Whoever Controls Logistics Controls China's EC: Sparks Fly in 'Zero Redelivery' Competition; Alibaba Has an Address Book for All of China," Wedge Online, October 29, 2018. Retrieved from https://wedge.ismedia.jp/articles/-/14258

The company has emerged as a solutions company that does not handle logistics itself, but rather improves efficiency by integrating the transportation data of multiple companies. The same invoices are used to transport goods between different logistics companies, and data such as when and where the goods were received and delivered is also shared. In addition, an all-China address database has been established under the initiative of Cainiao. Using this system, addresses will be selected from a database instead of being handwritten, and will be completely standardized.

In recent years, the "industrial internet" has become a new focus for industrial data utilization. It is a Chinese version of Industry 4.0 proposed in Europe and the industrial internet proposed in the US, and is an effort to upgrade the manufacturing industry through the use of big data and AI. In this area, too, it was the IT platform companies that took the lead in the cloud computing business. Although cloud computing offers solutions developed by third-party companies as an option,[106] it integrates not only the digitization of manufacturing sites and the use of AI, but also the distribution of data with the upstream and downstream supply chain.

As a result, the industrial internet is inevitably becoming more closely linked to supply chain management. A number of major new supply chain management departments are being established at Chinese universities.[107] One of them, according to the official website of the Supply Chain Management major at the Guangzhou City University of Technology School of Management, introduces the major as "a new commerce major that integrates logistics, information, industrial and commercial management, marketing, e-commerce, finance, law, and big data technology."[108]

The term C2M refers to mechanisms to quickly analyze consumer needs and communicate them to production operators. Chinese e-commerce giant Pinduoduo has succeeded in offering a lineup of low-priced products by establishing a system that allows producers, who are subcontracted factories, to sell directly on the internet.

6.3 Data Element Market Reforms Eyeing Industrial Data and "Wait and See First, Manage Later" Regarding Person Information

6.3.1 China's Data Legislation

China, where "savage development" has driven the use of data, has in recent years been rapidly developing its laws. The data protection legislation is based on the National Security Law that came into effect in 2015 as a foundational law, followed by the Network Security Law in 2016, then the Data Security Law and the Personal Information Protection Law all at once in 2021, plus the Civil Code amendment adding data and privacy-related content.[109]

[106] Tencent Cloud's solutions introduction website: https://cloud.tencent.com/solution/industrial-interconnection
[107] Kota Takaguchi, "History of Modern Chinese 'Supply Chain Management.'" GEMBA, March 22, 2021, https://gemba-pi.jp/post-231636
[108] Official website of the Supply Chain Management Major, School of Management, Guangzhou City University of Technology https://gl.gcu.edu.cn/2021/0711/c3560a110848/page.htm

Symbolic as the first law passed, the National Security Law prioritizes national sovereignty in cyberspace and security, such as preventing data from leaking overseas. In the backdrop of this is the "Total National Security Paradigm." A year before the implementation of the National Security Law, in 2014, General Secretary (President) Xi Jinping proposed the "Total National Security Paradigm" at the first meeting of the National Security Commission of the Communist Party of China. He also pointed out 11 areas of security: political security, homeland security, military security, economic security, social security, science and technology security, information security, ecological security, resource security, and nuclear security.[110] He stressed the need for security not only on the military front but also in many other areas. The fact that information was also considered part of this process was the starting point for the development of data legislation from a security perspective. Afterward, data legislation would also cover individual rights and protection. The Personal Information Protection Law of 2021 will largely regulate the protection of personal data and the unregulated use of data by companies.[111] The law has a broad scope with a total of 74 articles, but this paper will focus on one of these articles in particular, which focuses on curbing "savage development" type data use.

Article 6 states that personal information should be collected to the minimum extent possible for the intended purpose and prohibits the collection of information for any other purpose. With the growing belief that data is a resource, excessive information gathering was widespread, especially with smartphone apps. Unbridled data collection was common, with lottery apps collecting communication records, asking for permission to access any information that can be gathered from a smartphone, even if the app was just a simple game such as playing cards.[112]

In addition, while the principle of obtaining voluntary consent for the collection and use of personal information was established, it was also included that clear consent must be obtained, consent must be obtained again when the method of collection and use is changed or the purpose is changed, and that the provision of services must not be refused when the provision of personal information is refused. The goal is to avoid a situation in which even basic services such as search applications cannot be used without consenting to the provision of various types of data.

The most significant impact from the perspective of data distribution is that it specifies that consent must be obtained from the company acquiring the data when providing the information to a third party, clarifying the recipient, purpose, and specific type of data to be provided. This can be understood as a certain halt to the economic sphere in which platform companies and other companies share data with each other.

Article 24 also incorporated provisions stating that automated decision-making using personal information shall be fair and equitable and shall not engage in price discrimination. In recent years, "killing

109 Matsuo, G. and Hu, Y., "Protection of Personal Information and State Data Use," in S.Ishimoto, G. Matsuo and A. Moriwaki (eds.) (2022), *China's Digital Strategy and Law: Locating China's Information Laws and Digital Society*, Kobundo.

110 习近平：坚持总体国家安全观 走中国特色国家安全道路 - 高层动态 ," Xinhuanet, April 15, 2014 http://www.xinhuanet.com/politics/2014-04/15/c_1110253910.htm

111 Zhonghua people's republic 个人信息保护法 " 中国大网 http://www.npc.gov.cn/npc/c30834/202108/a8c4e3672c74491a80b53a172bb753fe.shtml

112 Kota Takaguchi, "Data Utilization, From 'Savage Growth' to Conversion," Toa, January 2021.

with big data" (killing regular customers using big data) has often been considered a problem in China. When using personalized pricing (in which individual prices were offered to each customer based on data) was conducted, it was suspected that regular customers, including paying members, were offered higher prices because they were judged to be "more likely to purchase even at higher prices." Although no cases have been uncovered at this time, there have been many accusations of victimization on social media. There is a strong sense of the potential danger that rapidly-evolving AI and algorithms are taking away individual decision-making power and interests. In March 2021, China issued the "Internet Information Service Algorithm Recommendation Management Regulations,"[113] which mandates the establishment of fair principles for algorithm utilization and the registration of algorithms used by major companies with government agencies. The "Provisions on the Administration of Deep Synthesis Internet Information Services"([114]), which came into effect on January 10, 2023, stipulates that deep fakes, i.e., AI-generated videos, sounds, images, and likenesses, must not be used for illicit purposes; legal provisions for protecting personal information used in AI training must be observed; facial and audio data used for training must be notified to the provider and consent obtained; and computer-generated data must be clearly marked even when used for legitimate purposes. As AI continues to develop, the scope that data protection legislation must cover is expected to expand significantly. In addition, the new law also specifies measures against information leaks and the obligation of platforms to undergo a third-party evaluation of their personal information protection.

In addition, the Chinese government established the Personal Information Security Specification[115] in May 2018 (revised in 2020), referring to the European GDPR (General Data Protection Regulation). This was succeeded by the Personal Information Protection Law, which differs in that it provides extremely strong penalties for violators, with a maximum penalty of confiscation of illegal income and a fine equivalent to 5% of sales. Since the promulgation of the Personal Information Security Specification, the China Consumers Association has periodically published a list of offending apps and urged their correction, and it is expected that pressure to comply with the law will further intensify.

However, it remains to be seen whether there will be an effective halt to the use of data by the government. In 2022, a Shanghai police database was compromised,[116] which included names, addresses, birthplaces, ID numbers, phone numbers, criminal history information, and petition records. The Personal Information Protection Law stipulates that, in principle, state agencies must comply with this law, and are obliged to notify the person in question when handling personal information in a manner that does not interfere with the performance of their duties. Mandatory provisions, including leakage, are also imposed, as are corporate provisions. The leak revealed that the Personal Information Protection Law, which has a

[113] 互联网信息服务算法推荐管理规定 ," December 31, 2021
http://www.gov.cn/zhengce/zhengceku/2022-01/04/content_5666429.htm
[114] 互联网信息服务深度合成管理规定 , November 25, 2022
http://www.gov.cn/zhengce/zhengceku/2022-12/12/content_5731431.htm
[115] 个人信息安全规范国标填补规则空白 ,2018 年 5 月 14 日
http://www.cac.gov.cn/2018-05/14/c_1122776896.htm?from=singlemessage
[116] "In Possibly the Biggest Data Theft in Chinese History, Hackers Say They Stole Data on 1 Billion People from Shanghai Police," Bloomberg, July 4, 2022 https://www.bloomberg.co.jp/news/articles/2022-07-04/REHL1MDWRGG201

certain deterrent effect on companies, is completely ineffective against the police.

How should personal information held by the government be properly handled? The hottest topic at the time of this writing (late December 2022) is the data from the COVID-19 measures application. Strict COVID-19 control measures were in effect in China from early 2020 through December 2022, utilizing a smartphone app called Itinerary Code, a health code that integrates an individual's travel history, vaccination history, PCR testing history, temperature reports, and train and aircraft boarding records.[117] The app is rarely used anymore since COVID-19 have been relaxed, but some localities have indicated that they intend to use this app and data for future administrative services.[118] It will be interesting to see whether surveillance society using big data in the name of public health will end up being temporary or will continue in the future.

6.3.2 Data Distribution Legislation

With the passage of the Personal Information Protection Law, the rules of regulation and distribution have largely been established for personal data. Data can be divided into three main categories: personal data, public data held by governments, and industrial data held by companies. The 2015 "Platform for Action to Promote Big Data Development"[119] set a goal of completing a unified national government data platform by 2018 for public data, but this has not been achieved as of yet. However, some localities continue to open up their websites and application programming interfaces (APIs) for using public data. To give an example, the Shanghai Public Data Open Platform offers a collection of 5,345 data collections, 2,233 of which are available in the form of APIs.[120]

Although there have been delays in industrial data distribution, efforts to form a data element market were explicitly stated in the 2020 "Guiding Opinions on the Development of Industrial Big Data" and in the 14th Five-Year Plan, "Chapter 18, Section 1: Establishment and Development of Data Element Market Rules."[121] In response, the Comprehensive Reform Perspective General Plan for Factor Marketization Positioning, released the following year, positioned data as one of the five major production factors along with labor, land, capital, and technology.[122] Seki (2022) interprets the aims of the plan as follows: "In the transition process from a planned economy to a market economy that began at the end of the 1970s, the marketization of factors of production has lagged behind that of goods and services. As a result, the utilization efficiency of the factors of production is low, and to solve the problem, the government has positioned the 'reform of the marketization of the factors of production' as the top priority in the reform

[117] Takaguchi, Kota (2021), "The Falsehood of China's 'COVID-19 Containment'", Chuokoron Shinsha.

[118] "How many health records are on hold, where are your personal records?" Caixin, December 22, 2022. https://www.caixin.com/2022-12-22/101980698.html

[119] " 国务院关于印发促进大数据发展行动纲要的通知 ," August 31, 2015, http://www.gov.cn/zhengce/content/2015-09/05/content_10137.htm

[120] Shanghai Municipal Public Mathematical Statistics Development Platform https://data.sh.gov.cn/index.html

[121] 中华人民共和国国民经济和社会发展第十四个五年规划和 2035 年远景目标纲要 , March 13, 2021, http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm For Japanese translation, see JST official website https://spc.jst.go.jp/policy/national_policy/downloads/r_gvm_2022.pdf

[122] " 国务院办公厅关于印发要素市场化配置综合改革试点总体方案的通知 ," December 21, 2021, http://www.gov.cn/zhengce/content/2022-01/06/content_5666681.htm

of the economic system." While there is certainly an obvious need to promote marketization reform of the factors of production, the positioning of data as a major factor of production is a surprise. That being said, data can be copied and ownership is difficult to determine. Once it has been given to another party, it is difficult to control, and there is also the possibility that it will fall into the hands of another user and be used for purposes different from the original contract. Many countries, including Japan, are exploring market-based data distribution, but no country has yet found a definitive solution. In this sense, the issue can be evaluated as extremely challenging. The Chinese government seems to understand the difficulties, and while the goal is to make positive progress in the pilot region by 2023 for the other five major production factor reforms, the modest goal for data is to achieve symbolic results in the pilot region by 2025.

What specific efforts will be required? While things are still in the exploratory stage and the future is uncertain, local governments are competing to build data trading centers. Although 24 data trading markets themselves were established by the end of 2019, including the Beijing-Zhongguancun Shuhai Big Data Trading Service Platform in 2014 and the Guiyang Big Data Exchange in 2015,[123] each exchange appears to have little track record. Guiyang Big Data Exchange, which set a goal of 10 billion yuan per day in transaction value when it was first established, announced in August 2022 that its cumulative transaction value had finally surpassed 100 million yuan.[124] Big data exchanges had been on the downswing, but factor market reforms have brought back the enthusiasm. There are more than 80 data exchanges, of which nearly 30 involve provincial governments alone.[125]

The mechanisms of the individual exchanges are not unified at all, and the Guiyang Big Data Exchange is a very primitive market whose main functions are a mall in which sellers list their products, and a bulletin board where buyers post the necessary data. Miscellaneous data on residents of an area and video data from aerial photographs are sold, but there are almost no transaction records.

The Shanghai Data Exchange, on the other hand, is new, being established in 2021, and will provide data via API. A mechanism will be established whereby data held by other companies can be purchased for a fixed price via the exchange's computer program. Some data products have already been put up for sale, but in parallel, the company is also working on rules for data management, and it appears that the policy now is to continue test sales and build up rules rather than to actively promote data trading. What is unique is the cross-border data support of the Beijing International Big Data Exchange. In principle, China's data legislation requires that personal and industrial data held by companies be stored in China and restricted from being taken overseas. The Beijing International Big Data Exchange will serve as a third-party organization to confirm that there are no illegal acts in taking the data out of the country.

Since each of these exchanges offers completely different services, it is honestly impossible to say at this point which exchange's approach will become the mainstream, but it does indicate a path to follow. According to the China Institute of Information and Communications Research, the key to making data

[123] "Daju zue Baiqinshu," China Institute of Information and Communications Research, December 2021, p.52.
[124] 贵州数据流通交易平台交易额破亿元 "2022 年 3 月 6 日 http://www.gov.cn/xinwen/2022-08/06/content_5704442.htm
[125] "Addition to the National Integration of the National Index Trading Market System," National Development and Reform Commission, December 20, 2022. https://www.ndrc.gov.cn/xxgk/jd/jd/202212/t20221219_1343660.html

a factor of production is to collect the data, determine the rights holders, set a fixed price, and the place for transactions.[126] In other words, it is necessary to clarify to whom the rights and profits of certain data belong, and to provide a place where commercialized data can be sold and bought for a fixed price. Local governments will continue to create and explore exchanges in this direction.

In an attempt to correct this confusing situation, the "Opinion on the Further Performance of Data Element Functions through the Establishment of Data-Based Systems" was promulgated in December 2022.[127] It includes language that "strictly regulates the number of data exchanges" and "establishes a uniform national system of standards for data trading, safety, etc." It is assumed that they were concerned about the aforementioned data exchanges getting in each other's way. The text also states that "problems such as market monopolies caused by uncontrolled expansion in the data area of capital are to be prevented and regulated in accordance with the law." The content of the report is a cautionary tale about data distribution centered on platform companies.

How to get past the challenges related to data distribution is a global topic. Although China's efforts have been in full swing along with factor market reforms, issues such as "avoiding fragmentation due to prior local initiatives" and "avoiding monopolization by platform companies" have become clear. We are now facing the difficult problem of whether distribution can be achieved while getting around these issues.

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[126] "China's Digital Economy," China Institute of Information and Communications Research, April 2021, p.80.
[127] " 中共中央国务院关于构建数据基础制度更好发挥数据要素作用的意见," December 19, 2022. Available at: http://www.gov.cn/zhengce/2022-12/19/content_5732695.htm

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7 Brain Circulation in Basic Research Fields, and Trends in China's Space and Nuclear Energy Development

7.1 Brain Circulation under US–China Conflict

China is the world's largest supplier of highly skilled talent. On April 24, 2022, People's Network reported that the number of graduates from higher education institutions in 2022 will exceed 10 million for the first time, reaching 10.76 million. Institutions of higher education include specialized courses (junior colleges), universities, masters, and doctoral programs. While there were only 950,000 graduates in 2000, the number of higher education graduates has increased 11-fold over the past 20 years and is expected to reach 11.58 million by 2023 (Figure 7-1).

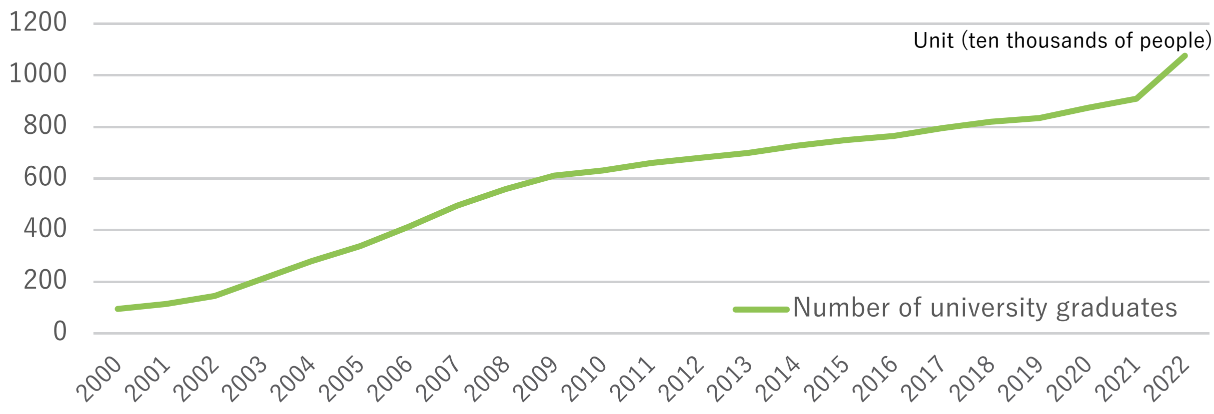


Figure 7-1: Number of graduates at Chinese institutions of higher education

The number of foreign students going overseas from China has also increased dramatically. The number of Chinese students in Japan has grown from just 1,000 in 1978, when the "reform and opening up" policy was launched, to 38,000 in 2000, and to over 700,000 in 2019. According to China's Ministry of Education, the cumulative number of foreign students from 1978, when reform and opening up began, to 2019 is about 6.56 million, and as of 2020, 1.65 million are continuing their studies and research abroad.[128]

The largest study destination is the United States, and foreign students are a valuable source of income for US universities. According to the American Association of International Educators (NAFSA),[129] the economic impact of international students in academic year 2021/22 was $33.8 billion and created 335,423 jobs. Approximately 30% of international students are Chinese students. In addition, Chinese

[128] http://www.moe.gov.cn/jyb_xwfb/gzdt_gzdt/s5987/201903/t20190327_375704.html,
https://www.afpbb.com/articles/-/3322732
[129] https://www.nafsa.org/

graduate students are not only research leaders, but also an important source of human resources for US companies. This is not limited to the giant IT companies of GAFAM (Google, Amazon, Facebook, Apple, Microsoft). Teruhisa Tsujino, former JAXA International Affairs Counselor, told the author that "the majority of engineers involved in the manufacture of rockets and satellites at NASA and SpaceX are Chinese and Hispanic," while a professor at the University of Tokyo's School of Engineering said, "A laboratory in the United States would not be possible without Chinese graduate students."

In recent years, however, the flow of foreign students from China to the United States has begun to change. In addition to the US–China conflict, the number of students choosing the US as their study destination has been declining due to fears of hate crimes during the COVID-19 pandemic. In fact, India has overtaken China as the leader in the number of visas issued for admission in September 2022. If this trend continues, it will inevitably affect global brain circulation, and not only between the US and China.

7.1.1 Latest Trends Among Chinese Students

The number of international students studying at US universities dropped sharply to less than 1 million in the 2020/21 academic year due to the COVID-19 pandemic. The number of students from China continues to decline, although it began to recover in FY2021/22. About 30% of foreign students in the US are from China, and 20% are from India (Table 7-1).

Table 7-1: Number of students and international students in the US (in 1,000 persons)

	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
Total number of students	20,185	19,831	19,828	19,720	19,744	20,327
Number of foreign students	1,079	1,095	1,095	1,075	914	949
China	351	363	370	373	317	290

Source: Open Doors[130]

The majority of Chinese students are in the natural sciences, especially engineering. Moreover, the numbers of graduate students (123,000) and students who continue their research work after graduation (51,000), called OPT (Optional Practical Training), are high compared to the number of undergraduate students (109,000), making them an indispensable force in university research laboratories.

Chinese students pursuing doctoral degrees in the US also account for about 10% of all doctoral degree holders, and 90% of them are in the natural sciences. This is almost three times that of India, which is in second place. Chinese researchers are deeply committed to the US science and technology research community. The number of Japanese is in the 100s (Table 7-2).

130 https://opendoorsdata.org/data/international-students/enrollment-trends/

Table 7-2: Number of PhDs Earned in the US

	2015	2016	2017	2018	2019	2020
Total	54,886	54,809	54,552	55,085	55,614	55,283
China	5,374	5,527	5,553	6,188	6,316	6,337
India	2,229	2,195	1,970	2,045	2,056	2,256
Japan	164	166	117	117	129	114

Source: NSF, survey of earned doctorates[131]

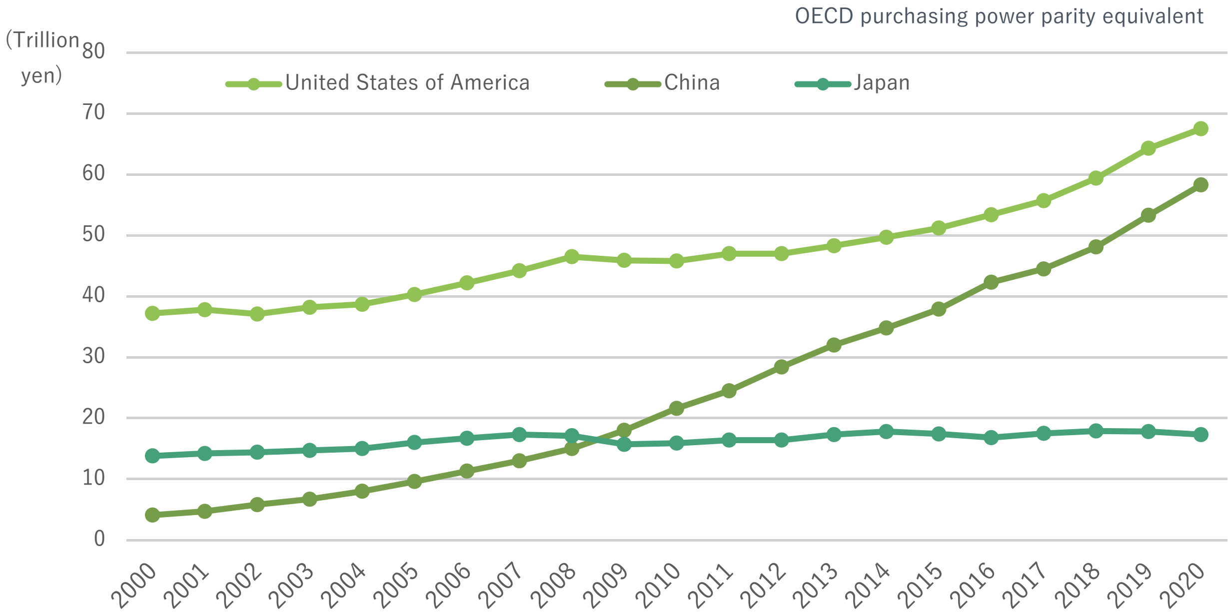
Although Chinese students' enthusiasm for studying abroad has not waned, the intensifying conflict between the US and China has led them to shift from the US, which had been the overwhelmingly most popular destination, to other countries. According to the "China Study Abroad Development Report (2000–2021)"[132] published by Southwestern University of Finance and Economics and the think tank Center for China and Globalization (CCG), "the spread of COVID-19 has not had a marked impact on Chinese students' study-abroad demand," but "we are entering an era of diversification in study destinations." Study abroad in the US had already been on a downward spiral since 2009, and "may reach a tipping point in FY2020," the report noted.

In addition, the "2021 White Paper on China Studying Abroad"[133] by major education-related company New Oriental reports that "the country with the most applicants as a study destination is the United Kingdom." In 2020, 29% of all applicants wished to study in the UK. Almost three-quarters of Chinese students go to four English-speaking countries: the United States, the United Kingdom, Canada, and Australia. An increasing number of foreign students are avoiding the US, which imposes visa restrictions, and Australia and Canada, where political conflicts continue, in favor of the UK, which has no visa restrictions. Furthermore, on February 28, 2019, the People's Daily[134] reported that there had been a marked increase in requests to study in European and Asian countries, with "Singapore and Japan being particularly popular." In addition to visa restrictions, security concerns due to COVID-19 prejudices, and high tuition fees, other reasons cited by Chinese students for avoiding the US include a deteriorating image of the US among Chinese youth.

7.1.2 China's Breakthroughs in Science and Technology

In terms of basic indicators of science and technology, China's research and development expenditures are closing in on those of the United States (Figure 7-2).

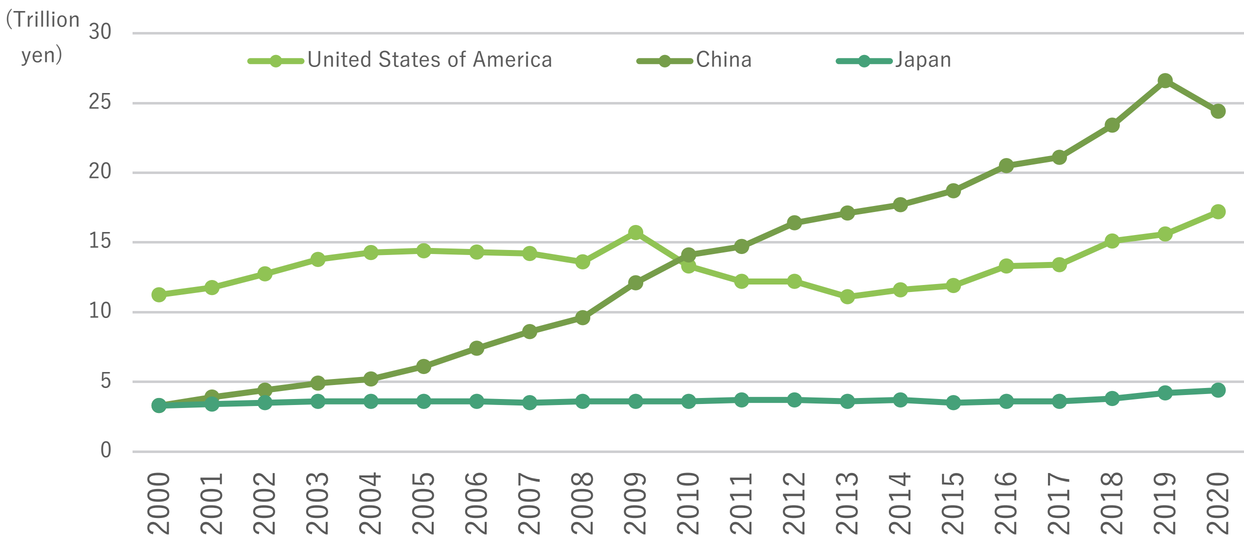
131 https://ncses.nsf.gov/pubs/nsf22300/report/temporary-visa-holder-plans
132 Wang Huiyao, Miao Green, 编著 (2022) China 國留学发展报告 (2020 ～ 2021), Social Science Literature Press, p.272.
133 Xin Dong Fang (2022): 2022 China Study Abroad White Book, Xin Dong Fang, 274p.
134 http://j.people.com.cn/n3/2019/0228/c94475-9550943.html,
https://www-overseas-news.jsps.go.jp/%e3%80%90%e3%83%8b%e3%83%a5%e3%83%bc% e3%82%b9%e3%83%bb%e4%b8%ad%e5%9b%bd%e3%80%91%e5%ae%89%e5%85%a8%e3%81%a8%e5%81%a5%e5%ba%b7%e3%81%8c%e7%95%99%e5%ad%a6%e3%82%92%e8 80%83%e3%81%88%e3%82%8b%e4%b8%8a/



Source: Science and Technology Indicators 2022

Figure 7-2: Total R&D Expenditures in the US, China, and Japan

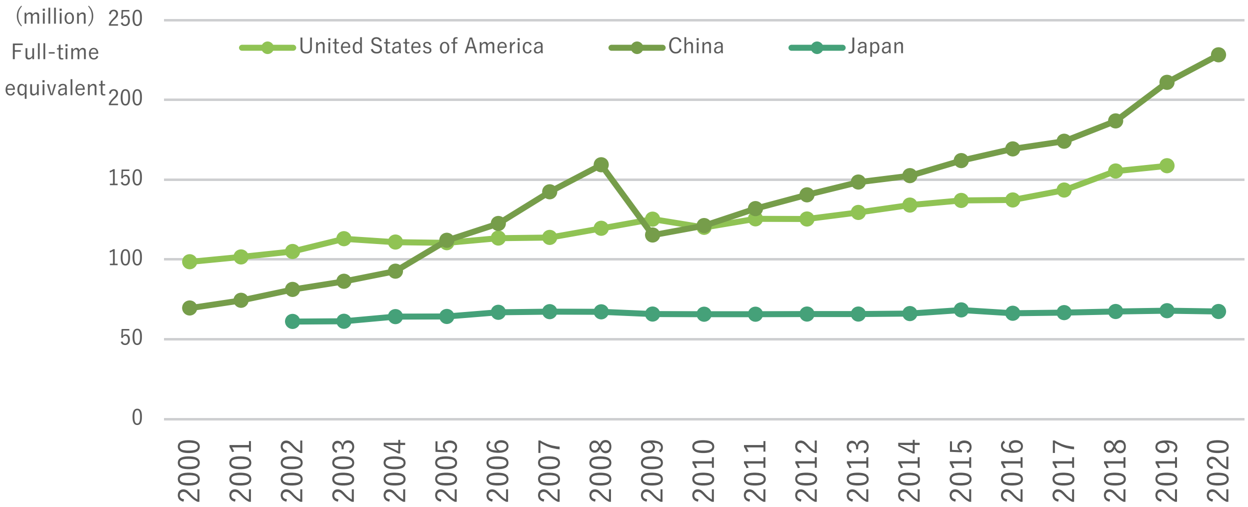
In particular, in terms of government spending on science and technology, China surpassed the US in 2010. It has been shown that scientific and technological achievements are positively correlated with the research and development expenditures invested (Figure 7-3). (The Crisis of Science Nation, Nagayasu Toyoda, Toyo Keizai, February 2019)



Source: Science and Technology Indicators 2022

Figure 7-3: Total R&D Expenditures in the US, China, and Japan

In terms of the number of researchers, China has more than 2.2 million researchers, compared to about 1.5 million in the United States. In his report to the 20th Congress of the Communist Party of China on October 16, 2022, President Xi Jinping emphasized the achievements of the country, saying, "We have accelerated the 'self-reliance and self-strengthening' of science and technology. The total research and development expenditures of society have increased from 1 trillion yuan to 2.8 trillion yuan, ranking second in the world, with the total number of research and development personnel ranking highest in the world." It is known that research output is proportional to the product of the number of researchers and research hours (Figure 7-4).



Source: Science and Technology Indicators 2022

Figure 7-4: Total R&D Expenditures in the US, China, and Japan

Research results are published in the form of papers. According to the "Science and Technology Indicators 2022"[135] published by the National Institute of Science and Technology Policy (NISTEP) in August 2022, China has overtaken the United States to take the top spot in the number of papers, the 10% most cited papers, and the 1% most cited papers of the highest quality, compared on a three-year moving average. In other words, China has achieved the triple crown in both quality and quantity. Especially for authors who have written high-profile, highly cited papers with a citation rate of 1%, Clarivate publishes the names of all researchers, their institutions, and countries of affiliation every year. By country, the US is in first place with 6,938 total authors, and China is in second place. China is growing while the US is declining. Japan is not even in the top 10 (Table 7-3).

[135] https://www.nistep.go.jp/research/science-and-technology-indicators-and-scientometrics/indicators

Table 7-3: Number of authors of top 1% most cited papers by country of affiliation

Rank	Country name	Number of researchers	Share (%)
1	USA	2,764	38.3
2	China	1,169	16.2
3	United Kingdom	579	8
4	Germany	369	5.1
5	Australia	337	4.7
6	Canada	226	3.1
7	The Netherlands	210	2.9
8	France	134	1.9
9	Switzerland	112	1.6
10	Singapore	106	1.5

Source: Clarivate Highly Cited Researchers 2022[136]

By institutional affiliation, the Chinese Academy of Sciences (Table 7-4) is close to Harvard University at the top of the list. Neither the University of Tokyo nor RIKEN are even in the top 50. Yoshinori Ohsumi, specially appointed professor and professor emeritus at the Tokyo Institute of Technology, who won the Nobel Prize in Physiology or Medicine in 2016, says, "China's scientific and technological capabilities are overwhelming." He cited the abundance of financial resources as a factor, saying that "decisions are made quickly because science and technology are promoted as a national policy." He also said, "I feel that there is less anxiety in Chinese society about being a researcher." (Business Insider, October 28, 2021)

Table 7-4: Ranking of the affiliations of the authors of the 1% most cited papers

Rank	Name of organization	Country name	Number of authors (persons)
1	Harvard University	USA	233
2	Chinese Academy of Sciences	China	228
3	Stanford University	USA	126
4	National Institutes of Health (NIH)	USA	113
5	Tsinghua University	China	73
6	Massachusetts Institute of Technology	USA	71
7	Max Planck Society	Germany	67
8	UC San Diego	USA	66
9	Oxford University	United Kingdom	63
10	University of Pennsylvania	USA	62

Source: Clarivate

136 https://clarivate.com/highly-cited-researchers/

7.1.3 Movement to Divide Brain Circulation under the Trump Administration

When the Trump administration took office on January 20, 2017, conflict between the US and China intensified. The New York Times reported on May 10, 2018 that the Trump administration planned to restrict visa issuance to Chinese researchers and restrict their participation in projects. On June 11, the US State Department published a notice stating that it would tighten visa screening in the technology sector related to "Made in China 2025." Visa restrictions were also extended to foreign students. Of the 10,313 publicly funded students who were scheduled to travel from China to the United States in 2018, 331 were not issued visas. On June 3, 2019, China's Ministry of Education issued the "2019 No. 1 Advance Warning for Study Abroad,"[137] making the unusual announcement that 182 (13.2%) of 1,353 students scheduled to study abroad from January to March were not issued visas, and also warned that there is a risk of "visa denial," "longer examination periods," and "shorter validity periods" for studying in the US. This quickly cooled the enthusiasm of Chinese students for studying in the United States.

Even within the US, there was opposition to visa restrictions on foreign students and researchers. Esther Brimmer, CEO of the American Association of International Educators (NAFSA), protested that "students should not be the bargaining chip," and Stephen Orlins, president of the US–China Commission, said, "This is tragic for the United States." On July 8, 2020, Harvard University and MIT filed a lawsuit against the Trump Administration seeking an injunction against restrictions on student visas.[138]

Regulatory tightening in the academic field continued thereafter. On August 13, 2020, the US Department of State designated the Confucius Institute US Center as an overseas mission of the People's Republic of China. There were 75 Confucius Institutes in the United States, 65 of which were located within universities. The US Department of Commerce also added Chinese universities to its sanctions list on December 18, 2020. In addition to the "Seven Sons of National Defence" (Beihang University, Beijing Institute of Technology, Harbin Institute of Technology, Harbin Engineering University, Nanjing University of Aeronautics and Astronautics, Nanjing University of Science and Technology, and Northwestern Polytechnical University), the sanctioned list has a total of 18 universities, including the University of Electronic Science and Technology of China, Sichuan University, National University of Defense Technology, Hunan University, Nanchang University, Renmin University of China, Tongji University, Xi'an Jiaotong University, Guangdong University of Technology, Beijing University of Posts and Telecommunications, and Tianjin University. It is highly unusual to add a university to the sanctioned list. In addition, on December 27, 2020, the US government revoked the visas of 1,000 people with concerns about their ties to the Chinese military. These included international students and researchers.

The arrest of Harvard University Professor Charles Lieber was the one that shook the scientific and technological community the most. Professor Charles Lieber is a world authority on nanotechnology and has received the Clarivate Citation Honor Award (2008), the Wolf Prize (2012), the Willard Gibbs Medal (2013), the Remsen Award (2016), the Welch Award in Chemistry (2019), and was a Nobel Prize candidate. On January 28, 2020, he was arrested by the FBI for covering up his involvement in the Chinese

[137] http://www.gov.cn/xinwen/2019-06/03/content_5397174.htm
[138] For example, https://www.newsweekjapan.jp/stories/world/2020/07/mit-5.php

"Thousand Talents Program" and received a guilty verdict on December 21, 2021. Other known names include Professor Feng Tao of the University of Kansas, Professor James Patrick Lewis of West Virginia University, Professor Xiao-Jiang Li of Emory University, Professor Qing Wang of Case Western Reserve University, Professor John Dong Chong of the University of Texas, and Professor Gang Chen of MIT. The prosecution is based on the fact that they received research funds from Chinese universities and other organizations but did not report them to the authorities.

At its annual meeting in February 2019, the American Association for the Advancement of Science (AAAS), one of the world's most prestigious scientific organizations, selected Professor Jian-Wei Pan of University of Science and Technology of China for its Best Paper Award, as the first person in the world to realize space quantum communication. Professor Pan is a favorite student of Anton Zeilinger, professor at the University of Vienna and winner of the Nobel Prize in Physics in 2022. However, the US government did not issue a visa to Professor Pan, and he was unable to attend the award ceremony. Michinari Hamaguchi, President of the Japan Science and Technology Agency (JST), who attended the annual meeting, said in a press briefing that "visa restrictions by the US government will undermine US science and technology capabilities in the long run."[139]

On January 20, 2021, the Biden administration took office. On August 25, 2021, the US Embassy in Beijing announced that it would issue 85,000 visas for Chinese students. At the same time, it issued a message stating, "Chinese students and researchers have contributed greatly to the diversity of the US, doubling in the past decade. We are proud of our personal ties with Chinese students," but it is unclear whether more Chinese students will go to the United States.

7.1.4 Brain Circulation and the Future of Scientific Hegemony

Suzuka University of Medical Science President Nagayasu Toyoda's book "The Crisis of Science Nation" (Toyo Keizai, 2019) is a good book that comprehensively analyzes the correlation between various indicators of science and technology, such as R&D expenditures, number of researchers, number of papers, number of citations, university rankings, and number of international patent applications. The most important point is that the data showed that "the number of academic papers is proportional to GDP." Academic papers are the engine of economic growth. What is needed, then, to increase the number of scholarly papers? The first is research and development spending. The book clarified that when governments increase R&D spending, the number of papers increases after a few years. Also, as companies increase their R&D expenditures, the number of patent applications increases. The second point is the number of researchers. The definition of "researcher" conforms to the OECD's Frascati Manual[140] and is not a so-called "head count." It is converted into "Full Time Equivalence (FTE)," the amount of time that researchers devote to their research. If China increases its R&D spending and number of researchers at the current rate, it appears certain to catch up with and surpass the scientific and technological capabilities of the United States sooner or later.

[139] Haruo Kurasawa (2020): China's Ambition for Science and Technology Hegemony: Space, Nuclear Power, and Huawei, Chuokoron Shinsha, p.252.
[140] OECD (2015): Frascati Manual 2015, OECD, 400p., https://doi.org/10.1787/24132764

There are already data that show how this trend is budding. The contributions of Chinese researchers affiliated with US universities and research institutions are boosting the scientific and technological power of the United States. According to the results of "hot papers" in the field of materials science by the Evidence Analysis Office of the Japan Science and Technology Agency (JST), which show a rapid increase in the number of citations in a short period of time, 12 out of a total of 41 (about 30%) are researchers of Chinese origin. Although the survey only covers the field of materials science, it shows that Chinese researchers are making important contributions to cutting-edge scientific fields in the United States.

On the other hand, the number of US students studying in China has plummeted even more than the number of students from China studying in the US has declined. In the 2011/12 season, 14,887 US students were studying in China, while there were only 2,481 in 2019/20 and 382 in 2020/21, showing a significant decrease. Of course, the Chinese government's "zero-COVID policy" against new COVID-19 infections certainly had an impact, but the decline in the number of American students may lead to a long-term decline in mutual understanding.

Changes are also evident in international coauthored papers. According to "Benchmarking Scientific Research 2021 (NISTEP),"[141] the 2017–2019 moving average of international coauthored papers as a percentage of all papers originating in the United States was 45.5%. China was the top destination for international co-authorship at 27.4%, far ahead of the UK in second place at 14.0%. By field, China was also top in all of the eight fields of chemistry, materials science, physics, computers and mathematics, engineering, environmental and earth science, clinical medicine, and basic life sciences, with clinical medicine as the exception, in which it ranked second. However, according to an analysis conducted by the Yomiuri Shimbun and National Institute of Natural Sciences Specially Appointed Professor Amane Koizumi, international coauthored papers between the US and China in eight of the 27 fields, including materials science, energy, and computing, decreased by 14%–25% in 2021 compared to 2019. (Yomiuri Shimbun, November 6, 2022)

It is difficult to determine whether these changes are a long-term trend, as they are partly due to the effects of COVID-19. However, the possibility that geopolitical changes will affect brain circulation in the scientific and technological fields cannot be denied. In fact, JST President Kazuhito Hashimoto said at a press briefing on August 23, 2022, "We have been approached several times by those seeking scientific and technological cooperation with Japan due to geopolitical changes."[142]

7.2 China's Space Exploration Making Great Strides

7.2.1 "He who controls space controls the future."

Space exploration is also a barometer for measuring a country's scientific and technological capabilities (Table 7-5). China has made remarkable strides in the space field, including the development of rockets and satellites, manned spaceflight, space experiments, and planetary exploration. The "space race" between the US and the Soviet Union that unfolded in the wake of the "Sputnik Crisis" in 1957 ended in

141 https://www.nistep.go.jp/wp/wp-content/uploads/NISTEP-RM312-FullJ.pdf
142 Haruo Kurasawa (2022): No More to See: Japanese Science is the 'Galapagos,' FACTA ONLINE, pp. 60-62.

victory for the United States with the manned lunar exploration of the Apollo Program. Today, at the beginning of the 21st century, China has emerged as a rival to the United States in this area. China's first successful manned space flight was in 2003 with Shenzhou 5. Following in the footsteps of the former Soviet Union and the United States, the country single-handedly developed rockets and spacecraft capable of sending humans into outer space and sustaining life. In 2021, the 100th anniversary year of the founding of the Communist Party of China, China successfully sent a probe to the surface of Mars. Currently, both China's "Tianwen-1" and the US's "Perseverance" are continuing their explorations on the surface of Mars, symbolizing the "space race" between the US and China.

In his speech at the 20th Party Congress, President Xi Jinping first mentioned "manned space flight" and "lunar and Mars exploration" as achievements in the space field. For China, space development is an instrument of national prestige. Space is also a "war-fighting domain." China considers earth observation satellites (the "eyes" of space), communications satellites (the "nerves" of space), and navigation and positioning satellites to be its "space infrastructure," and considers protecting them to be a key national security issue. Zhang Ji, general designer of China Aerospace Science and Technology Corporation, who is responsible for the development of Long March 9, which will be used for manned lunar exploration, said in March 2019, "Whoever controls space controls the future."[143] Will the US or China win the "future"? The curtain has been drawn on the "second space race."

Table 7-5: History of China's Space Program

1957	Soviet Union successfully launches first satellite, Sputnik
1969	US Apollo 11 achieves the first manned lunar landing
1970	China successfully launches its first satellite, Dong Fang Hong 1, on Long March 1.
2000	Navigation and positioning satellite Beidou-1 successfully launched
2003	Shenzhou-5 makes China's first successful manned space flight
2007	Chang'e-1 successfully enters lunar orbit
2011	Tiangong-1, China's version of a space station, is successfully launched
2019	Chang'e-4 successfully makes a soft landing on the far side of the Moon
2020	Navigation satellite system Beidou is completed
2021	Mars explorer "Tianwen-1" makes a successful soft landing

7.2.2 Completion of China's Space Station Tiangong, and the Future of Space Experiments

China's manned space flights began in 2003, some 40 years after the US and the Soviet Union. As of the

[143] https://www.recordchina.co.jp/b658407-s0-c30-d0142.html#:~:text=%E9%80%B2%E5%B1%95%E2%80%95%E4%B8%AD%E5%9B%BD%E3%83%A1%E3%83%87%E3 %82%A3%E3%82%A2-,%E7%B1%B3%E3%82%A2%E3%83%9D%E3%83%AD5%E5%9E%8B%E3%81%AB%E5%8C%B9%E6%95%B5%E3%81%99%E3%82%8B%E8%83%BD%E5%8A%9B%E3 80%81%E4%B8%AD%E5%9B%BD%E3%83%BB%E9%95%B7%E5%BE%81,%E9%A0%86%E8%AA%BF%E3%81%AB%E9%80%B2%E5%B1%95%E2%80%95%E4%B8%AD%E5%9B%BD%E3%83 A1%E3%83%87%E3%82%A3%E3%82%A2&text=%E4%B8%AD%E5%9B%BD%E8%88%AA%E5%A4%A9%E7%A7%91%E6%8A%80%E9%9B%86%E5%9B%A3%E3%81%AE,5%E5%9E%8 B%E3%81%AB%E5%8C%B9%E6%95%B5%E3%81%99%E3%82%8B%E3%80%82

end of September 2022, their astronauts have stayed in space for a cumulative total of 1,341 days, ranking fourth in the world after Russia, the United States, and Japan. With the full-scale operation of China's space station Tiangong, scheduled for the end of 2022, Japan's 346-day lead will be reversed in one year.

Tiangong is the "national space laboratory." Although small, with a total mass of about 80 tons (roughly one-fifth of the International Space Station [ISS]'s 420 tons), it is composed of state-of-the-art modules and spacecraft. The core module Tianhe (22.6 tons), which controls the whole system, two experimental modules Wentian (23 tons) and Mengtian (23 tons), plus the manned spacecraft Shenzhou (7.8 tons), the unmanned supply ship Tianzhou (about 13.5 tons) and the space telescope Xuntian (about 20 tons). To launch modules weighing more than 20 tons, the Long March 5B was developed with a low-orbit transport capacity of 25 tons.

Tianhe was launched on April 29, 2021, Wentian on July 24, 2022, and Mengtian on October 31, 2022. The three modules were reconfigured in space in a T-shape, and on November 30, Shenzhou 15 docked with Tiangong and successfully established a three-ship structure with Shenzhou 14, which was already connected. This is the first time that six astronauts have stayed in space at the same time, and Tiangong will soon be officially operational.

Space experiments in microgravity environments cover a wide range of fields including life science, materials science, drug discovery, microgravity physical science, earth science, and astronomy. Of particular importance are studies of human bodily functions in microgravity, biological effects at the cellular level, and gene expression. The three astronauts who spent about six months in Tiangong aboard Shenzhou 14 conducted experiments covering nearly every physiological system in the human body, including cardiovascular, bone, muscle, immune system, biorhythms, and behavioral history. The objective is to obtain basic data for future long-duration stays in space. Seeds of various plants, including Arabidopsis thaliana (thale cress), have also been brought to Tiangong for germination experiments.

Tiangong is attracting attention because of the uncertain future of the US-led ISS. The ISS will reach the end of its life in 2024, but the Biden administration announced on December 31, 2021, that it will continue operations until 2030. In response, NASA announced on February 1, 2022, that it would turn over operations after 2024 to the private sector and, after the end of operations in 2030, reenter at Point Nemo in the Pacific Ocean for disposal.[144] About 250 astronauts have stayed on the ISS so far, and more than 3,000 space experiments have been conducted. However, the Russian-made Zarya module launched in 1998 and the Zvezda module launched in 2000 are aging rapidly, and there are unresolved concerns that they will pose operational problems. On December 15, 2022, a coolant leak occurred on the Russian spacecraft Soyuz MS-22 while docked to the ISS, and extra-vehicular activities in the Russian compartment were suspended.

There are also concerns that the US–Russia confrontation following Russia's invasion of Ukraine could hinder disposal if Russian cooperation is not forthcoming. The ISS is controlled by Russian technology. In the United States, space ventures Blue Origin and Nanoracks, as well as major aircraft manufacturer Northrop Grumman, are planning successor aircraft, but the future is uncertain. If the life of the ISS

[144] https://www.nasa.gov/sites/default/files/atoms/files/2022_iss_transition_report-final_tagged.pdf

cannot be extended, space experiments will surely come to be monopolized by Tiangong.

7.2.3 The US–China "Space Race" for the Moon

The competition for the first manned lunar exploration of the 21st century is also intensifying. Chang'e-4 made its first successful soft landing on the far side of the moon on January 3, 2019 (Table 7-6). On March 27, US Vice President Pence revealed this rivalry, saying, "China became the first nation to land on the far side of the Moon and revealed their ambition to seize the lunar strategic high ground and become the world's preeminent spacefaring nation."[145] He then emphasized that "the first woman and the next man on the Moon will both be American astronauts, launched by American rockets, from American soil," and worked to launch the Artemis manned lunar exploration program. With the aim of sending a manned lunar mission in 2025, the unmanned spacecraft Orion was launched on November 16, 2022 by a new Space Launch System (SLS) rocket, and after orbiting the Moon, returned to Earth on December 11. This year marks exactly 50 years since Apollo 17 completed the last manned Moon mission.

China's Chang'e lunar exploration program is entering its fourth phase. The first phase, "繞," is the insertion into lunar orbit, the second phase, "落," is the soft landing on the Moon, and the third phase, "回," is the sample return. The plan has gone according to schedule, and Chang'e-5 successfully brought back 1,731 grams of lunar samples. Analysis is now underway, and a Chinese research group announced in January 2022 that it was the first in the world to directly confirm the presence of water.

Table 7-6: Chinese Lunar Exploration Projects

October 24, 2007	Chang'e-1 successfully launched to observe the Moon's surface from lunar orbit
October 1, 2010	Successful launch of Chang'e-2 to observe the Moon from a distance of100 km
December 2, 2013	Successful launch of Chang'e-3 and soft landing on the Moon
December 8, 2019	Successful launch of Chang'e-4, soft landing on the far side of the Moon
November 24, 2020	Successful launch of Chang'e-5, successful sample return

The mission of the fourth phase by Chang'e-6, 7, and 8 is to build the basic structure of the "International Lunar Research Station." China plans to build a scientific research base by 2035 in a part of Antarctica that may have water. The "basic structure" that Phase IV aims to build includes a "lander," a "lunar rover," a "flying probe," and a "suborbital orbiter." In addition to using nuclear batteries as an energy source, the project plans to build a communication network, transportation, and life-support systems, including space suits. The use of "regolith" (loose dirt) for the construction of the structure is also being considered. The first group of the fourth phase, Chang'e-6, has already been completed and aims to return samples from the far side of the Moon. Since communication with the ground is not possible on the far side of the Moon, the operation of Chang'e-6 is designed to be fully autonomous.

Development of the large rocket Long March 9, which will send a human to the Moon, is also underway.

[145] https://trumpwhitehouse.archives.gov/briefings-statements/remarks-vice-president-pence-fifth-meeting-national-space-council-huntsville-al/

The Long March 9 is comparable to the "Saturn V" used in the Apollo program, with a projectile capacity of 150 tons in low Earth orbit and 50 tons in Earth-Moon transfer orbit, and is said to be planned to be used to explore Mars, Jupiter, and asteroids.[146]

On November 21, 2022, Wu Weiren, a Chinese engineer and chief designer of China's lunar exploration program, specified for the first time the timing of a manned flight to the Moon, saying, "The basic structure of the lunar scientific research base will be completed around 2028."[147] Considering that NASA's Artemis mission is running behind schedule, it is becoming a delicate situation as to which of the two countries will succeed in completing the first manned lunar mission of the 21st century.

7.2.4 The Future of the "Second Space Race"

The advantage of the US is its overwhelming private-sector vitality and the existence of space ventures known as "NewSpace." China moved into the lead in satellite launches in 2018, but SpaceX's launches are on track to surpass China's in 2022. Broad international cooperation is also a forte of the United States. The Artemis Pact has already reached 20 member countries, including the United States, Japan, Canada, the United Kingdom, Italy, and France. China has found no influential partners other than Russia.

On the other hand, China's strengths include rapid decision-making by the Communist Party of China and abundant financial and human resources. In an interview with the author, Mr. Teruhisa Tsujino, former counselor in JAXA's International Affairs Department, explained the reason for China's breakthrough: "It is the result of their willingness to learn humbly from developed countries, to thoroughly investigate the causes of their failures, to make sure they get things done, and they make good on their promises." Manned exploration of the Moon is not the end of the story. The "Second Space Race" will continue with a sample return from Mars and a manned flight to Mars.

7.3 The Road to Becoming a Nuclear Superpower

7.3.1 China's Diverse Reactor-Type Strategy

The first commercial nuclear power plant in the United States, the Shippingport Atomic Power Station, reached criticality on December 2, 1957. Earlier, a graphite-moderated gas-cooled reactor (Calder Hall type) had started commercial operation in the UK in 1956. China began research in the early 1950s, but it was not until April 1994 that its first nuclear power plant, the Qinshan Nuclear Power Plant, went into operation. Thirty-seven years after the US, it became the 30th country in the world with nuclear power plants (Table 7-7).

[146] Although the exact specifications cannot be determined, they are listed below. https://baike.baidu.com/item/%E9%95%BF%E5%BE%81%E4%B9%9D%E5%8F%B7%E8%BF%90%E8%BD%BD%E7%81%AB%E7%AE%AD/7335935?fr=aladdin
[147] For example, https://spc.jst.go.jp/news/221104/topic_3_04.html

Table 7-7: History of Nuclear Development in China

1950	The Chinese Academy of Sciences Jindai Physics Institute begins nuclear research and development
1955	Sino-Soviet Atomic Energy Agreement concluded
1960	China conducts first nuclear test
1968	China conducts first hydrogen bomb test
1985	Qinshan Nuclear Power Plant construction begins
1994	Qinshan Nuclear Power Plant begins operations

According to the "China Nuclear Power Development Report 2022”[148] published by the China Nuclear Energy Association on September 21, 2022, the number of nuclear power plants currently in operation in China is 53, ranking third in the world after 93 in the United States and 56 in France (Table 7-8). China has 23 nuclear power plants under construction. With the US having only two reactors under construction, Vogtle Units 3 and 4, and France having only one, Flamanville Unit 3, it is certain that the China will overtake France to become the second largest nuclear power by 2023, and by around 2030, it will overtake the US to become the largest nuclear power in the world.

Table 7-8: List of Nuclear Power Plants in China

Power plant name	Reactor number	Reactor type	Output	Developer	Start date
Changjiang (Hainan Province)	1	CNP600	65.0	CNNC	2015.12.25
	2	CNP600	65.0	CNNC	2016.08.12
Fangchenggang (Guangxi)	1	CPR1000	108.6	CGN	2016.01.01
	2	CPR1000	108.6	CGN	2016.10.01
Fangjiashan (Jiaxing, Zhejiang Province)	1	CP1000	108.9	CNNC	2014.12.15
	2	CP1000	108.9	CNNC	2015.02.12
Fuqing (Fujian Province)	1	CP1000	108.9	CNNC	2014.11.22
	2	CP1000	108.9	CNNC	2015.10.16
	3	CP1000	108.9	CNNC	2016.10.24
	4	CP1000	108.9	CNNC	2017.09.17
	5	Hualong One	116.1	CNNC	2021.01.30
	6	Hualong One	116.1	CNNC	2022.03.25
Daya Bay (Guangdong Province)	1	M310	98.4	GNIC	1994.02.01
	2	M310	98.4	GNIC	1994.05.07
Haiyang (Hainan Province)	1	AP1000	125.3	SPIC	2018.10.22
	2	AP1000	125.3	SPIC	2019.01.09

[148] Zhang Tingge, Minryong Li, Yun Heping (eds.) (2022): China Nuclear Energy Development Report (2022), Social Science Literature Press, p.216.

Hongyanhe (Liaoning Province)	1	CPR1000	111.9	CGN	2013.06.06
	2	CPR1000	111.9	CGN	2014.05.13
	3	CPR1000	111.9	CGN	2015.08.16
	4	CPR1000	111.9	CGN	2016.09.19
	5	ACPR1000	111.9	CGN	2021.07.31
	6	ACPR1000	111.9	CGN	2022.06.23
Ling Ao (Shenzhen, Guangdong Province)	1	M310	99.0	CGN	2002.05.28
	2	M310	99.0	CGN	2003.01.08
	3	CPR1000	108.6	CGN	2010.09.20
	4	CPR1000	108.6	CGN	2011.08.07
Ningde (Ningde City, Fujian Province)	1	CPR1000	108.9	CGN	2013.06.18
	2	CPR1000	108.9	CGN	2014.05.04
	3	CPR1000	108.9	CGN	2015.06.10
	4	CPR1000	108.9	CGN	2016.07.21
Qinshan I	1	CPN100	33.0	CNNC	1994.04.01
Qinshan II	1	CNP600	65.0	CNNC	2002.04.18
	2	CNP600	65.0	CNNC	2004.05.03
	3	CNP600	66.0	CNNC	2010.10.21
	4	CNP600	66.0	CNNC	2012.04.08
Qinshan III (Jiaxing, Zhejiang Province)	1	CANDU6	72.8	CNNC	2002.12.31
	2	CANDU6	72.8	CNNC	2003.07.24
Sanmen (Taizhou, Zhejiang Province)	1	AP1000	125.1	CNNC	2018.09.21
	2	AP1000	125.1	CNNC	2018.11.05
Tianwan (Lianyungang, Jiangsu Province)	1	VVER1000	106.0	CNNC	2007.05.17
	2	VVER1000	106.0	CNNC	August 16, 2007
	3	VVER1000	112.6	CNNC	2018.02.14
	4	VVER1000	112.6	CNNC	2018.12.22
	5	ACPR1000	111.8	CNNC	2021.09.08
	6	ACPR1000	111.8	CNNC	2021.06.02
Yangjiang (Yangjiang, Guangdong Province)	1	CPR1000	108.6	CGN	2014.03.26
	2	CPR1000	108.6	CGN	2015.06.05
	3	CPR1000	108.6	CGN	2016.01.01
	4	CPR1000	108.6	CGN	2017.03.15
	5	ACPR1000	108.6	CGN	2018.07.12
	6	ACPR1000	108.6	CGN	2019.07.24

Taishan (Taishan City, Guangdong Province)	1	EPR	175.0	CGN/EDF	2018.12.13
	2	EPR	175.0	CGN/EDF	2019.09.07

Source: Prepared by the author based on data from "Trends in Global Nuclear Power Development" and other sources.

At the core of China's nuclear reactor-type strategy are "diversification" and "domesticization." Based on the M310 pressurized water reactor introduced from France, the company has independently developed the CNP600, CP1000, ACP1000, CPR1000, and ACPR1000. Since the Fukushima Daiichi nuclear accident in 2011, China has adopted a policy of approving only the construction of state-of-the-art nuclear reactors. The development method will be to first introduce advanced nuclear reactors from overseas, and then increase the rate of domestic production, leading to independent development. The latest reactors introduced by China include the AP1000 pressurized water reactor from Westinghouse of the United States, the EPR European pressurized water reactor from AREVA of France, the VVER1000 and VVER1200 Russian-type light-water reactors, and the CANDU6 Canadian-type heavy water reactor. Based on the AP1000, the CAP1000 was also developed using domestically produced technology. The only reactor that does not exist in China is the boiling water reactor (BWR) that caused the accident at the Fukushima Daiichi Nuclear Power Plant. Sun Shun, then deputy researcher at Tsinghua University's Institute of Nuclear Energy and New Energy, said the following in a February 2017 speech:[149]

> "China's nuclear development will first absorb the design, construction, and operation technologies of developed countries, and then build more reactors. In this way, China has developed the capacity to design, build, and operate its own nuclear reactors ranging from 300,000 kilowatts to 1.4 million kilowatts."

7.3.2 Strategic Nuclear Reactors Hualong and Linglong

China has positioned the 1-million-kilowatt Hualong One and the smaller Linglong reactors as strategic reactors. Hualong One is a strategic nuclear reactor jointly developed by China National Nuclear Corporation (CNNC) and China Global Nuclear Group Corporation (CGN). It is characterized by an output of 1 million kilowatts and a safety system consisting of two layers: "active plus passive." Passive safety is a system that automatically injects cooling water into the core in the event of power loss or pipe rupture, and was adopted for the AP1000. In addition, the containment vessel, which confines radiation in the event of an accident, has two layers, and according to Chinese data, is an order of magnitude safer than other third-generation reactors. In China, Fujian's Fuqing Units 5 and 6 have already started operation, and Pakistan's Karachi Units 2 and 3 have entered commercial operation. Argentina has also decided to adopt this system, and the comprehensive design review for its introduction in the UK "Bradwell B" was completed on February 7, 2022. The British endorsement[150] will give China an edge in the international market. China intends to export Hualong One to Belt and Road Initiative countries, and has reportedly

149 https://spc.jst.go.jp/event/crc_study/study-101.html
150 https://bradwellb.co.uk/uk-hpr1000-nuclear-technology-accepted-for-use-in-uk/

already approached more than 20 countries, including Brazil, Kenya, Poland, the Czech Republic, Romania, South Africa, and Thailand.

On the other hand, Linglong One is a small reactor with an output of 125,000 kilowatts, and is said to be modularized and has a passive safety system that allows it to be deployed in cities and industrial parks. The construction of the first unit of the reactor, which reflects the world's mainstream shift in nuclear energy development toward small modular reactors (SMRs), began on July 13, 2021, in Changjiang, Hainan Province. The downside of SMR is its economics. The chief designer of the Linglong One, Song Danqi, said in an interview with Xinhua on October 29, 2021, "We have lowered construction costs through design innovation, system simplification, and mass production." In addition to power generation, Linglong is also expected to meet the needs of heat supply, seawater desalination, and oil extraction. CNNC Secretary Lu Tie-chung said, "Looking toward the South China Sea, there are many small islands in countries along the Belt and Road Initiative, such as in the Philippines, Indonesia, and Malaysia. There will also be needs in remote areas such as Saudi Arabia" (October 29, 2021).

7.3.3 Global Trends and China's Challenges

China is expanding the scope of its research and development beyond light-water reactors. On December 27, 2020, the construction of the second fast reactor, CFR-600, began in Xiapu, Fujian Province. Now only Russia, India, and China continue to develop fast reactors. In addition, the HTR-PM, a small high-temperature gas-cooled reactor under construction in Shandong Province's Shidao Bay, will reach criticality in September 2021. The HTGR is expected to be used not only for power generation but also for hydrogen production. In addition, research is being conducted on the fusion reactor "EAST" and molten salt reactors. China covers most of the major "innovative next generation reactors" in the world (Table 7-9).

Table 7-9: Major Innovative Next-generation Reactors Worldwide

Reactor type	Reactor name	Country name	Manufacturer name	Output (10,000kw)
Light-water reactor	RTIM-200	Russia	Rosatom	17.5
	KLT-40S	Russia	Rosatom	3.5
	VOYGR	USA	New Scale	7.7
	BWRX-300	USA, Japan	GE Hitachi	30
	SMR-160	USA	Holtec	16
	UK-SMR	United Kingdom	Rolls-Royce	47
	Linglong One	China	CNNC	12.5
	ACPR-50S	China	CGN	6
	NUWARD	France	EDF	17
Fast reactor	BREST-300	Russia	Rosatom	30
	Natrium	USA	TerraPower	34.5
	ARC-1000	USA	ARC Nuclear	10

Molten salt reactor	Hermes	USA	Kairos Power	3.5
	SSR-W	United Kingdom	Moltex	30
	ISMR	Canada	Terrestrial Energy	19
High-temperature gas-cooled reactor	Xe-100	USA	X-Energy	8
	HTR-PM	China	Tsinghua University	21
Micro reactor	eVinci	USA	Westinghouse	0.5
	Aurora	USA	Oklo	0.15
	MMR	USA	USNC	1
	U-Battery	United Kingdom	Urenco	0.4
Nuclear fusion reactor	Helion	USA	Helion Energy	
	SPARC	USA	CFS	
	ST-HTS	United Kingdom	Tokamak Energy	
	FDP	UK/Canada	General fusion	
	Linear fusion reactor	USA	Tri Alpha	
	EAST	China	Chinese Academy of Sciences	

Source: Prepared by the author based on news reports and other sources.

China has set a goal of increasing its installed power generation capacity in 2050 from the current level of approximately 50 million kilowatts to 400 million kilowatts. It is a tremendous plan, equivalent to 400 million-kilowatt class nuclear reactors. In addition, the "China Nuclear Energy Development Plan 2021" forecasts that the installed power generation capacity will be 70 million kilowatts in 2025 and 120 million kilowatts in 2030, and that the share of nuclear power in total power generation will reach 8%, up from the current share of about 5%.

On the other hand, there are many challenges. In a September 2020 speech to the United Nations, President Xi Jinping declared that carbon dioxide emissions would "peak" by 2030 and that China would become "carbon neutral" by 2060. In order to position nuclear power as a baseload power source to realize the "two carbon (twin-carbon)" policy, it will be essential to construct nuclear power plants in inland areas where the demand for electricity is expected to increase. The China Western Development and the Belt and Road Initiative have increased demand for electric power in Sichuan, Hunan, Hubei, Anhui, and Jiangxi provinces, but although there are several plans, the Chinese government has not made a decision to date. Large inland rivers and lakes are used for drinking water, agricultural water, and industrial water, and water resources are already strained, leaving concerns about the supply of cooling water for nuclear reactors. Moreover, once an accident occurs, the damage could extend to major cities along the coast.

Above all, citizen opposition cannot be ignored. Since the Fukushima Daiichi nuclear accident, about 40% of Chinese citizens are said to be against nuclear power plants. In fact, the construction of a planned nuclear fuel plant in Guangdong Province in 2013 was cancelled due to opposition from residents. Again in 2016, a plan to build a reprocessing plant in Lianyungang, Jiangsu Province, was brought up but was forced to be withdrawn due to opposition from residents.

With the ever-changing geopolitics of energy, including the US–China conflict and Russia's invasion of Ukraine, whether China will continue to pursue nuclear power development or shift to renewable energy is now the key to the future of the global nuclear power industry.

7.4 Sino-Japanese Science and Technology Cooperation in the Conflict between the US and China

Science and technology are inherently intended for the welfare of humankind, not as tools in a struggle for hegemony. On the other hand, science and technology are directly related to industrial innovation and security, making them susceptible to political conflict. The US in particular has become sensitive to the outflow of dual-use "advanced infrastructure technologies."

In Japan, too, the debate on "economic security" has been very heated. At the government level, the Cabinet Minister of Economic Security was appointed in March 2021, and on May 11, the "Act on the Promotion of Ensuring National Security through Integrated Implementation of Economic Measures" or the so-called "Economic Security Promotion Act"[151] was passed. In 2023, a think tank named "Specific Critical Technology Research Institute" is scheduled to be established. At the private-sector level, the Japan Institute of International Affairs and the Nakasone Peace Institute, both leading think tanks, are holding a series of seminars on the topic of economic security.

There is a long history of science and technology cooperation between Japan and China. According to "40 Years of Science and Technology Exchange between Japan and China"[152] (Japan Science and Technology Agency), in 1952 the Science Council of Japan made a request to the Japanese government to open a forum for academic exchange, and in 1954 the first Chinese academic and cultural delegation visited Japan. Since the normalization of diplomatic relations between Japan and China in 1972, scientific and technological exchanges between the two countries have been developing, albeit with twists and turns. Today, China is our largest trading partner, which is even mentioned in elementary school textbooks. For Japan, China is both a rival and a partner.

The following are the author's thoughts on the future of Sino-Japanese scientific and technological cooperation, but please note that these are personal opinions. First, China's scientific and technological capabilities should be evaluated levelly and without prejudice. While we do not intend to unilaterally praise China's scientific and technological capabilities, we should face the reality that China has overtaken Japan and is now close to the US as far as the data is concerned. Professor Takuzo Aida of the University of Tokyo, who has been named a Nobel Prize candidate, says candidly, "We have a lot to learn from China."[153]

Second, international cooperation, not only with China, but at least in the field of basic science, should

[151] https://www.cao.go.jp/keizai_anzen_hosho/index.html

[152] Japan Science and Technology Agency, Center for Integrated Research Exchange in China (2014): 40 Years of Science and Technology Exchange between Japan and China, Japan Science and Technology Agency, China Center for Integrated Research Exchange, 237p., https://spap.jst.go.jp/investigation/report_2014.html#05

[153] Haruo Kurasawa (2022): No More to See: Japanese Science is the 'Galapagos,' FACTA ONLINE, pp. 60-62.

not be hindered. The achievements of basic science are the common property of humankind and a legacy for the future. The essence of science, which is the welfare of mankind and the search for truth, should transcend the concept of "nations." Third, from a practical standpoint, looking back at the realities of Japanese society, with its declining birthrate and aging population, the challenge is how to attract highly skilled human resources from China. Eiichi Nakamura, a special professor at the University of Tokyo who is nominated for the Nobel Prize for his research in fullerene science and other areas, says, "It is a miracle that this was possible with only Japanese people."[154] We should learn from the UK's shrewdness in continuing to accept large numbers of Chinese students.

Naturally, it is imperative to improve Japan's scientific and technological capabilities. Professor Takaaki Kajita of the University of Tokyo, a Nobel laureate in physics, is harsh about it: "Japan is not heading toward becoming a science and technology nation in the least" (Nikkan Kogyo Shimbun, November 18, 2017). There are still many unique studies in Japan. There is no other way but for the government and companies to work together to promote research and development investment and human resource development.

What is the worst thing that could happen to Japan in the field of science and technology? It would be to be abandoned not only by the US and China, but also by the global science and technology community.

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China: A Science and Technology Superpower (Yukihide Hayashi, Chukoh Shinsho, July 2013)

The Truth about China, a Science and Technology Superpower (Shin'ichi Isa, Kodansha Gendai Shinsho, October 2010)

The Day China Rules Space (Setsuko Aoki, Shincho Shinsho, March 2021)

Overview of Science and Technology in China [2014-2021] (National Institute of Science and Technology Policy, Japan Science and Technology Agency, Asia and Pacific Research Center)

China's Ambition for Scientific and Technological Supremacy (Haruo Kurasawa, Chuko Shinsho La Clef, June 2020)

[154] Haruo Kurasawa (2022): No More to See: Japanese Science is the 'Galapagos,' FACTA ONLINE, pp. 60-62.

8 Current Status and Future Prospects of the Research and Development of Genome-Edited Foods in China

8.1 Current Status and Results of the Development of Genome-Edited Foods

(Main Points) The research and development of the genome-edited foods, etc. in China[155] is very vigorous, and the number of patent applications and acquisitions fully utilizing the PCT is increasing remarkably against the backdrop of food[156] security measures and the establishment of the secret patent system, etc. Research and development facilities and a rich human resource base with overseas experience are the twin pillars of the Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences, forming a robust cluster with research and development themes covering all agricultural and livestock products as its pillars. This paper suggests that promising marketable results may aim for industrialization through incubation under the watch of research facilities, and bring about significant changes in the current state of agricultural infrastructure. The discussion of the safety of genome-edited foods is undeniably important, but it is not the direct subject of this paper, so it will be omitted here.

8.1.1 Current Status

(1) Definition of "Genome-Edited Foods, etc."

First, we should define "genome-edited foods, etc." but this paper will keep it at a broad level. This is because the findings and achievements in this field are likely to be increasingly explored and developed in the future, and we must be reluctant to prescribe the future from the present point in time. In fact, similar views are scattered among experts, and the view of Bartkowski and Baum,(1) for example, seems to be typical. In addition, because genome editing technology is inherently concerned with the molecular level of gene sequences, it has the potential to expand into areas outside of its original objectives, which could cause the development of food products to jump several steps to the level of the development of drugs. In other words, the foggy nature of the boundaries between disciplines may be one of the reasons why this term is so difficult to define. However, as there are some procedural obstacles in examining the trend of "genome-edited foods, etc." without any signposts, and this paper will tentatively define "genome-edited foods, etc." as follows.

Genome-edited foods, etc. means primary agricultural and livestock products, fish and shellfish products in general, processed foods, organisms used as ingredients of such products, their genes, methods to

[155] A system whereby an application is filed and published in all member countries under the Patent Cooperation Treaty.

[156] In this paper, "food" is the generic term for grains, fruits and vegetables, livestock products, fish and shellfish, etc., and "foodstuff" is cereals (edible grains; in China, it also includes potatoes).

eliminate or control fungi and insects that hinder the growth of agricultural and livestock products and fish and shellfish, and methods to increase the growth rate and yield of agricultural and livestock products and fish and shellfish, developed directly or indirectly using genome editing technology.

The main methods of finding out about the current status of research and development of "genome-edited foods, etc." in China include information on the results of related research facilities (websites of each research facility), information from the Intellectual Property Office (China Patent Proclamation), published literature (CNKI, Google Scholar, research journals edited and published by research institutes and universities, world-renowned scientific journals, etc.), and reliable online information. The following lines of argument also essentially rely on these.

(2) Current status of research and development

(1) Overview

China has also made a national effort to research and develop genetically modified foods, but has imposed strict restrictions on their practical and commercial application in the food sector because of unresolved consumer concerns. Basically, it is in accordance with the Cartagena Law, an international regulation that aims to prevent adverse effects on biodiversity through the implementation of regulatory measures for the use of genetically modified organisms, etc., and there seems to be no prospect of lifting the regulation in the country. On the other hand, genome-edited foods have not been specifically regulated and have been treated in the same way as genetically modified foods, but the issuance of the "Guidelines for the Safety Evaluation of Genome-Edited Plants for Agricultural Use"[157] has given further impetus for research and development.

The following examples of major research and development of genome-edited foods in China are taken from before the issuance of these guidelines, but they reflect a proactive attitude, as if in reaction to the current situation in which the marketability of genetically modified foods is not progressing as expected.

(2) Development Examples

This section will mention a few examples of research and development, which will lead to an overview of the overall results described thereafter.

One of the genome-edited foods and other products developed by China that has attracted particular attention is a "drought-resistant wheat" (2014, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences) that is resistant to drought diseases, particularly powdery mildew, which is a problem in agricultural fields worldwide. Although it has been pointed out that there is still room for further research, the results are regarded as an epoch-making achievement.(2)

Next is an example of research and development aimed at expanding soybean grain size and increasing soybean oil content and proteins, and is the result of joint research between China and the United States (Institute of Genetics and Developmental Biology, Zhejiang University, and the University of Illinois). The

[157] 农业用基因编辑植物安全评价指南（试行）, Ministry of Agriculture and Rural Affairs, January 2022, http://www.moa.gov.cn/ztzl/zjyqwgz/sbzn/202201/P020220124647592197651.pdf (I think January 24, but effective February? 1

core of this case study is the discovery that the genes GmSWEET10a and QmSWEET10b contribute to the improvement of soybean properties.(3)

The tomato material (CN110777163A), which produces lycopene-rich fruits using genome editing technology from the Institute of Horticultural Crops, Xinjiang Academy of Agricultural Sciences, is another achievement. This research case is an example of development to increase lycopene content in tomatoes. Lycopene is a type of pigmented carotenoid that exhibits red, orange, and yellow colors, and is one of the most outstanding antioxidants.

8.1.2 Results

As described below, the research and development of genome-edited food products is being conducted by a wide range of parties, many of which follow the secret patent system (first country application system, described in 8.3.1) filing applications with the China National Intellectual Property Administration. Since patent applications require a certain level of technological maturity, it can be assumed that the range of research and development cases currently being pursued is vast, including preliminary research and development projects that have not yet reached that stage.

Here, we present the full list of patents and their characteristics as of 2021, based on keyword searches for "CRISPR" and "genome editing." "CRISPR" is the latest and most important of the three genome editing technologies (nucleases). "Genome editing" refers to picking out edited foods, etc. using the two enzymes other than CRISPR (ZFN and TALEN). However, if these two keywords were not included in the name of the patent right, it is possible that they were left off the list, although the number is not likely to be large.

Table 8-1 is a representative example for the period from the filing date starting in 2015 until 2021. There were 30 cases, covering a wide range of fields including rice, wheat, corn, carrots, tomatoes, peanuts, forage crops, other plants, cattle, pigs, bees, and fish. Research and development organizations include the Chinese Academy of Agricultural Sciences (eight), the Chinese Academy of Sciences (four, including one jointly), and China Agricultural University (three).

Table 8-1: China's Genome Editing Patent Rights in Agriculture, Livestock, Food and Feed

	Patent Right Annual	Name of facility acquired	Research and Development Case Studies
1	2015	Institute of Crop Science, Chinese Academy of Agricultural Sciences	A type of promoter recognized by maize RNA polymerase III and its applications
2	2015	Institute of Crop Science, Chinese Academy of Agricultural Sciences	Site-directed mutagenesis to produce compact maize genetic resources and its applications
3	2016	Institute of Genetics and Developmental Biology, Chinese Academy of Sciences	Method of obtaining plants with enhanced drought tolerance
4	2016	Gangnam University	CRISPR Cas9 system for Bacillus subtilis genome editing and its construction method

5	2016	Guizhou University	Method of raising GHR gene knockout homozygous pigs
6	2016	Institute of Crop Science, Chinese Academy of Agricultural Sciences	A method to increase rice indigestible starch content by genome editing and dedicated sgRNA
7	2017	Mongolian University	Site-specific knock-in method for goat T β 4 gene based on CRISPR/Cas9 technology
8	2017	Beijing Academy of Agriculture and Forestry, Chinese Academy of Sciences	Genome editing to generate male-sterile tomato lines and Its applications
9	2017	Institute of Genetics and Developmental Biology, Chinese Academy of Sciences	Gene editing system and plant genome editing method using the system
10	2017	Fujian University of Agriculture and Forestry	Method of removing honey bee eggs by microinjection
11	2017	Beijing Institute of Animal Husbandry and Veterinary Medicine, Chinese Academy of Agricultural Sciences	Multi-omics integrated precision breeding method for pigs
12	2017	Research Center for Molecular Plant Science, Chinese Academy of Sciences	Chloroplast genome editing
13	2017	Infinite Biopharmaceuticals	Methods for evaluating the in vivo effects of pharmaceutical or food compositions and active ingredients
14	2918	Institute of Crop Science, Chinese Academy of Agricultural Sciences	Application of LbCpf1-RR mutants in plant gene editing with the CRISPR/Cpf1 system
15	2018	Chinese Academy of Agricultural Sciences	Application of RLI1 protein in the regulation of rice leaf angle
16	2018	Hunan University of Arts and Sciences	Breeding methods to reduce cadmium content in rice grains
17	2018	Jiangsu University	A type of BdREF2 gene that regulates synthesis and metabolism of plant ferulic acid and its applications
18	2918	Beijing Academy of Agricultural and Forestry Sciences	How to obtain carrot mutant strains
19	2918	Fuzhou University	Genome editing, a method for precise site-specific gene knock-in in fish
20	2918	Hunan Hybrid Rice Research Center	Methods to improve transformation efficiency of chloroplast genes using genome editing technology
21	2918	Institute of Biotechnology, Fujian Academy of Agricultural Sciences	A type of very early rice breeding method
22	2019	Institute of Biotechnology and Nuclear Technology, Sichuan Academy of Agricultural Sciences	Vectors for plant genome editing and their construction methods and applications

23	2019	China Agricultural University	Vector sets for plant gene editing and their applications
24	2019	Institute of Crop Science, Chinese Academy of Agricultural Sciences	Methods and Technological Systems for Improving Wheat Resistant Starch Content by Genome Editing
25	2020	South China Agricultural University	Application of rice RIP2 protein in the regulation of plant leaf angles
26	2020	Institute of Crop Science, Chinese Academy of Agricultural Sciences	Genome Editing Methods to Improve Rice Disease Resistance and sgRNAs Used for the Methods
27	2020	South China Agricultural University	Methods and Applications for Regulating Amylose Content and Gel Viscosity in Crop Seeds
28	2020	Shenzhen University	Methods and applications of producing peanut mutants, peanut mutant genes and their encoding proteins
29	2020	China Agricultural University	Method of producing double muscle rump cattle similar to naturally mutated Belgian Blue cattle
30	2021	China Agricultural University	Alfalfa CRISPR/Cas9 Genome Editing System and its Applications

Source: China National Intellectual Property Administration

One of the characteristics is the wide range of research and development items. In this respect, in the case of Japan, the emphasis appears to be on commerciality, while in the case of China, the perspective seems to be on raising the quality and quantity of food in general. Of these, emphasis is placed on growth and disease control in rice. In terms of technological approaches, it can be seen that the diversity of technologies specific to each research facility is reflected.

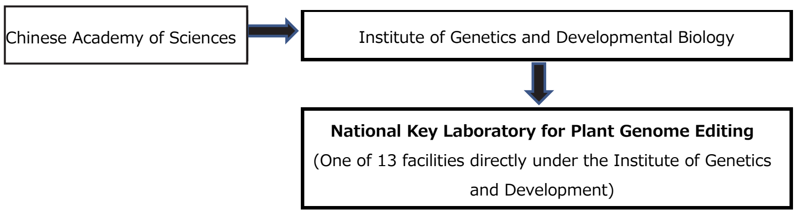
8.1.3 Case Studies of Research and Development Organizations

The Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences, an organization directly under the Ministry of Agriculture and Rural Affairs, are the core organizations in charge of research on genome editing technology in China, while universities and private research institutions are positioned in a complementary role to these two giant organizations. The two organizations themselves have numerous internal research facilities, each of which is responsible for research with subdivided fields and topics, as well as for fostering high-level research personnel. Research and human resource development related to genome editing technology in China is one of the characteristics of an extremely layered and broad cluster. This section will discuss representative research facilities from the Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences and discuss some of their specific activities.

(1) National Key Laboratory of Plant Genomics, Chinese Academy of Sciences

(i) Purpose of the research facility

The National Key Laboratory of Plant Genomics is a leading research organization under the Chinese Academy of Sciences as shown in Figure 8-1: it is related to the Institute of Genetics and Developmental Biology (directly affiliated) and Institute of Microbiology (related). It has 34 laboratories and a genome editing technology application platform. The laboratory was established in 2003 (with the approval of the then Ministry of Science and Technology) as an upgraded version of the former Open Laboratory for Plant Biotechnology. To meet the strategic needs of national agricultural development and international plant science development, the laboratory aims to contribute to national food security and sustainable agricultural development through the molecular design of crops and the mining of genetic resources for crop breeding, and to work on the elucidation of plant genome structure and breeding for this purpose.



Source: Prepared by the author.

Figure 8-1: Organizational Relationships of the National Key Laboratory for Plant Genome Editing

(2) Research system

At the beginning of 2022, the laboratory will have 44 regular research supervisors (including 3 graduate students), 156 research staff, 160 doctoral students, 97 post-doctoral researchers, and about 40 master's students, making a total of about 500 research and educational personnel. There are about 14 research personnel per laboratory, including about 10 graduate students, so the number of research professionals is quite substantial. Research expenditures (2021) totaled 90.9 million yuan (about JPY 1.54 billion at 1 yuan = 17 yen) for a total of 249 research projects in all laboratories, 2.53 million yuan (JPY 43 million) per laboratory, and 579,000 yuan (JPY 9.84 million) per person. The breakdown was 111 items from the National Natural Science Foundation of China, 18 items from the Ministry of Science and Technology, 81 items from the Chinese Academy of Sciences, and 12 other items for international cooperation.

(3) Characteristics of Key Research Results

The laboratory has been granted a large number of patents: 68 (including non-food and other patents) in the three years 2019–2021. Although the patent applicant name is set as the Institute of Genetics and Developmental Biology, these are substantially the results of research conducted in this laboratory. Although it is difficult to describe the research characteristics in aggregate, and it would only be natural for them to use the latest genome editing technology (CRISPR/cas9), some of the patent titles reveal the laboratory's attitude toward responding to new needs in the food market: "Application of LEPTO1[158]

[158] A type of gene: author's note.

and its encoding protein in controlling rice fertility" (patent number ZL201811452764.9., approved date 2020.11.03), "Method for creating high anthocyanin[159] dark purple tomato material by genome editing technology" (Patent No. L201710761276.5., Approval date: 2021.03.19), "Method for making ultra-small tomatoes" (Patent No. ZL201910936056.0., Approval date: 2021.08.20), etc.[(4)]

(2) Agricultural Genomics Institute at Shenzhen, Chinese Academy of Agricultural Sciences

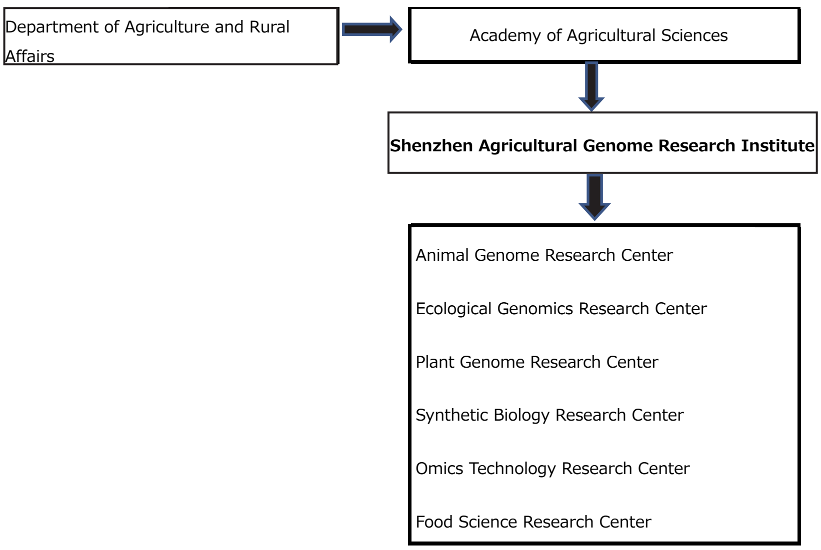
(i) Purpose of the research facility

The Agricultural Genomics Institute at Shenzhen was established in 2014 by the Chinese Academy of Agricultural Sciences, an organization directly under the Ministry of Agriculture and Rural Affairs. This facility is characterized by its dedication to increasing agricultural production through the development of genome editing technology by integrating biology and big data science. The projects awarded since the Institute was established include 52 national-level projects worth 480 million yuan[160], 60 patents for agricultural genome editing technologies (including non-food products), four projects for the development of new varieties approved by the national government, and 13 projects for the development of new varieties approved by provincial governments.

(2) Research system

The institute is organizationally composed of six research facilities as shown in

Figure 8-2. They are the Animal Genome Research Center, the Ecological Genome Research Center, the Plant Genome Research Center, the Synthetic Biology Research Center, the Center for Omics (OMICS) Technology and Innovative Drug Research, and the Food Science Research Center.



Source: Prepared by the author.

Figure 8-2: Organizational Relationships of the Agricultural Genomics Institute at Shenzhen

159 A type of pigment: author's note.
160 May include administrative and other expenses other than China net research expenses.

The Animal Genome Research Center has 62 research personnel, including 30 graduate students, working on breeding and improvement with three livestock genome editing technology teams, with a focus on swine. The Ecological Genome Research Center, with 52 researchers, is engaged in research on the effects of parasites and other harmful microorganisms on agricultural and livestock products, as well as their elimination and degradation. The Plant Genome Research Center is divided into three research teams, including the Genome Editing Big Data Application Team, and is working on breeding and improvement including plant genome analysis. The Synthetic Biology Research Center has 139 research personnel working on agricultural synthetic biology (agricultural transcriptomics and metabolomics) research.[161] The Omics Technology Research Center has 27 personnel and is engaged in agricultural genome editing research and development domestically and overseas, especially in the construction of a big data cloud computing platform with agricultural biomics data as its core. The Food Science Research Center, under the leadership of 20 researchers, focuses on food safety and nutrition centered on food science, omics, and big data. It integrates biomedical science, food science, and informatics, and works to build a science and technology innovation model of a reverse chain process starting downstream: "from table to farm."

(3) Characteristics of Key Research Results

The most significant features of the 60 patent rights (including food products, etc.; 89 total including those with applications submitted) that were obtained by the institute as of December 2021 is that all of them are in the fields of agriculture, livestock, microbiology, etc., covering a wide range of topics, and almost all of the applicants are solely from the institute, showing the depth of the institute.

Of the 60 patents, two symbolic ones will be discussed here. One is "Method for detection and application of SNP marker[162] on age of pigs reaching 100 kg body weight" (CN112342298B), an invention that helps to select superior swine breeds with that reach 100 kg body weight in fewer days of life, reducing the breeding cycle time and improving breeding efficiency and accuracy (100 kg swine weight is optimal at time of shipment: author's note). Another one is "Method for labeling QTL genes associated with rice 1000 grain weight under low nitrogen conditions"[163] (CN105441457B). Under stress from low nitrogen (conserving fertilizer: author's note), it can be applied to 1000-grain selective breeding of rice, which helps genetic selection in the seedling stage of the next-generation rice breeding population and improves breeding efficiency.[(5)]

(3) Incubation

(1) Zhongnong Haiyin (Shenzhen) Biological Technology Company[164]

One of the problems facing the Chinese food production sector in the field is the widespread presence of

161 Transcriptomics is the study of the messenger RNA (mRNA) present in living cells, while metabolomics is the study of the metabolites produced by biological activities to elucidate life phenomena through comprehensive analysis: author note.

162 DNA = region of deoxyribonucleic acid sequence in which a particular base is replaced by another base: author's note.

163 A mass of genes that determine quantitative traits of agricultural products: author's note.

164 https://www.znhaidao.com/

alkaline soils in arable land. In general, a pH of 7 or 8 or higher is hazardous to crop growth. To reverse this problem, Zhongnong Haiyin (Shenzhen) Biological Technology Company is working to develop and promote "seawater rice" accustomed to high alkalinity. This company was established in 2018 by the Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences, which aims to commercialize the technology to explore its potential. It is capitalized at 55 million yuan and is mainly involved in the utilization of the unique germplasm resources of seawater rice (alkali rice), the mining of functional genes, the selection of new varieties, working on cultivation models and technology research, the ecological restoration of salt-alkali mudflats, and the creation of functional foods made from salt-alkali rice. It established an internal "Salt Alkali Rice (Seawater Rice) Innovation Center," set up four new plants, and sold five brands of seawater rice under the seawater rice variety patent rights, and now has 33 planting bases in 12 provinces across the country.

The project focuses on "genetic mining of saltwater rice, research of special genetic resources, and breeding of new varieties," and adds alkaline soil restoration and improvement to the project, restoring 6.7 million hectares of alkaline soil and tidal flats (saline-alkali wasteland and secondary saline-alkali cultivated land) in the 10 years following the "14th Five-Year Plan". It also plans to cultivate 670,000 hectares of saltwater rice.[(6)]

The Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences filed a patent application in July 2019 for "Rice seedling stage salt tolerance gene qST12Pokkali and its application" (CN 110257546A), which is the result of research on salt tolerance in rice, and the company is in an advantageous position to apply this technology in order to commercialize saltwater rice, its area of expertise. By providing the basic technology, the Agricultural Genome Research Institute has an interdependent relationship in which its own technology is applied developmentally at the company

(2) Shenzhen Zhongnong Jingyue Biological Technology Co.[165]

Shenzhen Zhongnong Jingyue Biotechnology Co., Ltd. was established in June 2014 with a total capital of 1 million yuan by the Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences, and specializes in genome-edited food research, biological breeding and selective breeding of animals, plants and microorganisms. The objective is to commercialize the technologies developed by the Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences, its parent organization, and to serve as a link to industry and markets. Currently, the company collaborates with South China Agricultural University, Nanjing Forestry University, and Huazhong Agricultural University as well as the Chinese Academy of Agricultural Sciences. It has 41 new variety patent rights (published patents), eight software copyrights, two utility model patents, and was recognized as the first high-tech enterprise by Shenzhen City in 2018. In 2017, for the purpose of fully utilizing the technological advantages of relevant scientific research institutions and high-tech enterprises, a 10-year, 10 million yuan contract for the provision of functional bio-organic fertilizers, soil ecological restoration, organic ecology, organic tobacco, and other products and business consultancy services was signed with Shanghai Shunho New Material

[165] www.agct.org.cn
[166] http://www.shunhostock.com/

Technology Co.[166] to gain a foothold in the original business. The contract was signed for 10 million yuan (about 170 million yen) over 10 years. However, along with the position of the Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences, it appears that the institute is also focusing on independent research and development. The Institute of Agricultural Genomics of the Chinese Academy of Agricultural Sciences will probably want to further accelerate the development of a wide variety of genome-edited foods in order to expand its operations.(7)

The Institute of Agricultural Genomics at the Chinese Academy of Agricultural Sciences has "SNP markers and their detection methods for the age of pigs reaching 100 kg (optimal weight for fattening and shipping: author's note)" (see above), and has entrusted the application and practical use of these markers to the company. Additionally, "Method of cultivation of Puccinia bacteria on the leaves of the chrysanthemum plant Micania" (CN 111972265B) (patent rights) and other research on plant bacteria is expected to be lead to market opportunities.

8.2 Development Background and Structure

8.2.1 Background

The research and development of genome-edited foods and other products has become a stage for fierce competition between China and the United States. Since the WIPO database does not distinguish between genome-edited and other foods, the number of PCT patents published in the US and China by year in the Life Sciences and Food Chemistry sections, including these patents, is organized for reference in Table 8-2.

Table 8-2: Number of PCT Published Patents in Life Sciences and Food Chemistry (US–China Comparison)

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
life science	China	119	180	260	266	293	322	406	560	719	1035	1091	1438	6689
	America	2155	2094	2066	2226	2507	2149	2325	2552	2545	2779	3147	3409	29954
Food Chemistry	China	45	44	76	78	85	121	123	147	169	211	248	259	1606
	America	382	404	388	447	548	429	431	389	422	381	437	480	5138

Source: WIPO statistics database

The total from 2010 to 2021 is 6,689 in China and 29,954 in the US for life sciences and 1,606 in China and 5,138 in the US for food chemistry, with the US dominating with 4.5 times and 3.2 times the number in China, respectively. On the other hand, a comparison of the number of cases between 2010 and 2021 shows that China has an advantage in life sciences (12.1 times as many cases as the US 1.6 times) and in food chemistry (5.8 times as many cases as China 1.3 times as many as the US). Regarding the growth of the number of cases, China has more momentum than the US. If this trend continues, it will not be long before the number of cases in China exceeds that of the United States in a single year.

In addition, the number of applications in the US is higher from abroad than from China, with a lower extent of US residents. The number of CRISPR hits searched in the US patent database USTPO[167] was 1,422

[167] https://www.uspto.gov/

(December 2022), surpassing China in number, but there were not such a great number of agriculture and food-related items. This may reflect the fact that the self-sufficient food situation in the US is much more stable than in China.

The main factors prompting the research and development of genomic foods and other products in China, which may be higher than that in the US, are as follows: (1) concerns about the domestic food situation, specifically, the response to the rapidly advancing climate crisis, the world's highest use of chemical fertilizers and pesticides by area, the critical transformation of the farm family system that has supported agricultural production, and measures to combat pig, chicken, and other illnesses; (2) the slow marketability of genetically modified foods, and (3) the promising potential of genome editing technology itself.

In particular, the concern about the domestic food situation in (1) is related to the fact that the government itself has been forced to acknowledge the rapidly declining trend in food self-sufficiency. The food self-sufficiency rate, which has been said to be around 95% among experts (though with the complex expression of food self-sufficiency rate, which is different from food self-sufficiency rate for eating), may fall to around 80% (on a weight basis) by 2025, the end of the 14th Five-Year Plan.[(8)]

8.2.2 The National System

Although the main research facilities related to genome-edited foods are located in most of the universities of natural sciences, as shown in Figure 8-3, the bases for research and development can be found in two institutions: the Chinese Academy of Sciences and the Chinese Academy of Agricultural Sciences. Here, "research and development bases" refers to the foundations for conducting national genome editing research and the policy command tower. In the case of universities, it is common for these two research infrastructures to be involved in the form of investing human resources or sending key persons such as principal investigators to conduct their own studies. Like universities, they are positioned as both research and development actors and as cooperative partners in the two research and development infrastructures.

Nine facilities, including the Institute of Genetics and Developmental Biology, the core organization, are located under the direct control of the Chinese Academy of Sciences. In the same vein, China boasts NDGC,[168] a comprehensive database of various genes in genomics founded in 2019, and consisting of nine sections: Omics Raw Data Archive Database, Genome Database, Genome Mutation Database, Gene Expression Database, Epigenome Database, Life Science Wikipedia Base, Chinese Gene Database, Biological Information Tool Library, and System Operation and Maintenance. The Institute of Genetics and Developmental Biology has ten facilities, including the National Priority Laboratory for Plant Genomics and the Graduate School, which are used as case studies in this paper.

[168] National Genomics Data Center(国家基因组科学数据中心), https://ngdc.cncb.ac.cn/

Source: Prepared by the author, Note: Facilities in bold are those used as case studies in this report.

Figure 8-3: Overview of China's research and development system for genome-edited foods and other products (as of 2022)

Under the direct control of the Chinese Academy of Agricultural Sciences, there are eight facilities, including the Agricultural Genomics Institute at Shenzhen, which is the core facility and was featured as a case study. It is engaged in genome editing research and development, focusing on a wide range of agricultural and livestock products and foods. As mentioned earlier, policy positions on research, development, and commercialization of genome-edited foods and other products have traditionally been treated in the same manner as genetically modified foods. However, many believe that 2022 will mark a turning point in this positioning, and will give further impetus to research and development in China in a wide range of fields, including genome-edited foods. Although the target area is plants and does not apply to livestock, fish, and shellfish, it can be taken as a result of the priority given to expanding the foundation for overall food security, which is the first and foremost focus in China.

The specific document is "Safety Evaluation Instructions for Genome-Edited Plants for Agricultural Use (Trial)" (Ministry of Agriculture and Rural Affairs, January 24, 2022). This has created a unique official safety confirmation route for the application and inspection of genome-edited plants (grains, vegetables, fruits, and their processed products, etc.) imported, produced, and exported from overseas, including those produced by Chinese companies in cooperation with overseas companies. The inspection focuses on (1) ensuring the identity of the produced genome-edited genes between different generations (at least three generations), (2) the stability of its expression status (at least three generations), and (3) ensuring its safety for food use.

8.3 Economic Security and Genome-Edited Foods

China's so-called economic security system covers many areas, including intellectual property protection, patent right first application system, safe trade, safe investment management, and data security (big data, personal information, etc.).

8.3.1 Economic Security System

China is said to have been one of the earliest major countries to develop a system for economic security, and this is probably due to its Patent Law, which came into effect in 1984 and established the first national patent application system. Article 20 of the law stipulates that "any Chinese organization or individual who wishes to apply for a patent in a foreign country for an invention or creation completed in China shall first apply for a patent with the patent department and, after obtaining the consent of the relevant competent department under the State Council, entrust the application to a patent agency designated by the State Council. The 2020 amendment (latest version) provides that "Any organization or individual filing a patent application in a foreign country for an invention or utility model completed in China shall report the matter to the patent administrative department of the State Council for a confidential examination. Chinese organizations or individuals may submit international patent applications in accordance with relevant international treaties to which China is a party. An applicant who files an international patent application shall comply with the preceding paragraph." There is no change in the meaning of the main body of the article itself, only the addition of a statement regarding accession to the International Convention for the Protection of New Varieties of Plants, which is discussed later in the 2020 Amendment Act. The detailed operational provisions of this article are described in Section 10, "Special Provisions for International Applications" of the "Implementing Regulations" (revised in 2010) of the law from Article 101 onward.

Based on the accumulation of such an economic security framework, the policy position of IP protection in general has recently been improving, as can be seen in the "Guidelines for the Construction of a Strong Intellectual Property Rights State (2021–2035)"[169] (Party/State Council, September 2021) and the "Notice on the '145' National Intellectual Property Protection and Operation Plan" (State Council, October 2021). The "Notice of '145' National Intellectual Property Protection and Operation Plan"[170] (State Council, October 2021), etc. These are not only for external protection, but also for the protection of the rights of domestic developers.

First, the "Outline of the Construction of a Strong Intellectual Property Rights State" mentions new varieties of superior plants, genetic resources, etc., and says that the protection of these IPRs will create a path for the development of IPRs with Chinese characteristics, and that patent-intensive industries will account for 13% of GDP by 2025, contributing to the realization of a strong innovation-based nation and a comfortable society. The column "Construction Process of New Plant Variety Protection System" in the "Notice of the "'45' State Intellectual Property Protection and Operation Plan," mentions the International Union for the Protection of New Varieties of Plants (UPOV: 1961), of which China is a member. This union administers the International Convention for the Protection of New Varieties of Plants[171] (1991); China is

[169] State Council (2021): C.C.P.R. Central State Council Infor《知识产权强国建设要（2021-2035）》, State Council, http://www.gov.cn/zhengce/2021-09/22/content_5638714.htm
[170] State Council Notification of '145' National Intellectual Property Protection and Use Plan
[171] https://www.upov.int/edocs/pubdocs/en/upov_pub_221.pdf

now one of the signatories to the Convention, but further research is needed. In this connection, China is indeed using the "UPOVPRISMA" (an online tool(9) provided by the union for national governments to file applications to WIPO for breeder's rights for new varieties, etc.), which is used by 70 countries including Europe, the United States, and South Korea, but not Japan. As of 2022, it is only using it for vegetable lettuce. Extending this to all plants, as in other countries, would be one of the challenges from the perspective of enhancing the economic security system (note that this is different from PCT applications).

8.3.2 Secret Patents and Genome-Edited Foods

(1) China's Secret Patents

In general, "secret patents" are part of the economic security system, a system that prevents the overseas outflow of advanced technology with patentable value researched and developed domestically, if it might threaten national security or hinder future industrial development. At this stage, "patent rights" are often applied for and rights are not granted, and as already mentioned, this measure is effective at the stage prior to the application for patent rights. If, contrary to this, a foreign application is given priority, the patent right for the case in question will not be recognized in China. In addition, it may be regarded as leakage of state secrets and subject to criminal punishment (Article 78 of the "Patent Law"), which may force the applicant to file the application in China first.

However, as a practical matter, as China is a signatory to the Patent Cooperation Treaty (PCT) (1994), a domestic application is the same as an overseas application in terms of the system, and has the same effect as an application filed in all member countries. Since filing an application does not mean that an international patent has been obtained, the application is filed in the language of the country in which the patent is desired, and an international search organization (the patent management department of the country in question) conducts the search procedure.

However, in patent searches related to the research and development of genome-edited foods and other products, the ultimate goal is of course what is created, but empirically verifying how it was created is said to be a more difficult task. This tends to be more common the earlier the new technology is born, as there is a limited accumulation of validation knowledge, information, and specimen manipulation. From this point, one of the challenges is that it takes more time to confirm reproducibility in international patent searches.

(2) Case Examples

Three specific cases will be discussed as cases that were confirmed before PCT applications were submitted, which is the gateway to obtaining international patent rights.

One is on the cultivation of drought-resistant plants, which is of global technical interest, another on paddy rice with a shortened growing season, and the last on cadmium-suppressed cultivation of rice. The two rice-related technologies were chosen because rice is a globally important grain and the invented technology itself is highly versatile for use in other grains.

① Cultivation of drought-resistant plants

Drought-resistant plants were grown using CRISPR/Ca9 technology to obtain plants with enhanced resistance to drought. The application was filed in China by the Institute of Genetics and Developmental Biology at the Chinese Academy of Sciences in February 2016, and the patent was published in April 2020 (CN107119068 B). The PCT application was filed at the same time, and as a result, the "PATENTSCOPE" search on the WIPO site became available. When searched, the application is shown in the language of each country. The IPC classification confirms that it is C12N (microorganism or enzyme) 15/82 (for plant cells). At this point, it is the gateway to obtaining international patent rights.

② Paddy rice with a shortened growing season

The paddy rice with a shortened growing season uses CRISPER/Cas9 technology to control the maturity period by controlling the number of splits (new stems emerging from the root base) in the paddy rice plant, creating a superior low-splitting, early maturing variety with a growing season of 90 days or less. Filed in China by the Institute of Biotechnology, Fujian Academy of Agricultural Sciences[172] in October 2018, patent publication July 2021 (CN109156294B). At the same time, a PCT application was filed, IPC Classification A01G (Horticulture: Rice, etc.) 22/22 (Rice), and its contents are searchable.

③ Cadmium-suppressed rice (including upland rice)

Cadmium-suppressed rice plants use CRISPER/Cas9 technology, a breeding method that reduces the cadmium content of paddy rice seeds. The application was filed in China by Hunan University of Arts and Science[173] in April 2018, and the patent was published in July 2021 (CN108265077B). At the same time, a PCT application was filed, IPC classification C12N (microorganisms or enzymes) 15/82 (for plant cells), and the information can be searched.

8.4 Future Direction of the Development of Genome-Edited Foods

8.4.1 Development and Marketing of Food Products

The development of food products here refers to the creation of products that have the form and content of food products, while marketization refers to the commercialization of food products or the receipt of patent royalties or the sale of patent rights. None of the above is a promise that the company will always receive compensation after it is released to the public. In both cases, the value of the product must be recognized by the market.

Although there are not many promising marketable products at this point, this section selects a few that are easy to understand, and of which items (1) through (3) above are promising examples of early marketable products. In addition, there is (4) "How to create high anthocyanin[174] dark purple tomato material by gene editing" (Key Laboratory of National Plant Genomics, Chinese Academy of Sciences:

[172] https://www.faas.cn/cms/html/swjsyjs/index.html

[173] https://www.huas.edu.cn/

[174] A type of polyphenol, a blue-purple natural pigment that plants store to protect themselves from ultraviolet light, etc.: author's note.

China Patent No. ZL201710761276.5) (currently "ZL" is not required), and (5) "Method of Making Short Style Tomatoes" (Ibid: ZL201910936056.0), 6) "A type of insect resistant tomato" (Ibid: ZL201811452764.9.), (vii) "Methods for the analysis of plant endophytic bacterial groups" (Ibid: CN109750113B[175]), 8) "How to obtain carrot mutant strains" (Beijing Academy of Agricultural and Forestry Sciences: CN108841854B), (9)" Development of wheat resistant to powdery mildew" (Institute of Genetics and Developmental Biology, Chinese Academy of Sciences: CN104789588B), 10) "LEPTO1 (a gene in rice fertility regulation: author's note) and applications of its encoded proteins" (Ibid: ZL201811452764.9), (11) "Method for creating high anthocyanin (a kind of pigment: author's note) dark purple tomato material using genome editing technology" (Ibid: L201710761276.5), (12) "Methods and Applications for Detecting SNP Markers for Age of Pigs Reaching 100 kg Body Weight" (Agricultural Genomics Institute at Shenzhen, Chinese Academy of Agricultural Sciences: CN112342298B), (13) "QTL gene labeling associated with rice 1000 grain weight under low nitrogen conditions" (Shenzhen Institute of Biotechnology and Breeding Innovation, Chinese Academy of Agricultural Sciences: CN105441457B), (14) "Breeding method of growth hormone receptor (GHR) gene knockout homozygous pigs (small pigs: author's note)" (Guizhou University: CN106172237 B), (15) "Methods and Technological Systems for Improving Wheat Starch Resistance Content by Genome Editing" (Institute of Crop Science, Chinese Academy of Agricultural Sciences: CN110819654B), among others.

8.4.2 Summary–Possibility of Resource Reallocation

Although it will be some time in the future, it is not difficult to imagine that the further universalization of genome-edited foods and other products will bring revolutionary changes to the agriculture, forestry, and fisheries industries. The increase in yield per unit of land, labor, and capital will lead to savings in inputs, especially fertilizers and pesticides, and will also increase the nutrient content of foods and other products, lengthen their shelf life, and simplify their preservation methods, thereby reducing so-called food loss and potentially saving resources. (China's agricultural GHGs exceed those of the US by 922 million tons–2017(10)).

As the global population continues to grow, there is no prospect of resolving the absolute global shortage of food. At this stage there is an absolute shortage of several hundred million tons or more, even just focusing on grains.[176] Grain shortages in China are also becoming more pronounced, and there is a need to improve varieties and cultivation methods more than ever before.

In China, the actual number of people engaged in agriculture, forestry, and fisheries is decreasing, and institutional responses to soil capital degradation are being sought. On the other hand, as the outcomes of investments in genome-edited foods and other products begin to become apparent, there may be a shift toward smaller investment sources centered on the Ministry of Agriculture, Forestry and Fisheries. This could also be expressed as the emergence of the possibility of reallocating various resources in the food production sector.

It will be necessary to keep a close eye on whether the genome editing research described in this paper will produce results that meet these challenges.

[175] "B" is pending application and examination.
[176] Author's calculations.

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(2) https://baijiahao.baidu.com/s?id=1724556764841330190&wfr=spider&for=pc (confirmed December 2022)

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(5) The above is mainly based on the "Annual Report" (2021) published annually by the Institute and its website: https://agis.caas.cn/bsgk/yjsjj/index.htm (confirmed December 2022)

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Reducing Obstacles in Bacterial Genome Editing	https://spc.jst.go.jp/hottopics/2112/r2112_as.html	Science and Technology Topics	11/11/2021
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Part 18: Development of Advanced Genome Editing Food Technology (2) Application of CRISPR Technology after CRISPR9	https://spc.jst.go.jp/experiences/takahashi/takahashi_2107.html	Goro Takahashi’s Advanced Agri-Anatomy	09-09-2021
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(Appendix)

JST has long been engaged in research and information gathering on genome editing technology, and has published the results on its website. When I took this opportunity to consult with Yoshitaka Komatsu of JST/APRC about compiling a list of these and including them as references in this paper, Chie Kase, Editor-in-Chief of JST/SPC, agreed to do this complicated work for us. The list of 243 items received far exceeded expectations, and I have selected only those items directly related to food and other products for inclusion as references (Appendix). The number of such cases was 64, or less than 30% of the total. I would like to take this opportunity to express my gratitude.

9 Intellectual Property Legislative Developments in 5G Mobile Communications Technology

9.1 Introduction

At the top of the list of "strategic tasks and priorities" of "Made in China 2025" is "improving the nation's manufacturing innovation capability." The improvement of innovation capability means, in other words, the improvement of domestic research and development capability, and the accumulation of intellectual property rights, including patent rights, which is a byproduct of such R&D, is also considered as one of the outcome indicators, as well as a mission in itself, with specific directions indicated.

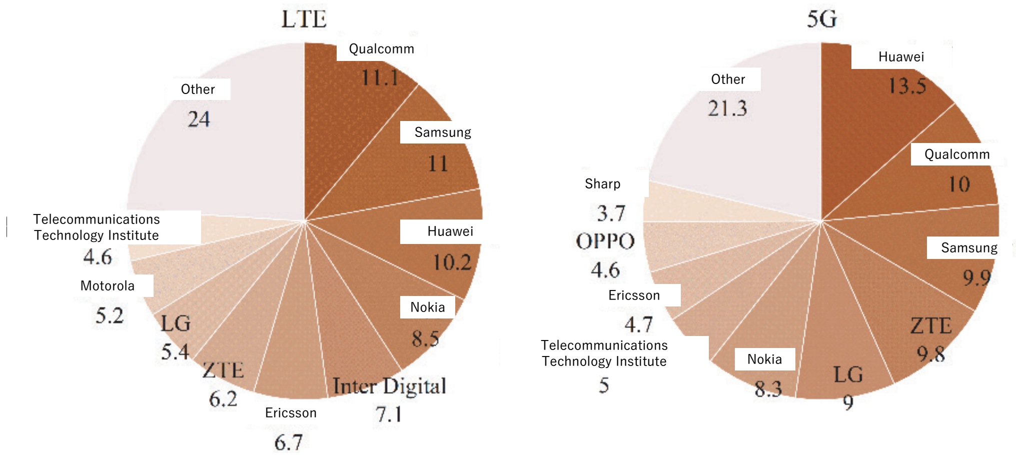
While most of the 10 key areas in "Made in China 2025" seem to be in the phase of accumulating intellectual property rights, including patent rights, next-generation information and communication technology, especially in the field of information and communication equipment centering on 5th generation (5G) mobile communication technology, seems to be in the phase of accumulating intellectual property rights and at the same time, utilizing global intellectual property rights through the implementation of its standard essential patents. As for "5th generation (5G) mobile communication technology," the advancement of the IoT has led to the development of not only typical information devices such as smartphones, but to the expansion of the base of implementation to include connected cars ("ICV" [Intelligent Connected Vehicles]). The patent system is a legal system that ultimately aims to promote industrial development through the harmonization of the protection and use of inventions. Regarding the "Standard Essential Patent" (hereinafter referred to as "SEP"), particularly 5th generation (5G) mobile communication technology and others, the question of how to establish and operate a legal system, and strike a balance between when both the right holder company and the implementer company are located in the country, could be an important industrial policy issue. This section will focus on 5th generation (5G) mobile communication technology as a type of next-generation information and communication technology, which is listed at the top of the priority areas, and follows the trends of industries involved in this field as they try to balance IP protection, focusing on smartphones and ICVs, which are the implementation areas of this technology.

9.2 Trends in 5GSEP-related industries

9.2.1 Shifts in SEP holders

First, we will review the holdings of the 5GSEP again. Figure 9-1 is a graph showing the share of patents held by SEP holders[177] for LTE (≈4G) and 5G, respectively.

Comparing the two generations, Qualcomm, Samsung, Nokia, and others, which had dominated in LTE, have decreased their market share in 5G, with Huawei replacing them in first place with a 13.52% share, up from 10.2%, ZTE in third place with a 9.83% share, up from 6.2%, and OPPO, which had less than 0.1% of the LTE market, in ninth place, with Chinese companies being notable for increasing their respective ownership percentages. As a result, Chinese companies, including VIVO, Xiaomi, and others, have a more than 40% share in 5G (Figure 9-1).

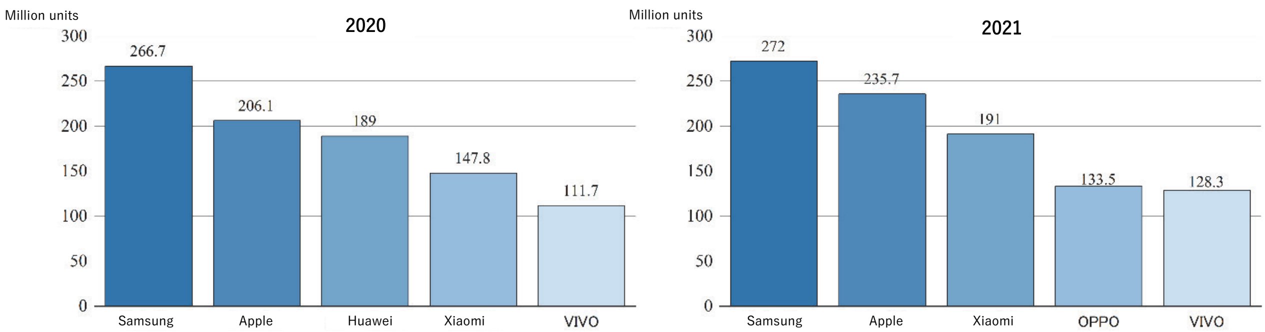


(Source: Prepared by the author)[178]

Figure 9-1: LTE/5G SEP Declaration Family Number Share (%)

9.2.2 Older Mounted Products–Trends in the Mobile Device Industry

Next, Figure 9-2 is a graph showing the top five global shipments of smartphones, the most typical implementation of SEPs for mobile communication technology.



Source: Prepared by the author based on data published by IDC on January 7, 2022

Figure 9-2: Top 5 Smartphone Shippers Worldwide

While the two strongest positions of Samsung and Apple remain unchallenged, there have been significant changes in third place and below. Huawei, which had the third largest market share in 2020,

[177] Here, data based on the number of declarations (number of patent families) were used, instead of data based on actual consistency with each standard.

[178] For LTE, we referred to the data in "ETSI Essential Declaration Patent Survey Report of LTE-related patents, Version 3.0" (https://www.cybersoken.com/file/lte03JP.pdf), and for 5G, we referred to the data in IAM "Who leads the 5G patent race as 2021 draws to the end?" (https://www.iam-media.com/article/who-leads-the-5g-patent-race-2021-draws-the-end).

was sanctioned by the US and disappeared from the ranking in the 2021 financial results with a significant 49.6% drop in revenue from its consumer business, including smartphones, with Xiaomi, OPPO, and VIVO taking its place. Huawei, which had previously been in the position of "SEP major right holder and major implementer," lost its position as a major implementer in the smartphone market in just one year. Huawei's case is unique in that there are political reasons behind it, but like Ericsson and Nokia, which have experienced similar transitions, Huawei is shifting its emphasis to revenue from royalties in the smartphone sector. The company announced the 5GSEP license fee collection in March 2021, and since then has supposedly been ramping up its licensing activities, which is exemplified by being "too busy and too fast developing...didn't have time."[179] In December 2022, Huawei announced the signing of a global cross-licensing agreement with OPPO that includes the 5GSEP, and around the same time, Huawei also announced that it was in negotiations with other major Chinese vendors.[180]

Also in December 2022, under the guidance of the State Intellectual Property Office (equivalent to Japan's Patent Office) and led by China Mobile, the largest state-owned telecommunications carrier, a "Alliance of Intellectual Property Rights in the Information and Communications Industry"[181] was established with 12 member companies including Huawei, ZTE, OPPO, and Xiaomi. The "5G Industry Intellectual Property Rights and Innovation Development Proposal" was released under the joint names of the 12 companies (organizations)[182] that are presumably members of the alliance. Although the specific course of action of this IPR Alliance remains to be seen, it appears from the proposal, "to jointly enhance the transparency, predictability, and rationality of standard essential patent licensing on the basis of fair, reasonable and nondiscriminatory (FRAND) licensing." It seems that one of their objectives is to promote the FRAND licensing of 5GSEPs among Chinese companies.

While Ericsson and Nokia, which have abandoned their position as implementers in the smartphone market, have filed lawsuits around the world as rights holders, there is no information on Huawei, at least at this point in time, that it has developed into a lawsuit or the like in the smartphone field. In August 2022, Huawei CEO Ren Zhengfei said in an internal forum that "it is better to close businesses that do not do well and drain huge resources and open them up to others," and it seems that the company is now "opening up" its rich SEP resources to its fellow juniors in the smartphone market.

9.2.3 ICVs as a New Mounted Product - Trends in the Automotive Industry

This section will trace recent developments in the Chinese automotive industry regarding ICV implementation of 5G and other telecom SEPs. As mentioned above, in the smartphone field, a number of leading domestic companies have gathered to promote the creation of voluntary platforms and rules, which are then backed up by government agencies, and a similar trend can be seen here. In particular,

[179] Huawei CEO Ren Zhengfei in June 2019
[180] Tencent.net, December 9, 2022 article
[181] For more information on the Alliance of Intellectual Property Rights, see my article "Intellectual Property Policy in the context of a Dual-Circulation Strategy" (https://spc.jst.go.jp/experiences/special/circulation/circulation_2207.html).
[182] China Mobile, China Satellite Network, China Academy of Information and Communications, China Information and Communications Technology Group, Huawei, ZTE, Honor, TCL, Tsinghua Unigroup, OPPO, Xiaomi, VIVO

the private sector made moves first in response to SEP infringement lawsuits against car companies in Europe starting around 2019, and there, under the guidance and backup of the public sector, a study of SEP licensing policies pertaining to ICVs was conducted and the development of guidelines as a result of that study is underway. Specifically, in October 2019, prior to the promulgation of the "Intelligent Automobile Innovation and Development Strategy" by the National Development and Reform Commission and others, nine automakers, including FAW (China FAW) and Beiqi (Beijing Automotive), established the "China Automotive Intellectual Property Rights Alliance" to remove barriers to IPR utilization and protect against significant IPR risks in the automotive industry. Then, in November 2020, the "Automobile Standard Essential Patent Working Group" was set up by China Automotive Technology Research Center Co.[183] and the abovementioned China Automobile Intellectual Property Rights Alliance, etc., on behalf of the Science and Technology Bureau of the Ministry of Industry and Information Technology and in the presence of the State Intellectual Property Office, the Antimonopoly Bureau of the State Administration for Market Supervision, and others. Since its inception, this working group has been studying important issues such as licensing models, with the goal of formulating "Automotive Standard Essential Patent Licensing Guidelines." On September 13, 2022, the "Automotive Standard Essential Patent Licensing Guidelines (2022 Edition)" was published jointly by the China Automotive Technology Research Center Co.

Table 9-1 presents a summary of some of these provisions, which are consistent in intent with the METI guidelines in Japan ("Approach to Calculating Fair Value of Standard Essential Patents for Multi-Component Products"[184]). In addition, Mr. Wang Junlei, Deputy Secretary General of the Intellectual Property Rights Subcommittee of the China Society of Automotive Engineering, who was involved in the formulation of these guidelines, specifically cited these METI guidelines in his keynote speech at the China Automotive Intellectual Property Rights Annual Conference in July 2021, and introduced some of their contents, which It is highly likely that they were used as a reference in the formulation of these Guidelines.

Table 9-1: Main Contents of the "Automotive Standard Essential Patent Licensing Guidelines"

Key Issue 1: Contracting Entity-License to All "Under the FRAND approval made by the standardizing organization or the IPR policy of the standardizing organization, any bona fide patent practitioner has the right to obtain a license to a standard essential patent, and the holder of a standard essential patent has the obligation to license it to any practitioner seeking a license, regardless of which level in the industrial chain he or she may be located. SEP rights holders may not collect duplicate SEP royalties from different tiers of manufacturers in the same industrial chain."

[183] Established in 1985, this is a central enterprise under the State-owned Assets Supervision and Administration Commission of the State Council (https://www.catarc.ac.cn/zxjj)
[184] https://www.meti.go.jp/policy/mono_info_service/mono/smart_mono/sep/200421sep_fairvalue_hp.pdf

Key Issue 2: Basics of Royalty Calculation "Regarding the basis for calculating SEP royalties, the product units to which SEP technology has actually contributed in automotive products should be used as the basis for calculating royalties, and inclusion of other product units unrelated to SEP technology in the basis for calculating royalties should be avoided. Regardless of whether parts or complete automobile products are used as the basis for calculating royalties, the actual value contribution of the SEP technology to the automobile product in question should be considered. In addition, SEP royalties calculated for the same automotive product should be generally the same regardless of the tier of the license, and there should be no significant differences in royalties due to differences in the tiers of the licenses."
Key Issue 3: Royalty Rates–Top-Down/Bottom-Up "The 'top-down' approach, the comparable license approach, etc. may be employed when calculating SEP royalties. Adopting a 'top-down' approach avoids the problem of loyalty stacking. This method requires first determining the maximum cumulative royalty rate for all SEPs in a particular standard, and then calculating the ratio of actual SEPs for different patentees to calculate the reasonable license ratio for different patentees. When adopting a comparable license approach, factors such as the licensing transaction entity, the licensed product, the licensed territory, the relationship between the licensed subject matter, and the notarization process of both the transaction subject matter and the licensed parties included in the license may be comprehensively considered. Whether adopting the 'top-down' approach or the comparable license approach, the actual percentage of SEPs of the patent holder and the geographic distribution of SEPs shall be taken into account, while at the same time taking into account the actual contribution of the SEP holder to the standard and the status of its proposal."

Huawei will continue to take the position of SEP major right holder with respect to ICVs, but it appears that, at least in the domestic market, Huawei is aiming to aggressively market communication modules and other products and to take the position of major implementer at the component level. After launching the MH5000 5G module for ICVs in April 2019, the company announced that it would launch a 5G automotive ecosystem with 18 automakers, including FAW, Changan, and Dongfeng in May 2020 to provide technology, platforms, and ideas to these partners. In April 2021, the company announced the launch of an automated EV ("ARCFOX- α T") jointly developed with one of its partners, Beiqi New Energy Source, under the brand name "Huawei Inside." Huawei may regard the issue of telecom SEPs in ICVs as part of the groundwork for building an ecosystem starting with Huawei, which includes not only telecom modules but also self-driving platforms, where competition is expected to intensify in the future. In fact, in July 2021, Huawei announced a license, including a 4GSEP, to a VW supplier, and in January 2022, there were reports that the two companies were moving to establish a joint venture in China with a view to developing self-driving technology. In December 2022, Huawei also announced a cross-licensing (Huawei licenses telecom SEPs to Pateo) with Shanghai Botei (Pateo), with whom it has had a partnership since 2018.

In contrast to these domestic developments, Huawei appears to be actively licensing to car companies outside of China. In 2019, when Daimler was sued by Sharp in Germany, Huawei, which was involved in the lawsuit as a supplier, was reportedly quick to sign a licensing agreement with Sharp to reduce the claims, but in December 2022, several Huawei IP department officials revealed that the company had signed licensing agreements with Mercedes-Benz, BMW, Porsche, Renault, and others. It was also reported that Huawei filed a lawsuit against Stellantis in Germany in November 2022. Huawei does not appear to be a member of Avanci[185] at this time, but outside of China, it has shown itself to be a strong rights holder, mainly pushing for licenses to automakers, following the logic of the Sharp vs. Daimler lawsuit in which it was involved, and is not willing to sue in the process.

9.3 Recent Trends in the Enactment and Operation of Domestic Legislation in China Concerning SEPs

Previous sections have followed recent developments in China's domestic smartphone and ICV industries with respect to telecom-related SEPs. From the aspect of SEP ownership, with the generational shift from 4G to 5G, Chinese companies have become the top SEP holders, and from the aspect of SEP (and inventions related to SEP) implementation, other Chinese companies such as OPPO have taken over Huawei's declining sales in the smartphone market. In the ICV market, we have seen that the automotive industry is moving in response to lawsuits in Germany and other countries.

If domestic industry is dominated by implementer-side firms, the direction of the IP legal system as a part of industrial policy is clear. However, as we have seen, in China, both the SEP right holders and implementers have a significant presence in the industry, whereas in the past, the implementers, including Huawei itself, were more predominant. Therefore, we will now explore how the Chinese legal system is attempting to respond to these changes in the industrial structure surrounding SEPs by following recent judicial, legislative, and administrative developments in China.

9.3.1 Recent Regulatory Trends for SEPs under Antitrust Laws, etc.

Intellectual property laws, especially those pertaining to technological creations such as patents, are designed based on the idea that the development of a country's industry will ultimately be promoted through a balance between the protection of rights and the promotion of the use of inventions, including by third parties, in accordance with the rights. In general, there are provisions to adjust the balance within the Patent Law, which is an intellectual property law. The Antimonopoly Law, which is a competition law, also attempts to adjust the balance by placing certain restrictions on the protection of rights under the Patent Law.

In China, guidelines and other developments have been underway since 2015 in the form of clearly stated standard essential patents.[186] As shown in Table 9-2, the main laws, regulations, guidelines, etc. concerning SEPs are mostly based on the Antimonopoly Law, including the judicial interpretation based on the Patent Law in Table No. 3 below, which basically tries to curb their enforcement to some extent.

[185] Automotive Telecommunications SEP Patent Pool.

[186] Prior to the 2018 reform of the State Council structure, law enforcement was divided between the Ministry of Commerce (responsible for business concentration, etc.), the State Development and Reform Commission (responsible for price monopolization, etc.), and the State Administration for Industry and Commerce (governing abuse of dominant market position, etc.). Currently, law enforcement functions are concentrated in the State Administration for Market Supervision and Administration, which was established to replace the State Administration for Industry and Commerce and other agencies.

Table 9-2: Major Laws, Regulations and Guidelines on SEPs

No.	Enactment/ year of publication	Name	Institution/Department	Overview
1	2015 (⇒ Revised 2020)	Provisions regarding prohibition of acts to exclude or restrict competition through abuse of intellectual property rights	State Administration for Industry and Commerce (⇒ State Administration for Market Supervision)	• The guidelines are based on the Antimonopoly Law and aim, among other things, to deter businesses from abusing their intellectual property rights to exclude or restrict competition. • In the process of formulating the draft, the committee heard opinions not only from domestic companies such as Huawei, but also from foreign companies such as Qualcomm and Samsung, as explained in the 2014 release of the draft for public comment. • Standard essential patents are subject to the prohibition of violation of FRAND obligations and other provisions regarding "abuse of a dominant market position" under the Antimonopoly Law. This appears to be the first provision in China that mentions FRAND obligations. • Revised in 2020, focusing on formal revisions due to structural reforms.
2	2015	Antitrust Guidelines on the Prohibition of Abuse of Intellectual Property Rights (Draft for public comment)	National Development and Reform Commission	• The Qualcomm case (see Table 9-3 No.2 below) is said to have prompted the National Development and Reform Commission to draft these guidelines. • The types of IPR enforcement actions (unfair terms, tying, refusal of license, etc.) identified with respect to abuse of dominant market position are common to the provisions in No. 1 above, and the criteria for judgment are also generally the same, although the Guidelines are more detailed in general.
3	2016	Interpretation on Some Issues of Application of Law in the Trial of Dispute over Patent Infringement by the Supreme People's Court (2) (*Judicial Interpretation[187])	Supreme People's Court	• The other provisions and guidelines listed in this table are mainly based on the Antimonopoly Law, whereas this judicial interpretation is based on the Patent Law. • Specifically, it stipulates that if the patentee intentionally violates the FRAND obligation and there is no obvious negligence on the part of the implementer, the request for injunction based on patent infringement shall not be granted (Article 24).

[187] Judicial Interpretations are specific rules of interpretation by the Supreme People's Court, etc., regarding specific criteria for judgment of each legal provision and other legal issues, and are binding on proceedings before the people's courts of all levels.

No.	Enactment/ year of publication	Name	Institution/Department	Overview
4	2019	Antitrust Guidelines for the Intellectual Property Rights Sector	Antitrust Commission of the State Council	• Regarding the enforcement of IPRs, the article goes further than the 2017 opinion draft to address standard essential patents separately and specifically lists the factors to be considered regarding the applicability of a dominant market position, competitive exclusion, and restrictive conduct (Article 27). • Compared to No. 1, it is more comprehensive, including provisions on business concentration, but the enforcement of IP rights is somewhat abstract.
5	2019 (⇒ Revised 2022)	Temporary Provisions on Prohibition of Abuse of a Market Dominant Position	State Administration for Market Regulation	• The regulations provide specific types of acts and judgment criteria for the abuse of a dominant market position among the types of monopolistic acts. • Revised 2022
6	2021	Patent Law (amended in 2020)	Standing Committee of the National People's Congress	• Although there is no direct provision on standard essential patents, the revised Patent Law, which has been in effect since 2021, includes a new provision stating that "if abusing a patent right to exclude or restrict competition constitutes a monopolistic act, it shall be handled in accordance with the Antimonopoly Law (Article 20)."
7	2022	Antitrust Law (revised in 2022)	Standing Committee of the National People's Congress	• Does not include direct provisions for the enforcement of IP rights, such as standard essential patents. • The provisions are seen to be aware of the abuse of the dominant market position of platform operators and the operational challenges of examining business concentrations.
8	2022	Provisions regarding prohibition of acts of excluding or restricting competition through abuse of intellectual property rights (draft for public comment)	State Administration for Market Regulation	• It substantially corresponds to the revised draft of No. 1. • The improvement of the rules for "key areas such as standard essential patents" is described as one of the pillars of the revision. In particular, the scope of regulatory acts in the process of establishing and implementing standards is expanded with respect to abuse of a dominant market position.

No.	Enactment/ year of publication	Name	Institution/Department	Overview
9	2022	Supreme People's Court Rules on Some Issues of Application of Law in Monopoly Civil Dispute Cases (Draft for Opinion Solicitation) (*Judicial Interpretation)	Supreme People's Court	• This is a revised draft of the 2012 Judicial Interpretation "Provisions on Some Issues Concerning the Application of Law in the Hearing of Cases of Civil Disputes Arising from Monopolistic Conduct," which significantly increases the number of provisions. • The new regulations include provisions on the jurisdiction of civil suits against foreign monopolies that affect the exclusion or restriction of competition in Japan (see below).

(Source: Prepared by the author)

Most recently, entering the year 2022, the Antitrust Law was notably revised for the first time since its enactment in 2007. That is,

- In April 2021, around the same time as the announcement of the draft amendment (October 2021) and the enforcement of the amended law, Alibaba was fined 18.228 billion yuan for abusing its dominant market position in deterring its own platform operators from opening stores on competing platforms.[188]
- The new provisions are designed to regulate platform operators, such as, "Operators shall not use data and algorithms, technology, capital advantages, and platform rules to engage in monopolistic acts prohibited by this Law (Article 9)," and other newly established provisions that are aware of the regulation of platform operators.

In light of the above, it is fair to say that the revision of the Antimonopoly Law itself was primarily aimed at strengthening regulation and monitoring domestic mega-platforms such as Alibaba and Tencent. Both before and after the amendment, the main body of the Antitrust Law contains no direct provisions on SEPs.

However, immediately after the promulgation of the revised Antimonopoly Law, the State

[188] Other examples:
December 2020: Decision to impose a fine of 500,000 yuan on Alibaba and others for violating the notification obligation regarding business concentration in mergers and acquisitions.
August 2021: A disposition decision was made against Tencent for concluding exclusive distribution agreements with a number of content holders in the music distribution business, including an order to terminate the exclusive agreements, on the grounds that this constituted a concentration of business.
July 2022: Decision to impose a fine of 500,000 yuan on Alibaba, Tencent, etc. for violations of obligations to notify regarding business concentration in M&A, etc.

Administration for Supervision and Administration of Markets solicited public comments on the "Provisions on Prohibition of Abuse of Intellectual Property Rights to Exclude or Restrict Competition" (Table 9-2, No. 8), in which the improvement of rules for "key areas such as standard essential patents" was given as one of the pillars of the revision. The draft provision also expands the scope of regulatory acts in the process of establishing and implementing standards, for example, in Article 16,

> "An entity that has a dominant market position...
> Violating fair, reasonable, and nondiscriminatory licensing in the licensing process for standard essential patents, improperly requesting a court or relevant department to issue a judgment, award, or decision prohibiting the use of relevant intellectual property rights without a bona fide negotiation process, and forcing licensees to accept unfairly high prices or other unreasonably restrictive terms (iii) make a claim or demand for a judgment, award, or decision
> (shall not act to eliminate or restrict competition.)"

This provision was added in an attempt to regulate so-called "hold-ups" from the front.

Since around 2015, China has adopted the slogan of transforming itself from an "IP superpower to an IP powerhouse" and has been advocating stronger IP protection both internally and externally. With regard to patent rights, the embodiment of such a "pro-patent" ethos can be seen not only in the content of specific legal provisions at the legislative stage, but also in their operation in the judiciary. In particular, the author has observed this trend in the actual decisions issued by the Supreme People's Court since the establishment of the IP Court in 2019. On the other hand, as mentioned above, with regard to SEPs, since 2015, and especially since 2019, various provisions and guidelines related to the Antimonopoly Law have been developed, and the tendency to protect implementers has increased, giving the appearance of a double standard. To explore the context, we will review the administrative penalties and investigative cases involving SEPs. Table 9-3 is a summary of administrative penalties and investigative cases involving SEPs.

Table 9-3: Administrative penalties and investigative cases involving SEPs

No.	Year of penalty / Year of start of investigation	Company subject to investigation/ punishment	Institution/ Department	Overview
1	2014	InterDigital	National Development and Reform Commission	• In 2013, the National Development and Reform Commission launched an investigation into IDC in connection with a civil lawsuit filed by Huawei with the Shenzhen Intermediate People's Court for violation of the Antimonopoly Law over the licensing of standard essential patents such as CDMA held by InterDigital. • The IDC subsequently offered corrective measures and in May 2014, the investigation was suspended.

No.	Year of penalty / Year of start of investigation	Company subject to investigation/ punishment	Institution/ Department	Overview
2	2015	Qualcomm	National Development and Reform Commission	• In November 2013, the National Development and Reform Commission opened an investigation into Qualcomm's alleged abuse of a dominant position in the SEP licensing market and in the CDMA, WCDMA, and LTE baseband chip markets. • As a result, an administrative penalty was imposed on Qualcomm for having a dominant position in the SEP license market and the baseband chip market, respectively, and for abusing that position, with the suspension of illegal activities and a fine of 8% (6.088 billion CNY) of the company's 2013 sales in China.
3	2019	Ericsson	State Administration for Market Regulation	• In April 2019, Ericsson was investigated for alleged abuse of a dominant position in the standard essential patent market based on a report and surrounding investigation.[189] • According to reports, several mobile phone manufacturers reported that Ericsson's licensing of 3G and 4G standard essential patents violates antitrust laws.[190] • On April 15, 2019, after the investigation began, Ericsson issued a statement that it would fully cooperate with the authorities' investigation and would continue to comply with its FRAND obligations. • Although the results of the investigation are unknown, it is assumed that no disposition decision has been issued.
4	2022	Nokia and others	State Administration for Market Regulation	• In June 2022, the State Administration for Market Supervision reported that it had launched an investigation into Nokia and other companies regarding antimonopoly issues surrounding 5G standard essential patent license fees, and sent questionnaires regarding pricing strategies and sales injunctions for 5G standard essential patent licenses.

In addition to the cases listed in Table 9-3, it was reported that in December 2021, the China Mobile Phone Federation, an organization under the China Telecommunications Industry Association, reported Japan's IP Bridge to the authorities for violating antitrust laws by abusing intellectual property rights.

Thus far, all penalties, investigations, etc. for violations of antitrust laws pertaining to SEPs have been

[189] China Antitrust Annual Report (2019)
[190] See article on People's Network, April 15, 2019.

directed against foreign companies. With Chinese device makers other than Huawei making great strides, the move to strengthen regulations under the provisions shown in Table 9-2, Item 8 can also be seen as aimed at protecting device makers other than Huawei, where there are still pre-4G generations at the implementation level and where infringement on past implementation could also be an issue, as well as with "long-established" SEP holders such as Nokia. It is possible to view this as an attempt to protect device makers other than Huawei, which have unresolved patent issues with "long-established" SEP holders such as Nokia. The academic community also offered opinions that supported these hypotheses.

Established in 2008, the International Intellectual Property Research Center of Peking University is a professional education and research institute affiliated with Peking University and entrusted by the State Intellectual Property Office to operate the "Peking University State Intellectual Property Office Strategic Implementation Research Base". The institute tracks global IPR development trends and conducts research on key themes in the implementation of the national IPR strategy. In December 2021, the Center hosted an expert panel on "Standard Essential Patent Policy in the Era of 5G," which expressed the following opinions (underlined by the author).

- Regarding Nokia's lawsuit against OPPO, Nokia is aiming for monopolistic pricing by filing a lawsuit. It is <u>suggested that domestic companies work with upstream and downstream manufacturers and industry associations in the supply chain to jointly file a report with the Antimonopoly Department</u> (Ma Yide, Professor, Chinese Academy of Sciences University).
- In the choice of remedies, the action of antitrust law is prominent (Li Yang, Professor, China University of Political Science and Law).
- I agree with the opinion that the issue of the rate should be resolved within the framework of the Antimonopoly Law and that <u>the pressure of the Antimonopoly Investigation will encourage agreement between the parties</u> (Li Mingde, Research Fellow, Chinese Academy of Social Sciences).

A basic consensus was then reached among all experts present, including the following.[191]

- The FRAND principle has been and remains a fundamental principle in the licensing of standard essential patents, and <u>judicial agencies and antitrust departments should actively intervene to ensure that right holders and implementers are able to negotiate reasonably back to the market</u>. China is a growth country in technological R&D, but it <u>is also a manufacturing powerhouse, and its expectations and adherence to the FRAND principle are even stronger</u>.
- The 5G era is not only an extension of the past 3G and 4G era, but also a process of restructuring the industrial structure. <u>Relevant Chinese enterprises, industry associations, and relevant government departments</u> need to <u>actively respond to the situation and create a fair competitive market environment for Chinese enterprises in the new industrial structure</u>.

Incidentally, will Huawei, a giant domestic rights holder company, not be adversely affected by the

[191] See Law Knowledge Network December 1, 2021 article (http://epaper.legaldaily.com.cn/fzrb/content/20211201/Articel09002GN.htm)

tightening of SEP regulations on an antitrust law basis?

Table 9-4 show the prices of the companies that have published royalties for 5GSEP mobile phones.

Table 9-4: 5GSEP Published Royalties (Mobile Devices)

Company name	Year of publication	Public royalties
Ericsson	2017	$5/unit (However, $2.5 for emerging countries such as India)
Qualcomm	2017	Stand-alone mode: 2.275% (2G/3G/4G/5G) Multi-mode: 3.25%
Nokia	2018	Max. 3 Euro/unit
Huawei	2021	Up to $2.5/unit

Multiply this by Figure 9-1's 5GSEP share, and Huawei's royalties are relatively quite low, and it seems difficult to argue that they are unreasonably high, at least with respect to rates. In addition, given the establishment of the Information and Communications Industry Intellectual Property Rights Alliance (see above), it seems unlikely that the company's SEP licensing activities in the smartphone market will be targeted by the antitrust laws at this time.

Note that the draft "Provisions on the Prohibition of Acts of Excluding or Restricting Competition through the Abuse of Intellectual Property Rights" (Table 9-2, No. 8) includes a new provision that recognizes the regulation of patent pools. Specifically, Article 14 of the draft adds a provision stating that patent pools with a dominant market position may not license patents at unfairly high prices.

As Wang Junlei noted above in his keynote speech at the July 2021 China Automotive Intellectual Property Annual Conference, "Since the Avanci platform was established, [...] the formation of automakers has not been so good." He also gave an explanation to the effect that Avanci's licensing fees were too high when viewed on a module basis. It is likely that the move is meant as a warning and deterrence against Avanci's moves in the US and Europe.

9.3.2 Judicial Trends After ASI

With regard to SEP litigation, the ASI by the Chinese courts has attracted particular attention in recent years, and the fact that both parties to litigation have been striking each other with injunctions across national borders, and that this in itself has the potential to spark international friction, was pointed out in my article "IP Policy in a Dual-Circulation Strategy."[192] In response, Western countries are shifting their responses from condemnation to concrete countermeasures: in February 2022, the European Commission filed a complaint with the WTO against the Chinese State Council's ASI and other cases, and in March, legislation was introduced in the United States to restrict the enforcement of foreign prohibition orders.

On the other hand, SEP right holder companies are also moving to contain ASI in China by taking the lead in the UK and other countries. The ASI is only a provisional injunction, and it is necessary to file a main lawsuit (e.g., in the OPPO vs. Sharp case, to determine the global SEP license terms). The SEP

[192] See https://spc.jst.go.jp/experiences/special/circulation/circulation_2206.html

right holder first sues the Chinese company as the implementer in Germany, etc., and then the Chinese company files an anti-ASI (AASI) to prohibit the filing of the main lawsuit and the filing of the ASI in the "home" country as a precautionary measure (January 2021: IP Bridge vs Huawei/UK Court, July 2022: Philips vs. OPPO/UK Court). Perhaps in response to these developments, the ASI that was frequently issued in China in 2020 seems to have died down at this point.

Although the ground rules for the ASI are Article 103 of the Code of Civil Procedure and the related judicial interpretation "Provisions on Some Issues of the Supreme People's Court's Application of Law in the Examination of Conduct Preservation Cases of Disputes Related to Intellectual Property Rights", the norms established by the Supreme People's Court in the Huawei vs Conversant case are not directly covered by these existing legal norms, For this reason, it would not be surprising if the Supreme People's Court were to issue a judicial interpretation rule that would fill the gap between the two if it were to get serious about the ASI, but that does not seem to be the concern of the judicial branch at the moment. One of the most recent developments regarding SEPs is No. 9, "Provisions on Some Issues of Application of Laws in Monopoly Civil Dispute Cases by the Supreme People's Court (Opinion Call Draft)," in Table 9-2. This judicial interpretation includes a new provision on the jurisdiction of civil actions against foreign monopolistic acts affecting the exclusion or restriction of competition in the country (Article 7). This is not a direct provision for SEPs, but it is a provision that confirms the Supreme People's Court decisions in 2020 (Sisvel vs. OPPO and Ericsson vs. TCL) and allows Chinese courts to have jurisdiction more loosely than in those decisions. In other words, based on this provision, the court where the plaintiff (Chinese company) is located may have jurisdiction as the place of occurrence of the infringement result that directly and substantially affects domestic competition by filing a lawsuit or negotiating a license outside of China.

Thus, after the frequent issuance of ASIs in 2020, judicial interpretations of SEPs, including provisions for domestic corporate remedies under the Antitrust Law, are being revised to follow administrative and legislative developments, but at this point, no notable developments have been observed.

9.4 Conclusion

China, which is transforming its economic model through a "dual-cycle" strategy, is in the midst of a trend toward stronger IP protection from a macro perspective, and as part of this trend, it is certainly in the midst of encouraging patenting in both the judicial, legislative, and administrative aspects of its economy. However, at least with regard to mobile devices and automobile implementation, the three authorities seem to be working in unison on the double standard of strengthening regulations on mobile communication-related SEPs through various laws, regulations, guidelines, etc. based on the Antimonopoly Law, thereby protecting domestic mobile device makers and domestic car makers instead of Huawei. In China, the judicial and administrative organs are subordinate to the legislative organs under the system of " 議行合一 ,"[193] a concept that is at odds with the "separation of powers," and it is undeniable that this

[193] It is not a concept that necessarily implies the identity of legislative and executive bodies.

particularity of the governance system has led to a sense of control and unity in the formulation and implementation of industrial policy.

While the regulation of mega-platforms under antitrust laws, as discussed in this chapter, has traditionally focused on controlling private companies, the situation is different for mobile devices and automobiles examined here, where such control and uniformity have manifested in distinct ways. The starting point is the private sector (especially leading domestic companies), and the public sector absorbs the opinions of the private sector and backs them up strongly and promptly compiles them into legal provisions, etc. The close cooperation between the public and private sectors and the strong presence of highly specialized research institutions directly under government agencies (academia) that act as a bridge between the two seem to be the strong driving force behind industrial policy vectors. The direction of these vectors can change in any way as the industrial structure changes in the future, but at this point, it is safe to say that the brunt of antitrust-based regulations is clearly directed at foreign rights holders, including Japanese companies. The SEP-related provisions listed in this chapter are in the revision stage at the time of writing this report, and it is necessary to continue to pay attention to these trends.

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