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Asia and Pacific Research Center

Taiwan's Science and Technology Capabilities: Innovation Policies of the Tsai Administration and Basic Research Trends

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Japan Science and Technology Agency

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This report is compiled as part of a research that surveyed and analyzed science and technology innovation policies, research and development trends, and associated economic and social circumstances in the Asia-Pacific region. It is being made public on the APRC website and portal site to enable wide use by policymakers, associated researchers, and people with a strong interest in collaborating with the Asia-Pacific region; please see the websites below for more details.

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Executive Summary

In recent years, Taiwan has performed well in economic development and social governance, not only playing a key role in the global semiconductor supply chain but also attracting international attention for its effective public health policy in responding to COVID-19 as well as its widespread digital construction in society. In the IMD World Competitiveness Rankings 2021, Taiwan ranked 8th out of 64 countries and achieved good results in scientific infrastructure, ranking 6th. In addition, the Tsai Ing-wen administration is making efforts to invest in the STI policy to improve Taiwan's economic structure.

This report investigates the policy trend and overall R&D trend of science and technology innovation in Taiwan, which could serve as the basis for the future direction of Japan-Taiwan science and technology cooperation. This report will be divided into three parts. The first part will analyze the overall situation of Taiwan's science and technology capabilities. The second part will analyze the situation and issues of science and technology innovation policies implemented during the Tsai Ing-wen administration. The third part will analyze the current situation of basic research in Taiwan. Finally, this paper will base on the current situation of the Japan-Taiwan basic research cooperation, in combination with the contents described above, to point out the proper future directions for cooperation in basic research.

The first part shows that Taiwan has high R&D investment and great performance in clinical medicine, engineering, chemistry, materials science, physics, information engineering, and other fields, while the industries are electronic manufacturing and semiconductor industry. In recent years, with the R&D investment and policy support from the government, industry, and university, Taiwan is gradually moving from a traditional electronic equipment manufacturing economy to a new economic model of information and communication services.

The second part compiled many of the science and technology innovation policies during Tsai Ing-wen regime, including "5+2 Innovative Industries Plan", "Six Core Strategic Industries" and so on, guiding the industrial structure to new key industries, which have the potential for future development or importance to social stability. However, there are also many problems in the implementation of the STI plan, such as the poor evaluation index setting of the plan, the lack of integration of various ministries when implementation, the low efficiency of the industry-university cooperation plan for the industry, the lack of reasonable evaluation and feedback mechanism, etc. In this regard, the Taiwan government also plans to strengthen the integration of interdisciplinary science and technology programs through the organizational reform and upgrading of the Ministry of Science and Technology, to solve the problems through the continuous adjustment of corresponding mechanisms.

The third part shows that the scientific and technological fields with good performance in Taiwan's basic research are aerospace science, materials science, physics, chemistry and clinical medicine. These fields not only have good research quality, but also have relatively large number of research, so they can be regarded as the priority direction for cooperation. As for ways to promote cooperation, this report suggests that from two aspects. First, various academic exchange activities can be held in specific scientific and technological fields to generate research opportunities. Second, setting up bilateral international research programs to provide scholars with funding and resources to keep the research going.

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1 Overview of Taiwan's Science and Technology Capabilities

1.1 Research Methodology

In the event of future collaboration between Japan and Taiwan on research and development (R&D) in the fields of science and technology, Japan should prioritize the selection of those scientific fields in which Taiwan has advantages and is focusing its R&D efforts on and collaborate with leading researchers to enhance the effectiveness of subsequent research. The framework for the survey and analysis of Taiwan's scientific and technological capabilities (Fig. 1-1) is divided into three main sections. This chapter clarifies Taiwan's science and technology capabilities by researching and summarizing the status of Taiwan's R&D resources, the fields in which R&D resources are concentrated, the status of R&D results, the scientific fields in which Taiwan has an edge in R&D and which have made rapid progress, and the fields of expertise and research subjects of outstanding and high-profile researchers working in Taiwan in recent years.

First, in terms of inputs, the report analyzes the status of R&D investment in Taiwan. Based on indicators related to R&D budgets and the number of researchers, the report investigates the current status of R&D investment in Taiwan as a whole. In addition, interviews were conducted with key personnel involved in Taiwan's science and technology policy, such as senior officials at the Ministry of Science and Technology, to conduct a more in-depth analysis of Taiwan's approach to science and technology policymaking and the basic direction of R&D budget allocation. This will provide a clear picture of the growth of R&D expenditure and the number of researchers in Taiwan, and in which departments and agencies, scientific and technological fields, and industrial sectors these resources are currently and will be concentrated in the future.

Next, the report analyzes Taiwan's academic papers and patents as outputs. The analysis will focus on the number of papers and citations, the number of patents, and other indicators used by this survey as outputs in the form of R&D results. In conducting this analysis, JST collaborated with Dr. Huang Mu-hsuan, Dean of the College of Liberal Arts, National Taiwan University, to clarify the overall picture of Taiwan's R&D results and the outstanding scientific fields, researchers, and science and technology among them.

Finally, as the outcomes are the enhancement of Taiwan's science and technology capabilities and, through the transfer of human resources and technology, the increase in innovation capacity of technology-intensive companies and creation of start-ups that leverage new technologies, Taiwan's current international innovation ranking, university (undergraduate) rankings, technology trade, technology-intensive companies, and the status of new start-ups will be analyzed. Through these analyses, the areas where Taiwan currently has an advantage in technological innovation will also be identified.

The report which follows describes the findings in line with these analytical frames.

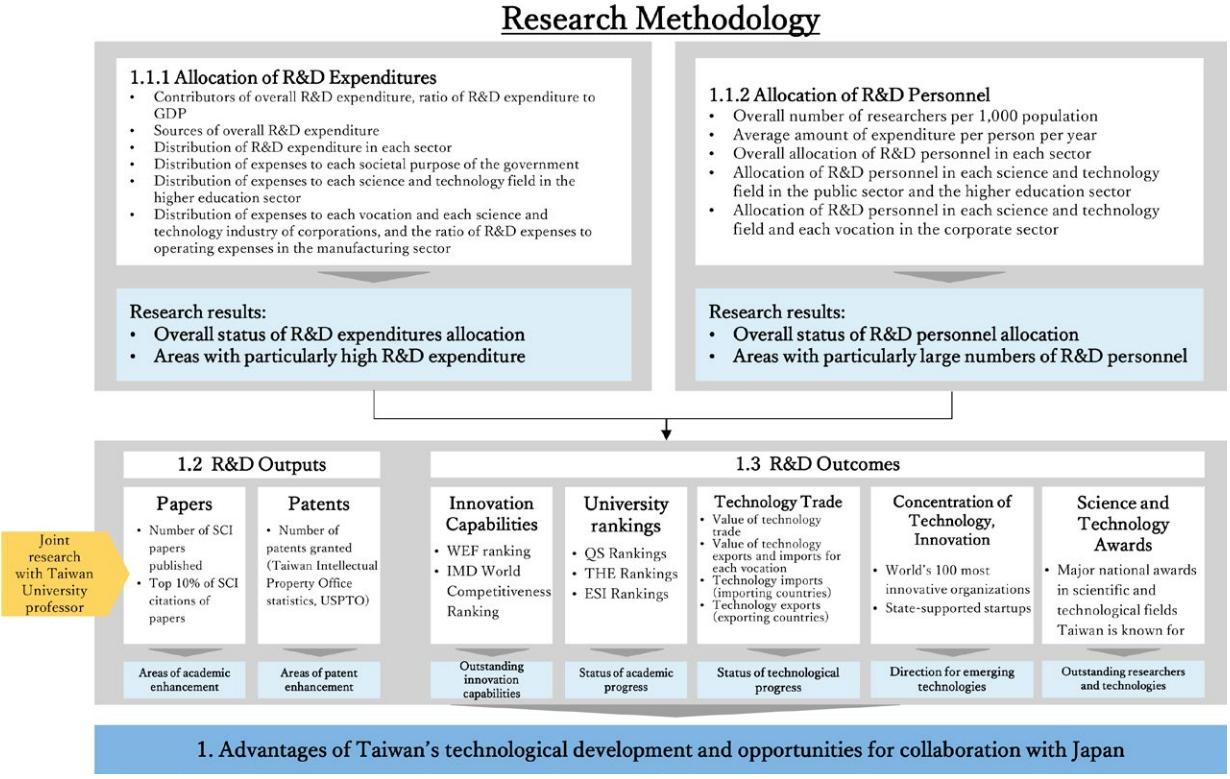


Fig. 1-1 "Overview of Taiwan's Science and Technology Capabilities": Survey, Analysis, and Method

(Figure created by the authors)

1.2 Science and Technology Inputs

1.2.1 Research and Development Expenditure

In the ten-year period between 2011 and 2020, Taiwan's R&D expenditure increased from approximately 415.4 billion New Taiwan dollars (TWD; 1.7862 trillion yen, converted at a rate of 1 TWD = 4.3 JPY, the same rate is used hereinafter) to approximately 718.7 billion TWD (3.0904 trillion yen), growing each year by an average rate of 6.28%. Moreover, the ratio of R&D expenditure to GDP also increased from 2.91% in 2011 to 3.63% in 2020, with particularly strong growth after 2016, indicating that various industries in Taiwanese society have been actively investing in science and technology R&D in recent years (Figure 1-2).

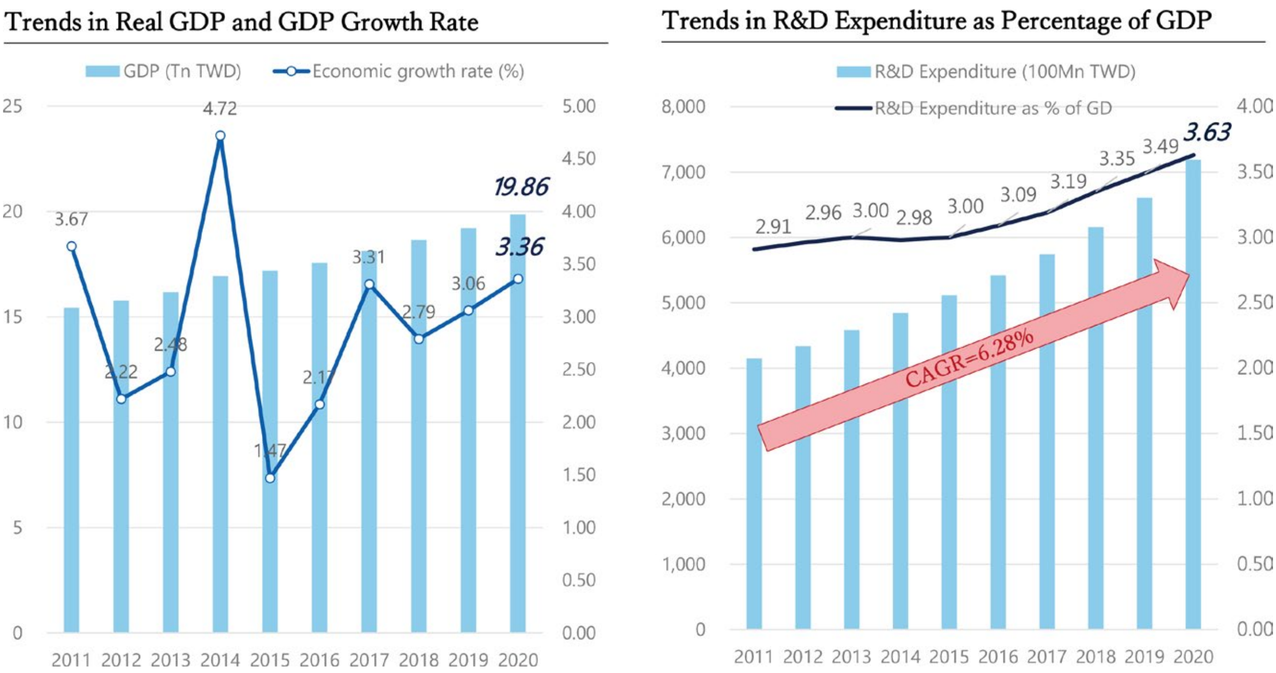


Fig. 1-2 GDP Growth and R&D Expenditure as Percentage of GDP

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

1.2.2 Contributors of and Sectors Using R&D Expenditure

Figure 1-3 shows the sources of and the sectors implementing R&D expenditure in Taiwan. R&D expenditures in Taiwan are mainly from the corporate sector (accounting for 82.5% in 2020) and the public sector (15.4% in 2020). Of these, corporate sector R&D expenditure is manly used for in-house research and development. On the other hand, R&D expenditure by the public sector is used to support public research institutions and institutions of higher learning.

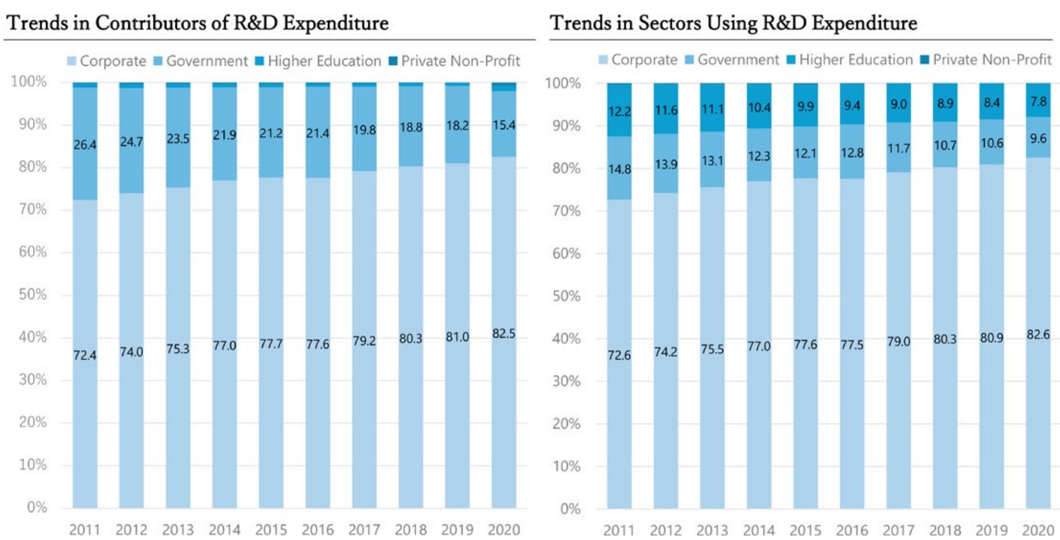


Fig. 1-3 Contributors of and Sectors Using R&D Expenditure

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

1.2.3 R&D Expenditure in the Corporate Sector

The corporate sector provides and uses the majority of Taiwan's R&D expenditure. In addition, since the ratio of expenditure allocated to R&D has been increasing over the last 10 years, it is important to pay attention to which industries Taiwan's corporate sector R&D expenditure are concentrated in. As the graph on the left-hand side of Figure 1-4 shows, corporate sector R&D expenditure is concentrated in the electronic components manufacturing industry, the personal computer, electronic products, and optical equipment manufacturing industry, and the publishing, video production, and telecommunications services industry. In 2020, these three industries accounted for 79.7% of Taiwan's total R&D expenditure, and among them, the ratio of R&D expenditure in the electronic components manufacturing industry has grown remarkably over the last decade.

On the other hand, looking at R&D expenditure as a percentage of sales allows us to determine how much emphasis each industry is placing on investment in research and development. As shown in the graph on the right-hand side of Figure 1-4, the top three industries in Taiwan's manufacturing sector in terms of R&D expenditure as a percentage of sales are personal computers, electronic products and optical equipment manufacturing (10.7%), pharmaceuticals and medical chemicals manufacturing (9.1%), and electronic components manufacturing (8.4%), as compared to an average of 3.2% for the manufacturing industry as a whole (all figures representing data from 2020). This shows that along with Taiwan's corporate sector R&D expenditure being chiefly concentrated in the electronics manufacturing industry, it is also the industry that companies are focusing on when investing. Meanwhile, in other industries such as the pharmaceuticals and medical chemicals manufacturing industry, the R&D expenditure amount is not large, but it accounts for a significant percentage of its sales, which indicates that this industry has potential for R&D investment and growth prospects and as such, its future developments should continue to be watched closely.

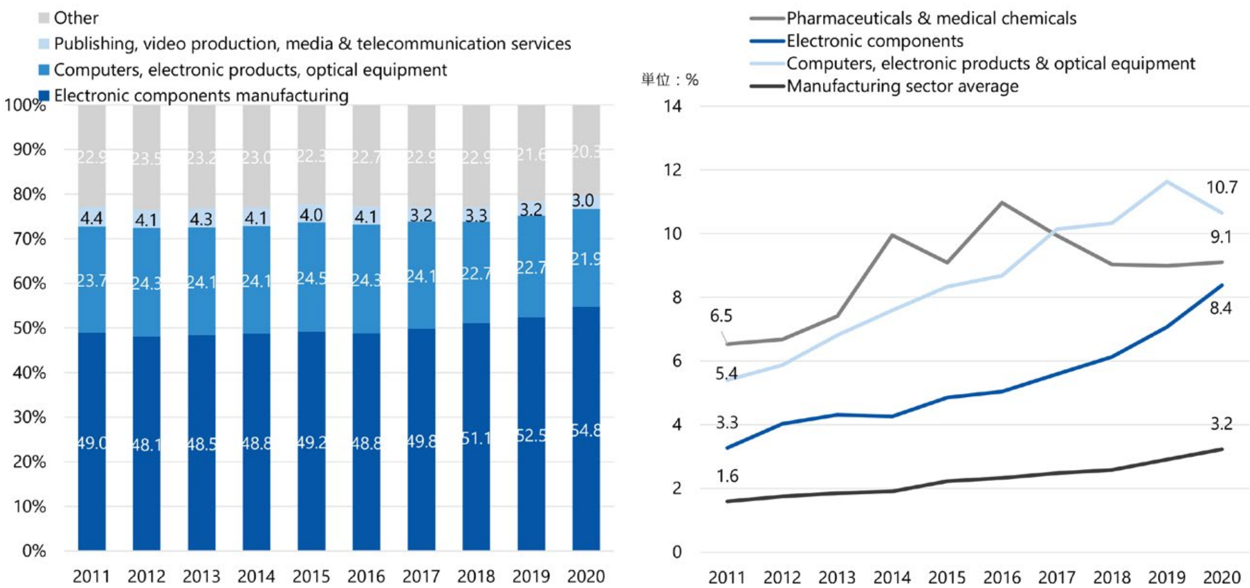


Fig. 1-4 Trends in the Distribution of Corporate Sector R&D Expenditure by Industry

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

1.2.4 R&D Expenditure in the Public Sector and the Higher Education Sector

Turning to the distribution of public sector R&D expenditure, the graph on the left in Figure 1-5 shows that investments are primarily being made to support health, industrial production, and for other purposes. Moreover, in recent years the ratio of government R&D spending invested for the purpose of national defense has also increased rapidly. This is related to the national defense science and technology item in the government's “5+2 (Five Plus Two) Innovative Industries Plan” submitted in 2016. On the other hand, as can be seen from the graph on the right in Figure 1-5, R&D expenditure in the higher education sector has been more heavily allocated to the fields of engineering technology and medicine due to the demand for industrial development and government policy plans.

The graphs show that the scientific areas in which the higher education sector mainly invests (industrial technology and medicine) and the socioeconomic development objectives in which the government mainly invests (industrial production and health) are similar in nature. This indicates that the policy direction and related plans of the central government in Taiwan affect the allocation of spending for each socioeconomic development objective in each industry and the direction of research and development in each scientific area in the higher education sector. Therefore, by analyzing the policy trends of the Taiwanese authorities and determining the future R&D priority areas in Taiwan's higher education, we can use the information obtained in our policies for cooperation between Taiwan and Japan on R&D.

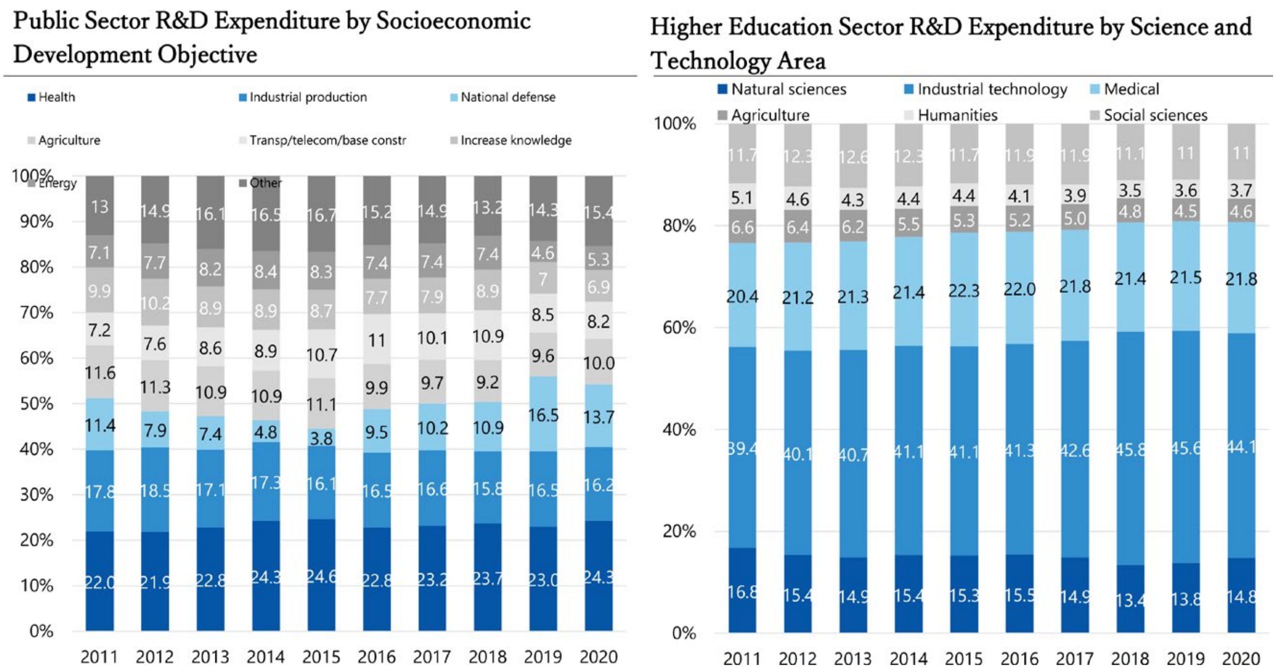


Fig. 1-5 Trends in the Distribution of Public Sector and Higher Education Sector R&D Expenditure

Source: Taiwan “Statistical Abstract on Science and Technology” (Figure created by the authors)

1.2.5 R&D Personnel

The allocation of R&D personnel is also an important element of research and development capabilities. Looking at Figure 1-6, the number of research personnel in Taiwan as a whole (the number of personnel belonging to R&D departments in industry, government, and academia, prorated in accordance with the ratio of dual employment when applicable) has increased every year, going from 130,000 people in 2010 to 164,000 in 2020, with an average annual growth rate of 2.2%. In addition, the average annual per capita expense use was around 3.1 million TWD (13.33 million yen) between 2010 and 2012, but began increasingly rapidly in 2013, reaching 4.4 million TWD (18.92 million yen) in 2020.

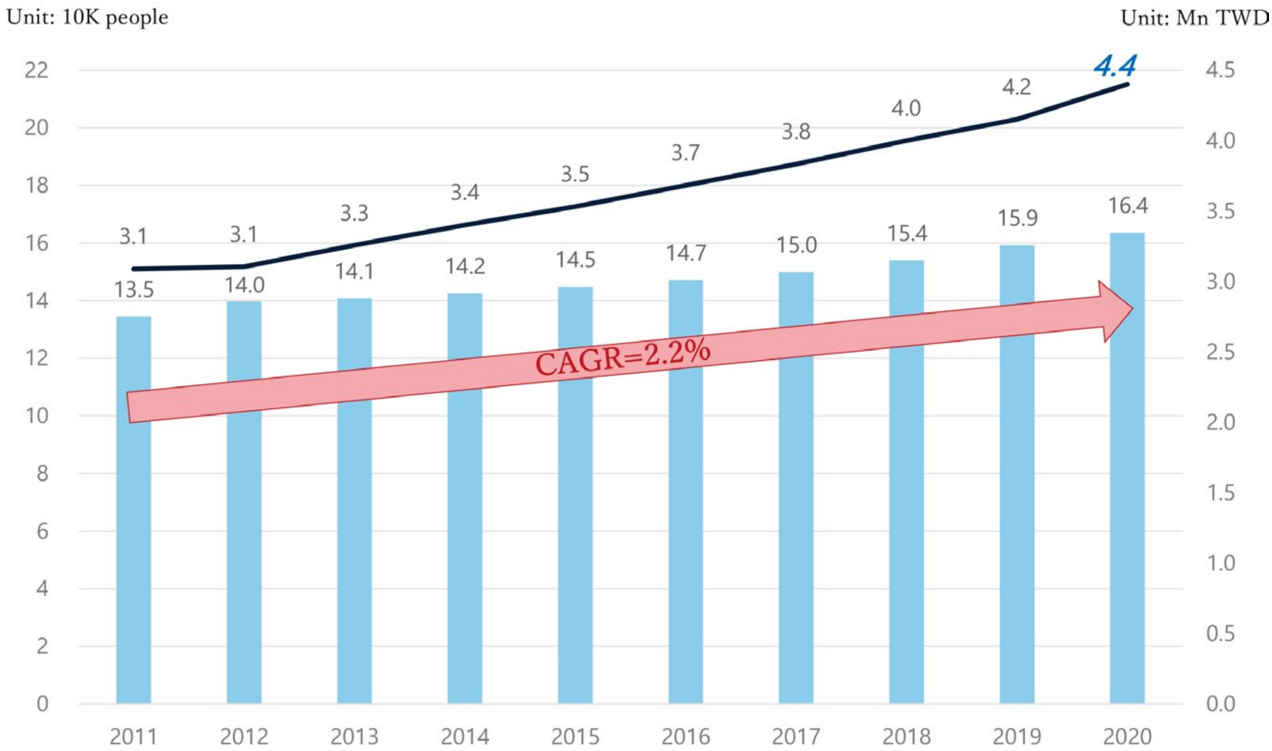


Fig. 1-6 Trends in the Number of R&D Personnel (FTE) and Average Annual Per Capita Expense Use

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

The number of R&D personnel in Taiwan is strikingly large for its population of 23.6 million people. Taiwan has roughly the same number of researchers as Italy, which has a population of 59.73 million, and the number of research personnel per 1,000 population is 13, second only to South Korea.

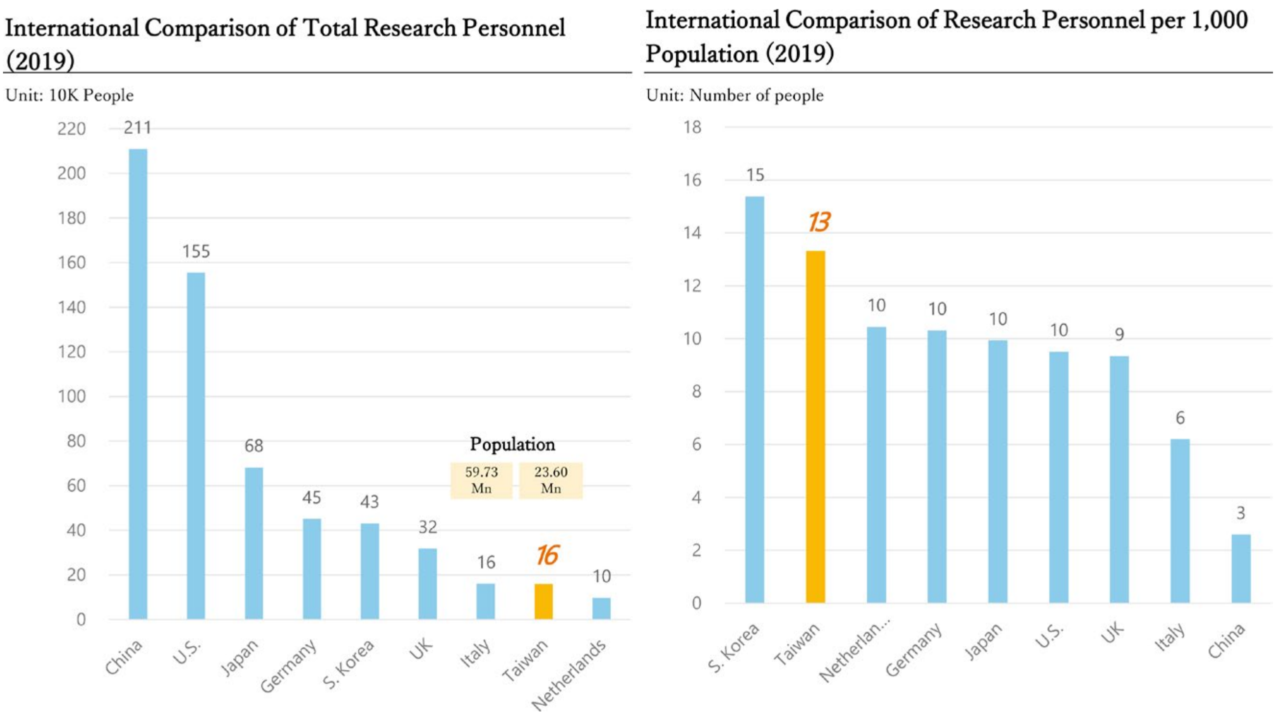


Fig. 1-7 International Comparisons of the Number of Research Personnel

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(1) Places of Employment of R&D Personnel

Taiwan's R&D personnel are mainly working in the corporate sector, and the percentages in the public sector and higher education sector have been gradually decreasing. The decline in the higher education sector is particularly clear, which shows that despite the research workforce growing overall, many R&D personnel are not choosing to work in the higher education sector, and are increasingly choosing other sectors or moving out of higher education to other sectors. This is related to robust demand for research personnel in the industrial sphere, along with the government's aggressive promotion of industry-academia collaboration programs in recent years. Taiwan's goal is to narrow the gap in basic technology levels between industry and academia through the flow of high-level human resources in its priority industries, as well as to apply human resources from academia in industry.

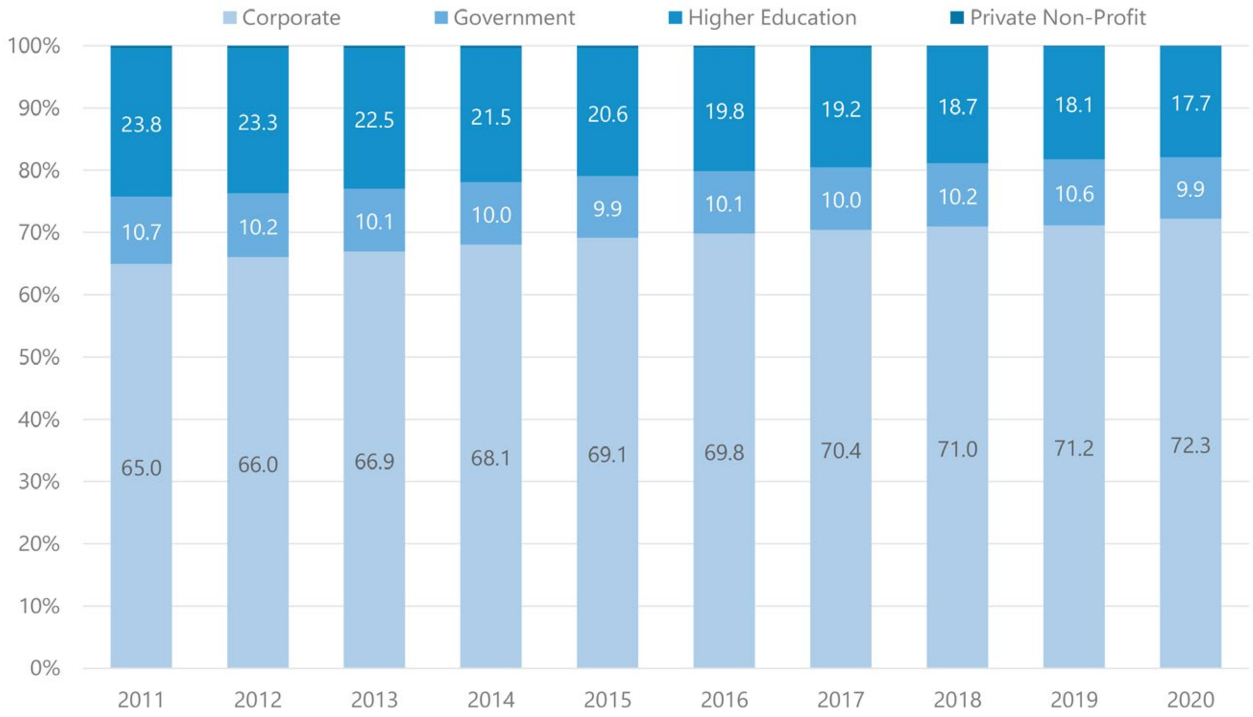


Fig. 1-8 Trends in the Percentages of R&D Personnel in Each Sector

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(2) Allocation of R&D Personnel in the Corporate Sector

As explained above, Taiwan's R&D personnel are mainly flowing into the corporate sector, and are concentrated in four industries in particular: electronic components manufacturing, personal computers, electronic products, and optical equipment manufacturing, publishing, video production, media and telecommunications services, and machinery and equipment. R&D personnel in these industries accounted for 75.7% of those in the corporate sector as a whole in 2020. This trend is similar to the previously described trend in R&D expenditures.

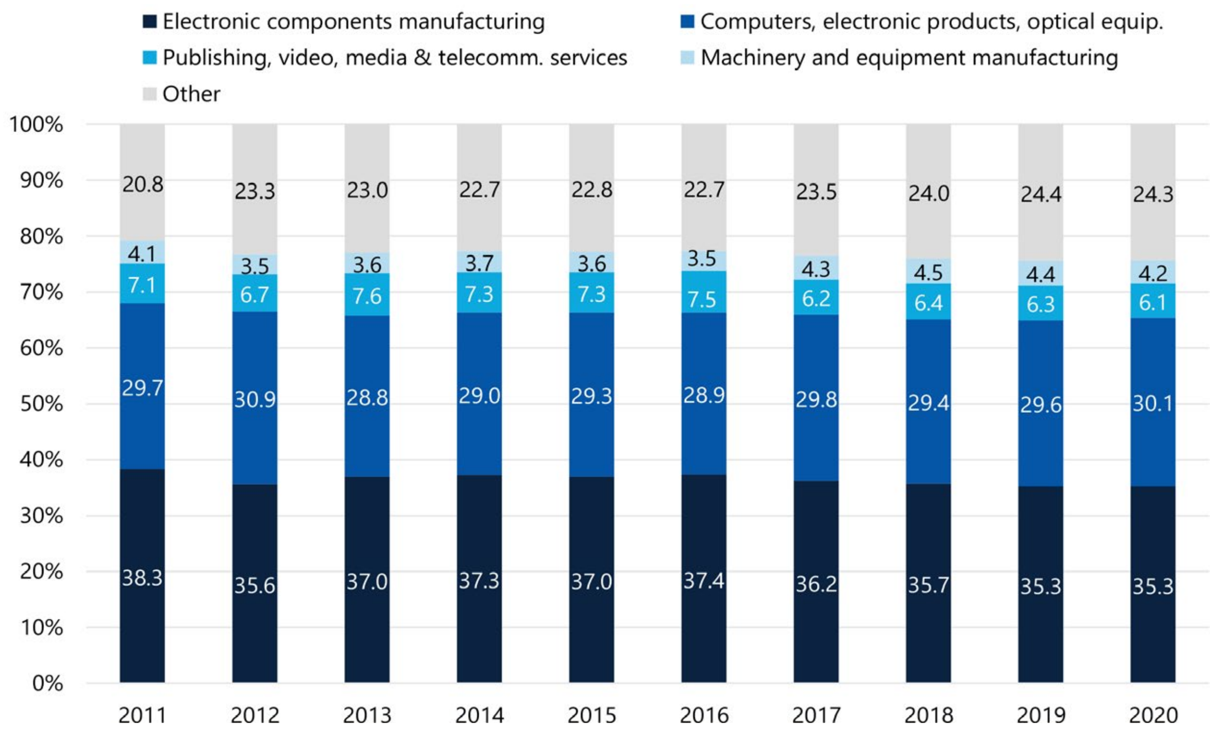


Fig. 1-9 Trends in the Percentages of R&D Personnel in the Corporate Sector by Industry

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(3) Allocation of R&D Personnel in the Public Sector and the Higher Education Sector

R&D personnel in the public sector and the higher education sector are mainly allocated to the natural sciences, industrial technology, and medical fields (accounting for 87.5% of R&D personnel in the public sector and 67.3% in the higher education sector), which is similar to the situation seen in R&D expenditures. However, in the higher education sector, the percentage of researchers in engineering technology is declining, while the percentage pursuing medical research is rising. With regard to the factors behind the former, considering the rapid jump in the ratio of R&D expenditure for engineering technology in the higher education sector (Figure 1-5) and the large amount of investment in electronic and mechanical engineering-related manufacturing in the corporate sector (Figure 1-4), the decrease in the percentage of researchers pursuing engineering technology is not due to less R&D resources being available and may be the result of poor prospects for the development of basic research.

Moreover, the current strong demand for industrial development in the field of engineering and technology, coupled with the government's support for collaborative industry-academia projects, has led to increased allocation to the corporate sector, where salaries are better and R&D resources are more plentiful. Meanwhile, the growth in medical researchers may be related to the fact that many are interested in pursuing R&D in the medical field thanks to the Taiwanese government's promotion in recent years of the "5+2 Innovative Industries Plan" and policies related to the development of the biotechnology medical industry.

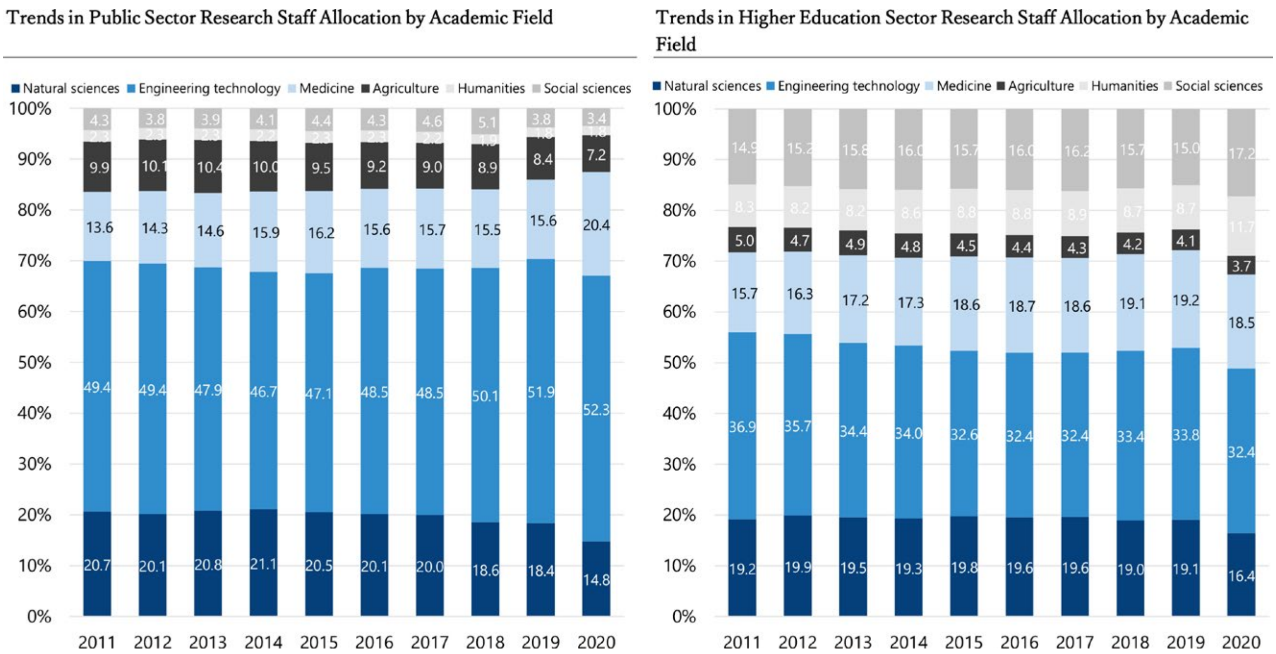


Fig. 1-10 Trends in the Allocated Percentages of R&D Personnel in the Public Sector and the Higher Education Sector by Academic Field

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(4) Number of University Faculty in Each Field

Table 1-1 shows that the top three fields in Taiwan in terms of the number of university faculty members are engineering, manufacturing, and construction, medical hygiene and social welfare, and arts and humanities, while the smallest number of faculty are in fields related to agriculture. Overall, the number of university faculty is on a declining trend, as only the fields of natural sciences, mathematics and statistics, information and communication science and technology, and medical hygiene and social welfare have increased slightly, and the change in numbers has been minor.

Table 1-1 Number of University Faculty in Each Field in Taiwan in 2012-2020

<table>
<tr><th>Field</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>CAGR</th><th>Percentage of each field in 2020</th></tr>
<tr><td>Education</td><td>1,577</td><td>1,580</td><td>1,544</td><td>1,593</td><td>1,538</td><td>1,436</td><td>1,437</td><td>1,434</td><td>1,429</td><td>-1.22%</td><td>3.12%</td></tr>
<tr><td>Arts and Humanities</td><td>7,037</td><td>7,319</td><td>7,223</td><td>7,178</td><td>7,031</td><td>7,245</td><td>7,052</td><td>6,991</td><td>6,997</td><td>-0.07%</td><td>15.27%</td></tr>
<tr><td>Social Sciences, Newspaper Studies, Library & Information Science</td><td rowspan="2">9,291</td><td rowspan="2">9,180</td><td rowspan="2">9,059</td><td rowspan="2">8,982</td><td rowspan="2">8,886</td><td>2,126</td><td>2,099</td><td>2,075</td><td>2,100</td><td rowspan="2">-1.51%</td><td>4.58%</td></tr>
<tr><td>Commerce, Management, Law</td><td>6,465</td><td>6,189</td><td>6,138</td><td>6,129</td><td>13.38%</td></tr>
<tr><td>Natural Sciences, Mathematics, Statistics</td><td rowspan="2">5,530</td><td rowspan="2">5,466</td><td rowspan="2">5,321</td><td rowspan="2">5,192</td><td rowspan="2">5,063</td><td>3,474</td><td>3,473</td><td>3,458</td><td>3,384</td><td rowspan="2">1.21%</td><td>7.39%</td></tr>
<tr><td>Information & Communication Science and Technology</td><td>2,646</td><td>2,856</td><td>2,760</td><td>2,705</td><td>5.90%</td></tr>
<tr><td>Engineering, Manufacturing, Construction</td><td>10,265</td><td>10,058</td><td>9,820</td><td>9,638</td><td>9,371</td><td>8,900</td><td>8,648</td><td>8,488</td><td>8,423</td><td>-2.44%</td><td>18.39%</td></tr>
<tr><td>Agriculture, Forestry, Fisheries, Veterinary Medicine</td><td>1,046</td><td>1,026</td><td>1,036</td><td>1,027</td><td>1,032</td><td>697</td><td>713</td><td>727</td><td>750</td><td>-4.07%</td><td>1.64%</td></tr>
<tr><td>Medical Hygiene, Social Welfare</td><td>6,601</td><td>6,605</td><td>6,766</td><td>6,753</td><td>7,003</td><td>6,808</td><td>6,824</td><td>6,851</td><td>7,014</td><td>0.76%</td><td>15.31%</td></tr>
<tr><td>Services</td><td>3,685</td><td>3,930</td><td>3,919</td><td>4,053</td><td>4,039</td><td>3,934</td><td>3,845</td><td>3,665</td><td>3,567</td><td>-0.41%</td><td>7.79%</td></tr>
<tr><td>Other</td><td>5,126</td><td>4,860</td><td>4,669</td><td>4,280</td><td>4,133</td><td>3,681</td><td>3,658</td><td>3,550</td><td>3,313</td><td>-5.31%</td><td>7.23%</td></tr>
<tr><td>Total</td><td>50,158</td><td>50,024</td><td>49,357</td><td>48,696</td><td>48,096</td><td>47,412</td><td>46,794</td><td>46,137</td><td>45,811</td><td>-1.13%</td><td>100.00%</td></tr>
</table>

Note: 1. Since 2017, the field of social sciences, commerce, and law has been divided into the two fields of social sciences, newspaper studies, library & information science and commerce, management, and law, the science field was renamed the natural sciences, mathematics, and statistics field, the new information & communication science and technology field was added, and the agricultural sciences field was renamed agriculture, forestry, fisheries, and veterinary medicine.
2. The database is statistical through 2020; data for 2021 is not included.

Source: Executive Yuan Major Gender Statistics Database (Table created by the authors)

1.3 Science and Technology Outputs and Results

1.3.1 Ranking in Science and Technology Innovation

As a result of the aforementioned investments in research and development resources and allocation of human resources, Taiwan is ranked highly in the WEF Ranking, the Nature Index, and the IMD Ranking. In the areas of "technological infrastructure" and "scientific infrastructure," Taiwan slots in tenth and sixth in the world respectively in the IMD Ranking, while the nation has attained the fourth-highest place in the WEF Ranking for "innovation capability."

Table 1-2 Global Rankings of Taiwan's Science, Technology, and Innovation in 2020

2020年の台湾科学技術とイノベーションに対するエネルギーの世界ランキング

WEF Ranking		Nature Index		IMD Ranking			
Innovation Capability		Scientific Infrastructure		Technological Infrastructure		Scientific Infrastructure	
Rank	Country/Region	Rank	Country/Region	Rank	Country/Region	Rank	Country/Region
1	Germany	1	USA	1	Singapore	1	USA
2	USA	2	China	2	Netherland	2	Korea
3	Switzerland	3	Germany	3	Sweden	3	Switzerland
4	Taiwan	4	UK	4	Finland	4	Germany
5	Sweden	5	Japan	5	USA	5	Israel
6	Korea	7	Canada	7	Hong Kong	6	Taiwan
7	Japan	8	Korea	9	China	8	Japan
13	Singapore	17	Singapore	10	Taiwan	10	China
24	China	20	Taiwan	17	Korea	17	Singapore
26	Hong Kong	27	Finland	32	Japan	23	Hong Kong

Source: World Competitiveness Yearbook 2021, Global Competitiveness Report 2019, Nature Index 2021 Tables (Table created by the authors)

1.3.2 University Rankings

While university ranking systems provide the easiest way of determining the competitiveness of each university, because individual ranking systems focus on different benchmarks, it cannot necessarily be said that any single ranking system serves as a completely objective indicator. Therefore, this report provides a breakdown of how Taiwan's leading universities are faring in the three most popular global university ranking systems today: the QS World University Rankings (QS Rankings), the U.S. News Global University Rankings (U.S. News Rankings), and the Times Higher Education World University Rankings (THE Rankings). The following is an analysis of how the rankings of Taiwan's leading universities have changed over the last five years (from 2017 to 2021).

(1) QS World University Rankings (QS Rankings)

Quacquarelli Symonds (QS), a private-sector British company specializing in education and training, has published its World University Rankings since 2004. The QS Rankings feature a peer-group review of universities' reputations, with emphasis on the ratio of students to faculty and the degree of internationalization. The indicators are broken up into academic reputation (50% of the score), internationalization (10%), research output (20%), and quality of instruction (20%). The peer group reputation survey is mainly in the form of a questionnaire, and bias is reduced by having the principle that respondents should not vote for their own institution or university. However, some people giving excessively high ratings has been a persistent problem, and the representativeness and objectivity of the survey targets remain questionable. Universities that have a long history or are well-known internationally are more likely to get high scores.

Looking at the rankings of Taiwanese universities in the QS Rankings over the years, only National Taiwan University has ranked in the top 100, hovering roughly in the middle of the pack and moving up little by little. The rankings of all of the other Taiwanese universities have fallen. Of note is the 2021 debut on the rankings of National Yang Ming Chiao Tung University, which is a university formed through the February 2021 merger of National Yang Ming University and National Chiao Tung University. These two universities were recognized for their achievements in medicine and engineering prior to the merger, and whether the new university will be able to leverage those respective strengths to achieve even greater results after the merger is a focus of attention.

Six Taiwanese universities ranked in the top 400 in the 2021 QS Rankings, National Taiwan University, National Tsing Hua University (Taiwan), National Cheng Kung University, National Yang Ming Chiao Tung University, National Taiwan University of Science and Technology, and National Taiwan Normal University, representing five general universities and one technical university. The QS Rankings system emphasizes the academic reputation survey, and as such these rankings represent the long-term reputation of a university's academic areas and in the job market. As these rankings do not merely reflect short-term outcomes, the results provide insight into the traditional reputation of each university in academia and industry.

Table 1-3 QS Rankings for Major Taiwanese Universities over the Last Five Years

University	2017	2018	2019	2020	2021
National Taiwan University	76	72	69	66	68
National Tsing Hua University (Taiwan)	161	163	173	168	180
National Cheng Kung University	222	234	225	234	252
National Yang Ming Chiao Tung University	-	-	-	-	268
National Taiwan University of Science and Technology	264	257	251	267	314
National Taiwan Normal University	289	308	331	331	334

Taipei Medical University	398	362	379	387	407
National Sun Yat-Sen University	388	402	410	416	412
National Taipei University of Technology	601-650	561-570	511-520	488	469
Chang Gung University	481-490	429	484	493	480
National Central University	391	415	427	465	521-530

Note: Universities are listed according to their 2021 rankings.

Source: QS official website (Table created by the authors)

(2) U.S News Rankings

National Taiwan University is the university in Taiwan with the best standing in the U.S. News Rankings system, ranking between 151 and 200. The next highest is National Tsing Hua University (Taiwan), which is ranked between 351 and 400, and other Taiwanese universities are ranked below 400.

National Taiwan University and National Tsing Hua University (Taiwan), the only two Taiwanese universities in the top 400, are both general universities. The U.S. News Rankings system combines thesis-related indicators and a reputation survey, but thesis-related indicators account for 75% of the score, with the percentage related to the number of citations of academic papers in particular reaching as high as 50%. Therefore, this ranking shows the influence of each university's research results, and as such research-oriented general universities dominate the rankings.

Overall, the standings of Taiwanese universities have fluctuated widely in this ranking system, and many universities have seen a continuing downward slide. This suggests that Taiwan's universities need to make efforts to increase the visibility of the research papers they are producing and the number of times they are cited. Universities should begin by encouraging professors and students to publish their research results in leading international academic journals, and at the same time, they need to proactively put together outstanding research teams and promote cooperation beyond the confines of institutions or countries.

Table 1-4 U.S News Rankings for Major Taiwanese Universities over the Last Five Years

University	2017	2018	2019	2020	2021
National Taiwan University	166	174	186	184	192
National Tsing Hua University (Taiwan)	370	341	358	363	375
National Yang Ming Chiao Tung University	-	-	-	-	587
National Cheng Kung University	519	545	605	635	635

Note: Universities are listed according to their 2021 rankings.

Source: U.S News official website (Table created by the authors)

(3) THE Rankings

Looking at the overall performance of Taiwanese universities in the THE Rankings system, National Taiwan University alone was in the top 100 in 2020, moving up and down between 100 and 199 in the other years, although basically on an upward trajectory. The next-strongest showing was by Taipei Medical University, which was ranked 231 in 2021. All other universities were out of the top 300.

The THE Rankings system uses a variety of evaluation indicators, and it emphasizes citations of academic papers and the learning environment, among others. As a result, the factors that influence the ranking results are more complex than those of the other rankings. Five Taiwanese universities ranked in the top 400, namely National Taiwan University, Taipei Medical University, National Yang Ming Chiao Tung University, China Medical University (Taiwan), and National Tsing Hua University (Taiwan), representing three general universities and two medical universities. Among them, National Yang Ming Chiao Tung University was the third-highest ranked Taiwanese university in 2021, the year that it was formed through a merger. This indicates that the combination of the educational resources and academic achievements of its two predecessor universities had an immediate effect on academic competitiveness. Meanwhile, China Medical University (Taiwan) was ranked higher on the THE Rankings than the QS Rankings or the U.S. News Rankings. This is due to THE Rankings' emphasis on the number of citations of academic papers, in addition to the fact that this university has many opportunities for collaboration with scholars who are often cited internationally, which helped it to rank in the top 400.

Table 1-5 THE Rankings for Major Taiwanese Universities over the Last Five Years

University	2017	2018	2019	2020	2021
National Taiwan University	198	170	120	97	113
Taipei Medical University	617	521	367	303	231
National Yang Ming Chiao Tung University	-	-	-	-	305
China Medical University (Taiwan)	565	505	589	493	318
National Tsing Hua University (Taiwan)	324	426	366	367	386
Asia University	839	934	842	805	586
National Cheng Kung University	538	591	628	600	637

Notes: 1. Universities are listed according to their 2021 rankings.
2. Universities ranked 200th or lower are estimated rankings.

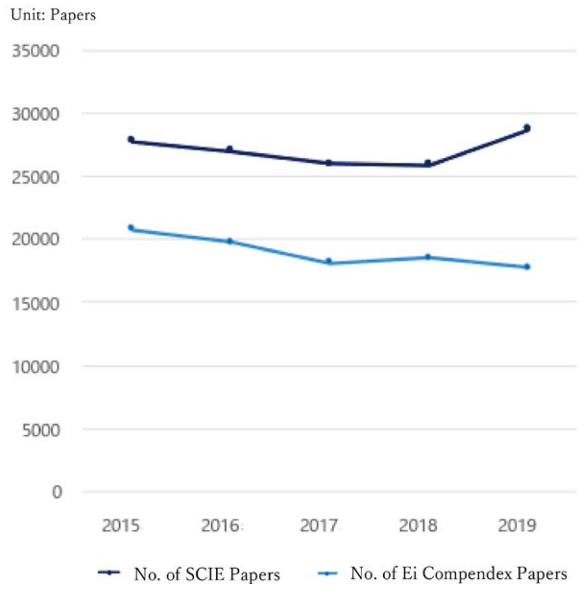
Source: THE official website (Table created by the authors)

1.3.3 Publication of Academic Papers

(1) Number of Papers Published

In terms of the number of academic papers being published, Taiwan has consistently published approximately 25,000 to 30,000 to papers a year over the last five years as shown on the SCIE (Science Citation Index Expanded: an index based on more than 9,500 of the world's most influential academic journals in 178 scientific fields), ranking 21st in the world for five consecutive years for the number of papers published. Meanwhile, the number of papers published as shown in the Ei Compendex (computerized engineering index: an engineering bibliographic database published by Elsevier) has decreased by nearly 15% from 20,821 in 2015 to 17,721 in 2019, with Taiwan's global ranking slipping from 15th to 19th. The reason for this may be related to the aforementioned decrease in recent years of the number of research personnel in the engineering and technology area in Taiwan's higher education sector. The area covered by Ei Compendex journals is engineering and technology, and the fact that the number of seasoned and highly experienced researchers in the engineering and technology area is decreasing in particular may explain the shrinking number of engineering-related articles.

Number of SCIE and Ei Compendex Papers Published in Recent Years



Global Ranking of SCIE and Ei Compendex Papers Published in Recent Years

	2015	2016	2017	2018	2019
SCIE papers published ranking	21	21	21	21	21
Ei Compendex papers published ranking	15	16	17	18	19

Fig. 1-11　Taiwan's SCIE and Ei Compendex Papers Published and Global Rankings in Recent Years

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

Table 1-6 shows the rankings for academic papers published in each country. The top ten countries in the global ranking are the United States, China, Germany, United Kingdom, Japan, France, Canada, Italy, India, and Australia. Aside from India, which moved up in the rankings, there have been no major changes in this group. Below the top ten as well, the rankings do not fluctuate very much. As for Taiwan, after dropping from 17th to 21st place in 2019, it is hovering around 20th in the world, ranking 4th in Asia after China, Japan, and South Korea.

Table 1-6 2012-2021 Global Ranking of Countries by the Number of Academic Papers

Country \ Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
U.S.	1	1	1	1	1	1	1	1	1	1
China	2	2	2	2	2	2	2	2	2	2
Germany	3	3	3	3	3	3	3	3	3	3
UK	5	5	5	4	4	4	4	4	4	4
Japan	4	4	4	5	5	5	5	5	5	5
France	6	6	6	6	6	6	6	6	6	6
Canada	7	7	7	7	7	7	7	7	7	7
Italy	8	8	8	8	8	8	8	8	8	8
India	11	11	11	10	10	10	10	9	9	9
Australia	10	10	10	11	11	11	11	10	10	10
Spain	9	9	9	9	9	9	9	11	11	11
South Korea	12	12	12	12	12	12	12	12	12	12
Brazil	15	15	14	14	13	13	13	13	13	13
New Zealand	14	13	13	13	14	14	14	14	14	14
Russia	13	14	15	15	15	15	15	15	15	15
Iran	28	26	22	22	22	21	20	16	16	16
Switzerland	16	17	17	17	17	17	16	17	17	17
Turkey	19	19	19	18	18	18	18	18	18	18
Sweden	18	18	18	19	19	19	19	19	20	19
Poland	20	20	20	20	20	20	21	20	21	20
Taiwan	17	16	16	16	16	16	17	21	19	21
Belgium	21	21	21	21	21	22	22	22	22	22
Denmark	24	24	25	24	23	23	23	23	23	23
Austria	25	25	26	26	26	25	25	24	25	24
Scotland	23	23	23	23	24	24	24	25	24	25
Portugal	33	33	31	31	31	29	27	26	27	26
Israel	22	22	24	25	25	26	26	27	26	27
Hong Kong	-	-	-	-	28	28	29	28	29	28
Mexico	29	29	29	29	30	30	28	29	28	29
Norway	30	30	30	30	32	32	31	30	30	30

Notes: 1. Countries are listed in order of the 2021 ranking data.
2. Only the top 30 countries are included.

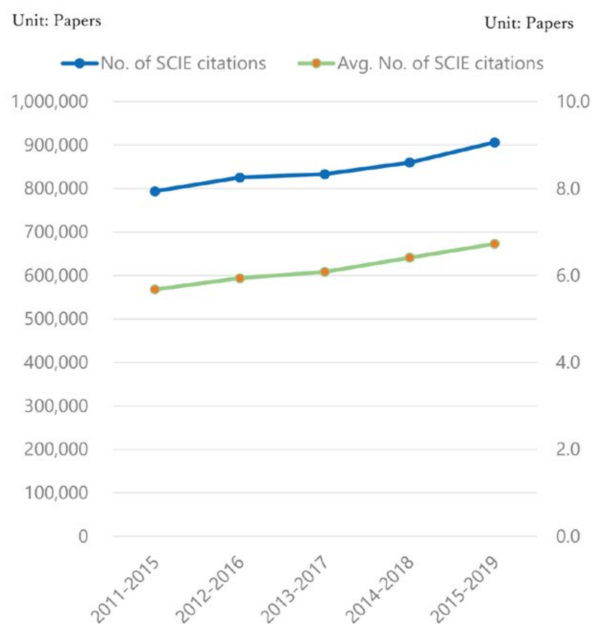
Source: ESI database (Table created by the authors)

(2) Number of Citations of Papers

In addition to the number of academic papers that are published, the quality of these papers is also an important factor in evaluating the overall research, and one measure of a paper's quality is the status of its citations. However, since the number of times a paper is cited increases with the number of times it is published, it is common to look at the "average number of citations per paper" in order to accurately gauge a paper's overall quality.

In recent years, both Taiwan's number of SCIE citations of papers and the average number of citations per paper have grown, and a comparison of statistical data from 2011-2015 and from 2015-2019 reveals a gradual increase in citations, as Taiwan's total number of SCIE citations of papers has increased from 790,000 to 900,000 and the average number of citations has risen from 5.68 times to 6.73 times. However, Taiwan's global ranking for the number of times papers are cited has declined slightly, dropping 3-4 spots lower for the total number of citations and the average number of citations. In terms of the total number of citations, Taiwan has been overtaken by Iran, Poland, Russia, and Singapore, while in terms of the average number of citations, it has fallen behind Malaysia, China, and South Korea. It can therefore be said that although Taiwan's citations are increasing, the number is not growing as much as other countries and regions.

Number of SCIE Citations of Papers in Recent Years, Average Number of Citations



Global Ranking of Number of SCIE Citations of Papers in Recent Years

	2015	2016	2017	2018	2019
Ranking of number of SCIE citations of papers	19	19	19	21	23
Ranking of average number of SCIE citations of papers	27	28	30	30	30

Fig. 1-12 Number of SCIE Citations of Papers and Global Ranking in Recent Years

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(3) Areas of Academic Research where Taiwan is Strong

Table 1-7 shows Taiwan's global share of the number of academic papers in each field in the last ten years (from 2012 to 2021). The top five fields for Taiwan in terms of where it has its largest shares of the world's academic papers are computer science, engineering, economics and business, materials science, and space science. The remainder of Taiwan's top ten fields includes several that are medical-related, such as clinical medicine, pharmacology, and toxicology. These results indicate that these fields have potential for future growth in Taiwan, and can therefore be said to have competitive advantages for R&D. This situation is also related to the aforementioned abundance of academic and research personnel in science, engineering, and medical fields. In particular, Taiwan's global share of papers in the field of space science increased from 1.05% in 2012 to 2.19% in 2021. This is a clear upward trend and one which can be attributed to the rapid development of science and technology in the global satellite and space field in recent years and the clear shift in the policy emphasis of the Taiwanese authorities. National defense and strategic industries have been set forth as important development goals in the Six Core Strategic Industries, with the vision of promoting self-reliance in national defense and positioning Taiwan as a key nation in the global aerospace industry supply chain. To this end, the government has increased its investment in R&D, and the number of papers published in this field is projected to continue to rise with the support of policies and related plans.

Table 1-7 Taiwan's Global Share of the Number of Academic Papers in Each Field from 2012 to 2021

Area	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Computer Science	3.90%	4.02%	4.08%	4.20%	3.37%	3.33%	4.33%	4.08%	3.75%	3.45%
Engineering	4.06%	4.10%	4.42%	4.33%	3.45%	3.24%	3.67%	3.35%	3.02%	2.75%
Economics & Business	2.17%	2.21%	2.27%	2.42%	1.99%	1.99%	2.60%	2.57%	2.52%	2.50%
Materials Science	2.81%	2.84%	2.87%	2.84%	2.29%	2.21%	2.61%	2.49%	2.33%	2.23%
Space Science	1.05%	1.16%	1.35%	1.47%	0.77%	0.81%	1.88%	1.99%	2.09%	2.19%
Physics	2.35%	2.41%	2.27%	2.30%	1.59%	1.56%	2.24%	2.17%	2.09%	2.03%
Clinical Medicine	1.53%	1.58%	1.71%	1.74%	1.40%	1.39%	1.77%	1.77%	1.76%	1.75%
Chemistry	1.73%	1.76%	1.81%	1.81%	1.47%	1.44%	1.75%	1.71%	1.67%	1.64%
Mathematics	1.48%	1.50%	1.69%	1.68%	1.28%	1.25%	1.60%	1.55%	1.54%	1.56%
Pharmacology & Toxicology	1.86%	1.88%	1.82%	1.80%	1.44%	1.39%	1.72%	1.67%	1.60%	1.56%
Molecular Biology & Genetics	0.98%	1.04%	1.21%	1.30%	0.98%	1.03%	1.53%	1.55%	1.53%	1.49%
Immunology	1.09%	1.15%	1.33%	1.40%	1.00%	0.99%	1.44%	1.45%	1.44%	1.42%
Multidisciplinary	0.53%	0.76%	21.02%	0.90%	0.96%	1.08%	1.27%	1.33%	1.36%	1.41%
Environment/ Ecology	1.29%	1.29%	1.32%	1.32%	0.93%	0.91%	1.29%	1.31%	1.35%	1.40%
Biology & Biochemistry	1.26%	1.32%	1.30%	1.35%	1.07%	1.05%	1.34%	1.32%	1.29%	1.29%
Social Sciences, General	1.02%	1.11%	1.12%	1.16%	1.04%	1.05%	1.24%	1.24%	1.23%	1.23%
Geosciences	1.22%	1.27%	1.27%	1.29%	0.88%	0.87%	1.29%	1.28%	1.24%	1.22%
Neuroscience & Behavior	0.88%	0.92%	1.06%	1.11%	0.87%	0.87%	1.18%	1.19%	1.21%	1.21%
Psychiatry/ Psychology	0.78%	0.85%	0.99%	1.05%	0.88%	0.89%	1.17%	1.16%	1.17%	1.15%
Microbiology	1.11%	1.13%	1.12%	1.15%	0.84%	0.82%	1.14%	1.11%	1.09%	1.08%
Agricultural Sciences	1.29%	1.33%	1.18%	1.16%	0.92%	0.89%	1.00%	0.95%	0.94%	0.91%
Plant & Animal Science	0.89%	0.88%	0.84%	0.85%	0.65%	0.64%	0.86%	0.87%	0.86%	0.86%

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. The academic fields are displayed in the order of the number of papers in 2021.

Source: ESI database (Table created by the authors)

By dividing the total number of citations of papers in a certain field by the corresponding number of papers, the average number of citations per paper in that field can be obtained. The average number of citations per paper in each field can then be used to estimate the academic impact of the research being done in that field. According to the analysis in the Table 1-8 below, in 2021, the fields in which the average number of citations of Taiwanese papers has increased significantly include space science, molecular biology and genetics, materials science, multidisciplinary papers, and chemistry. This shows the high quality and influence of the papers Taiwanese researchers are publishing in these fields.

Table 1-8 Taiwan's Number of Papers Divided by Average Number of Citations in Each Field from 2012 to 2021

Field	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Space Science	9.97	10.56	12.93	14.78	19.18	21.94	23.32	25.35	28.14	30.08
Molecular Biology & Genetics	13.49	13.46	15.37	15.08	15.69	15.85	16.38	17.43	18.62	20.09
Materials Science	6.96	7.37	8.22	9.14	9.92	10.72	12.12	14.16	15.74	16.25
Multidisciplinary	6.14	4.01	36.43	24.71	9.42	9.9	11.43	12	14.36	16.2
Chemistry	9.62	9.91	10.87	11.84	12.66	13.39	14.03	14.35	15.17	15.48
Biology & Biochemistry	10.29	10.49	11.71	12.15	12.59	13.01	13.2	13.66	14.52	15.01
Physics	6.59	6.81	8.6	9.31	10.08	10.63	11.51	12.19	13.95	14.9
Immunology	10.32	10.47	11.69	11.66	11.96	12.28	12.62	12.89	13.62	14.48
Neuroscience & Behavior	11.32	11.48	11.23	11.51	11.79	12.33	12.92	13.47	13.77	14.24
Geosciences	8.38	8.24	9.9	10.72	11.31	12.11	12.78	13.5	14.17	14.06
Pharmacology & Toxicology	9.41	9.53	10.21	11.01	11.55	11.88	12.63	13.05	13.52	14.06
Clinical Medicine	8.66	8.77	8.9	9.74	10.16	10.65	11.26	12.13	13.19	13.82
Agricultural Sciences	8.23	8.51	8.99	10.2	11.13	12.02	12.37	12.68	13.07	13.16
Microbiology	11.37	11.02	11.19	11.57	11.78	11.96	11.84	12.14	12.71	12.91
Plant & Animal Science	7.07	7.24	7.43	8	8.41	8.81	9.48	10.1	10.85	11.16
Environment/ Ecology	8.46	8.39	9.16	9.73	10.14	10.33	10.55	10.84	11.15	11.09
Psychiatry/ Psychology	5.72	5.82	6.41	7	7.36	7.8	8.23	8.76	9.6	10.39
Engineering	4.68	4.95	5.47	6.11	6.7	7.3	7.64	8.21	9	9.19
Computer Science	3.05	3.3	4	4.57	5	5.58	6.54	7.35	8.06	8.85
Social Sciences, General	3.74	3.99	5	5.47	5.76	5.79	6.26	6.74	7.49	8.05
Economics & Business	3.21	3.69	3.61	4.14	4.56	4.96	5.55	6.25	7.14	7.6
Mathematics	3.12	3.13	3.61	3.92	4.15	4.38	4.43	4.6	4.79	4.9

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals
2. The academic fields are displayed in the order of the number of papers in 2021.

Source: ESI database (Table created by the authors)

1.3.4 Status of Patent Applications

(1) Number of Taiwanese Patent Applications in the U.S.

Patent applications are another important benchmark of R&D results. Therefore, this report examines the status of Taiwanese patent applications in the U.S. as well as the status of patent applications in Taiwan by other countries and regions. As shown in Figure 1-13, Taiwan's patent applications in the U.S. have remained between 11,000 and 13,000 annually, which is good overall; in 2015 and 2016, Taiwan ranked fifth. However, Taiwan's ranking has dropped slightly in recent years, as China has significantly increased its volume of applications for U.S. patents.

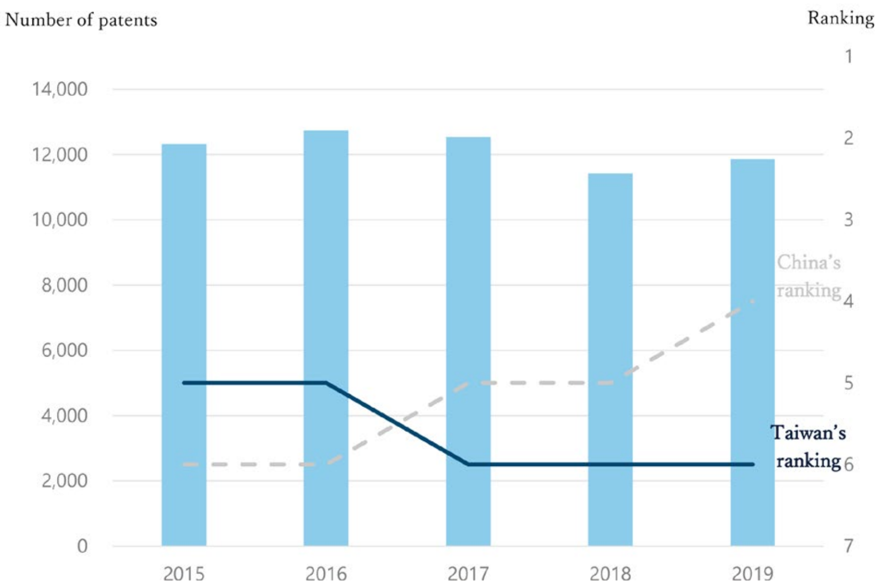


Fig. 1-13 Number Obtained and Ranking of Taiwanese Patents in the U.S.

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(2) Patent Applications in Taiwan

According to statistical data from the Intellectual Property Office of the Ministry of Economic Affairs (Figure 1-14), Taiwan's patent applications are concentrated in four fields: semiconductors, computer science and technology, electronics and energy devices, and optics. In recent years, the semiconductor and computer science and technology fields have seen the largest increases in patent applications, while there has only been slight growth in the other fields.

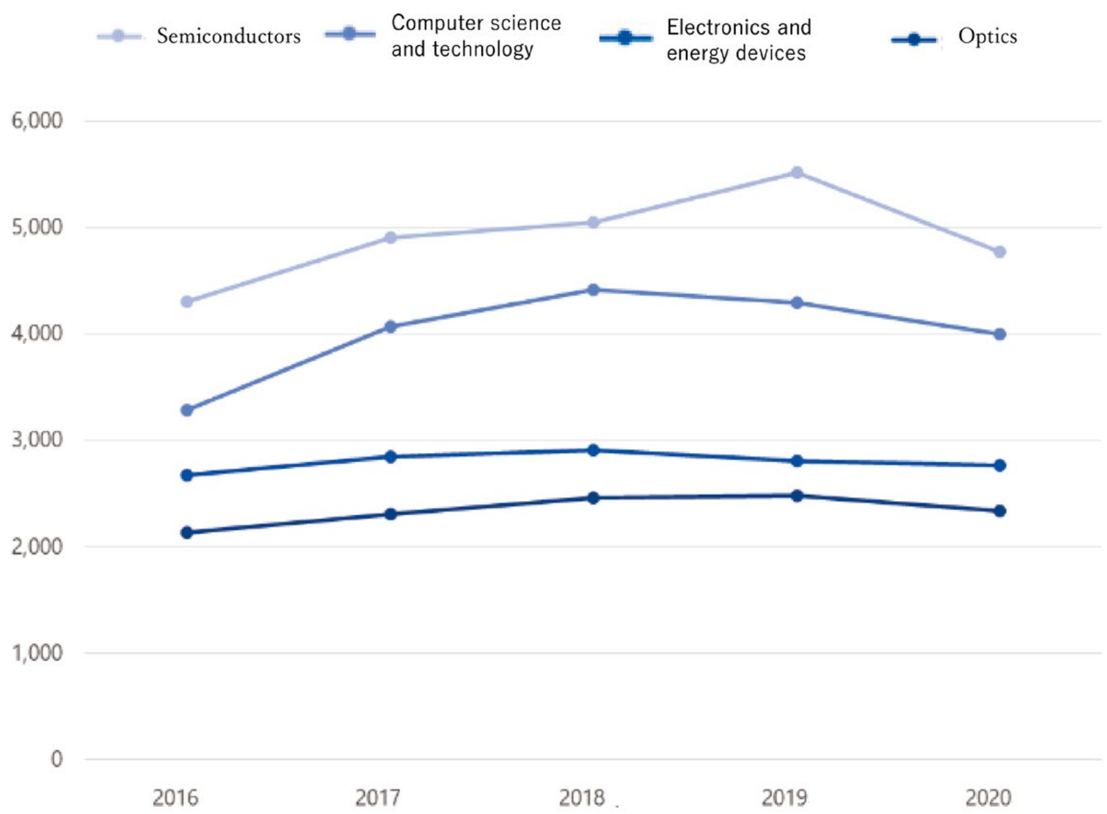


Fig. 1-14 Number of Taiwanese Patent Applications in Major Science and Technology Fields

Source: Statistical data from the Int ellectual Property Office, Ministry of Economic Affairs, Taiwan
(Figure created by the authors)

The main countries and regions applying for patents in Taiwan differ in each key field (Figure 1-15). While Taiwan has the largest number of patent applications in all four key fields, Japan is the main applicant country for patents in semiconductors, electronics and energy devices, and optics. It can therefore be said that Taiwan and Japan have superior technological advantages and potential for cooperation in these areas.

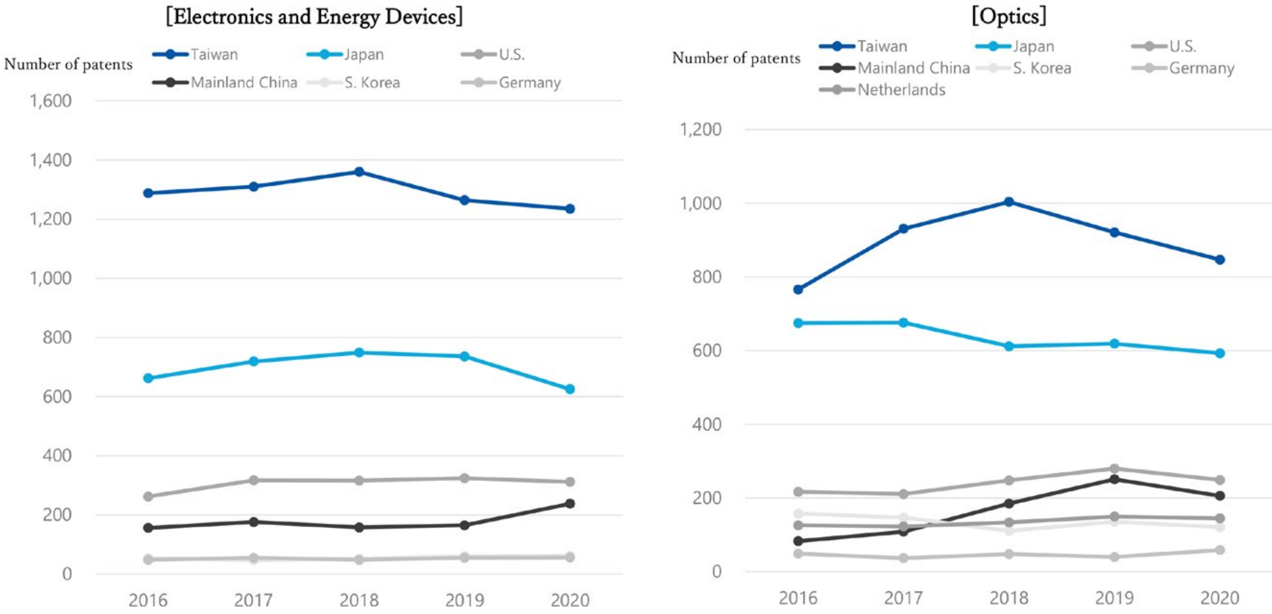


Fig. 1-15 Main Countries and Regions for Patent Applications in Key Fields in Taiwan

Source: Statistical data from the Intellectual Property Office, Ministry of Economic Affairs, Taiwan
(Figure created by the authors)

Next, we will turn to the companies applying for these patents. As seen in Figure 1-16 (in which Taiwanese companies are shown in blue and Japanese companies are shown in red), Taiwan Semiconductor Manufacturing Company (TSMC) is the main applicant in the fields of semiconductors, computer science and technology, and optics, but many Japanese manufacturers are also major applicants for Taiwanese patents in their respective fields. Examples include Tokyo Electron (TEL), Disco hi-tec, KIOXIA, Nitto Denko, and Sumitomo Chemical.

In addition to foreign companies, Taiwanese universities and research institutes are also major applicants for patents in Taiwan. The leading universities in terms of patent applications are National Cheng Kung University, National Tsing Hua University (Taiwan), and National Taiwan University. Applications for patents by these universities in 2020 were clearly on the rise, with an average growth rate of nearly 45%. Meanwhile, Taiwan's leading main research institution in terms of patent applications is the Industrial Technology Research Institute.

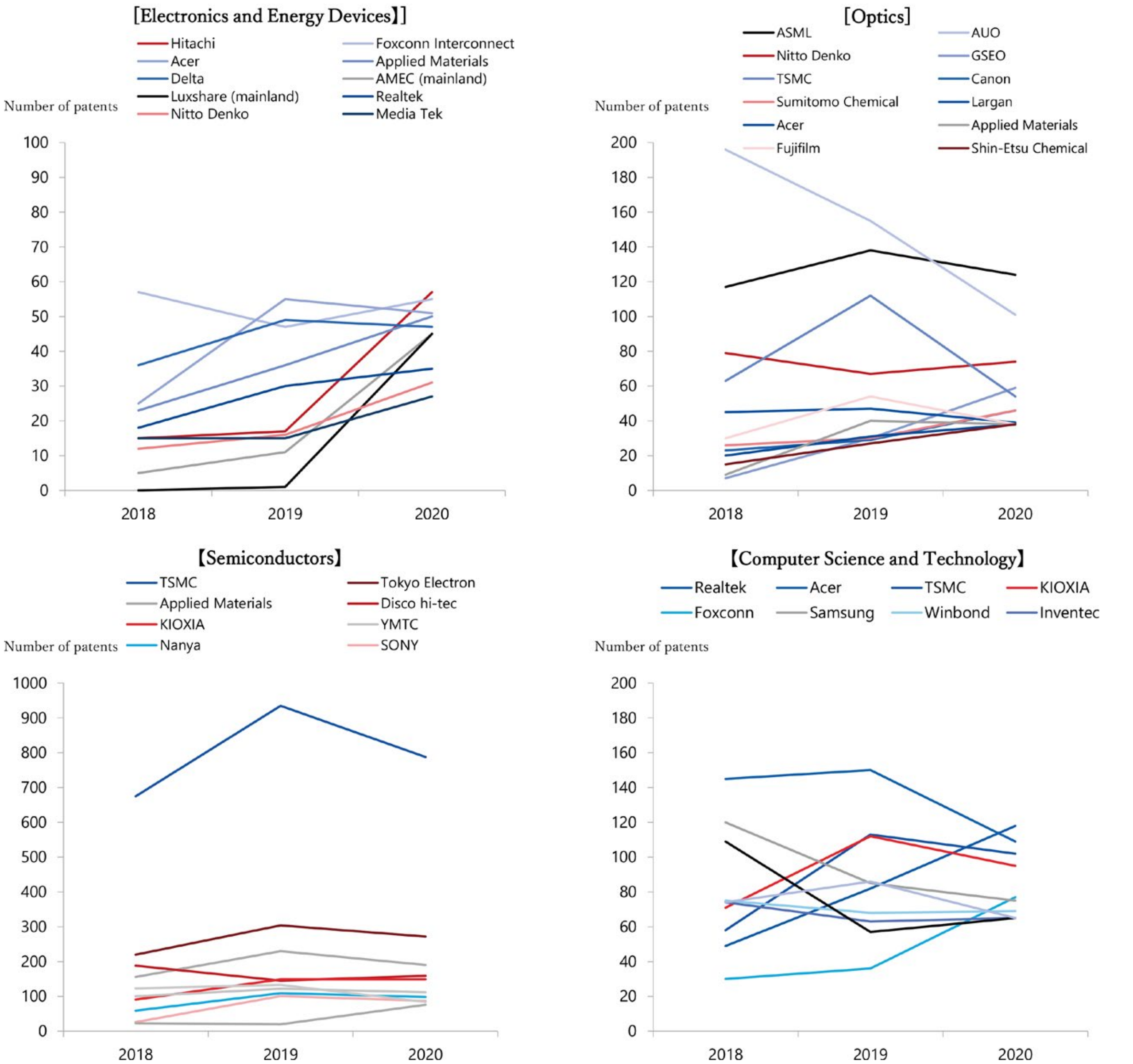


Fig. 1-16 Number of Patent Applications Filed in Each Field by Major Applicants (Companies)

Source: Statistical data from the Intellectual Property Office, Ministry of Economic Affairs, Taiwan
(Figure created by the authors)

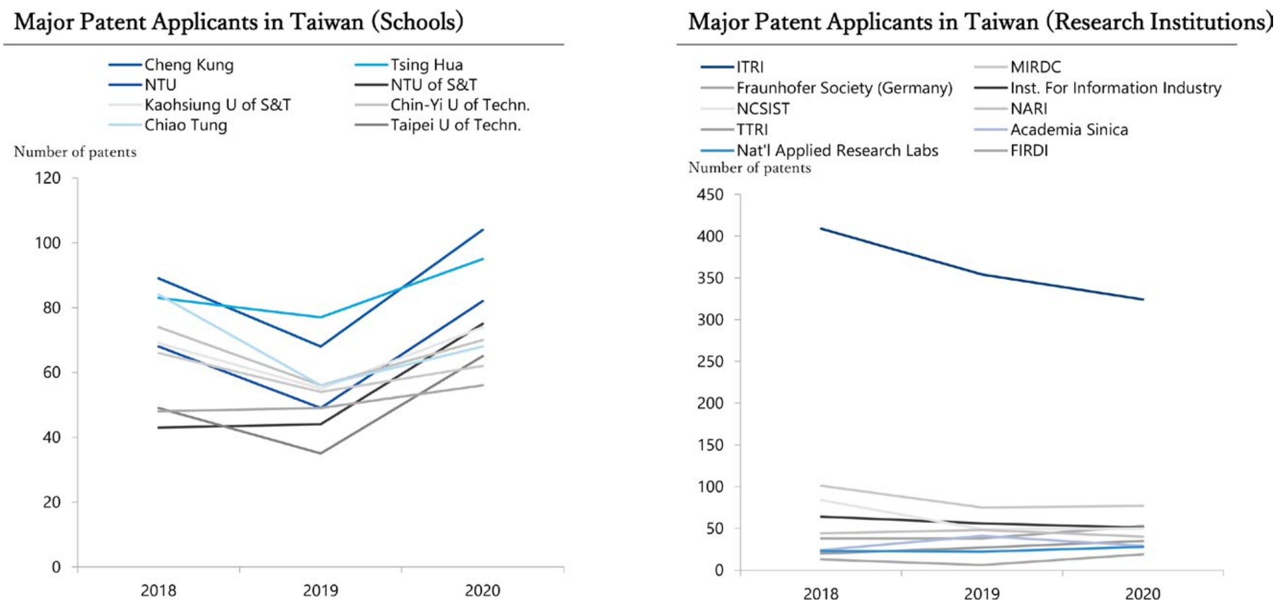


Fig. 1-17 Major Applicants for Invention Patents in Taiwan (Academic and Research Institutions)

Source: Statistical data from the Intellectual Property Office, Ministry of Economic Affairs, Taiwan (Figure created by the authors)

1.3.5 Technology Trade Balance

(1) Trends in the Technology Trade Balance

Looking at Taiwan's technology imports and exports, Taiwan's technology exports have grown steadily in recent years, indicating that Taiwan's technological competitiveness has become stronger (Figure 1-18). In addition, there was a clear decrease in technology imports from 2015 to 2018, revealing a significant improvement in Taiwan's technology trade balance. Technology imports, primarily from the U.S., dropped off sharply in 2017, and this trend continued in 2018. As for technology exports, there has been clear growth in Taiwan's exports to other countries and regions. As a result, the technology trade deficit has shrunk from approximately 124.0 billion TWD (533.2 billion yen) in 2015 to 13.5 billion TWD (58.1 billion yen) in 2018, an improvement of 110.5 billion TWD (475.2 billion yen).

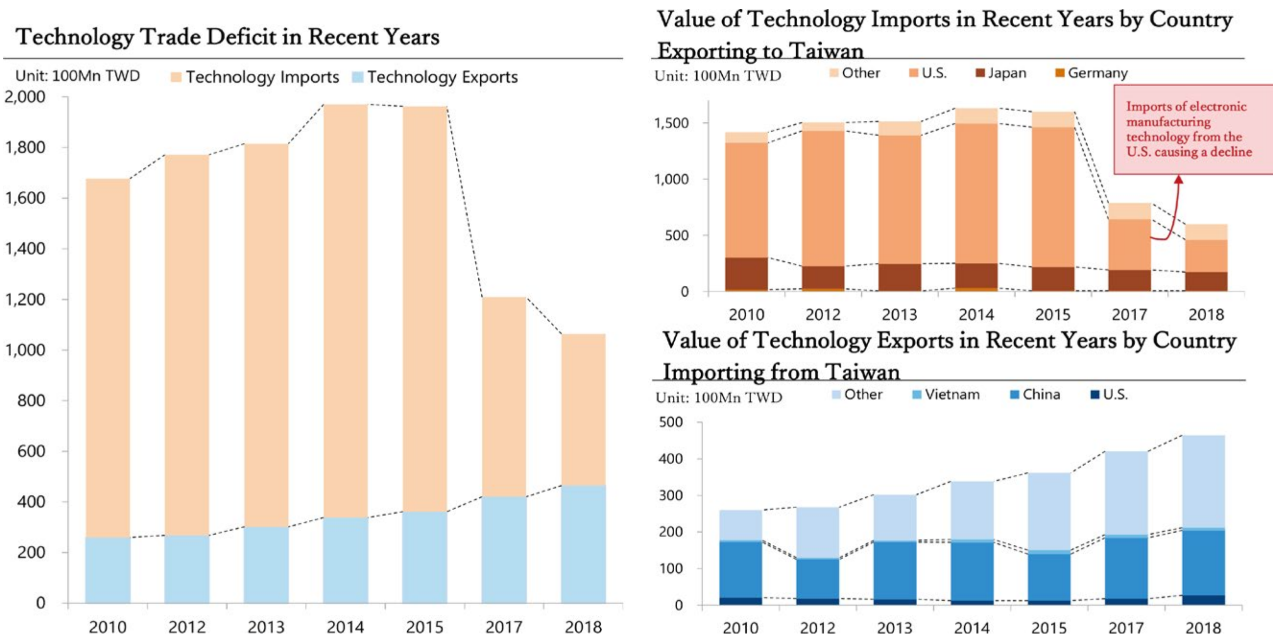


Fig. 1-18 Changes in Taiwan's Technology Imports and Exports to Date

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

(2) Factors Leading to the Improvement in Taiwan's Technology Trade Balance

To see how Taiwan's technology trade balance has improved, we will examine the status of Taiwan's imports and exports of technology by industry. Table 1-9 reveals that Taiwan's technology imports and exports are mainly concentrated in the electronic parts manufacturing and the personal computers, electronic products, and optical product manufacturing industry. According to research conducted by the Ministry of Economic Affairs, while the 2015 technology trade balance for the electronic parts manufacturing industry had a deficit of 74.7 billion TWD (321.2 billion yen), by 2018 the industry had made a turnaround to record a surplus of 85 million TWD (365.5 million yen). Meanwhile, whereas the technology trade deficit for the personal computers, electronic products, and optical product manufacturing industry stood at 39.5 billion TWD (169.9 billion yen) in 2015, by 2018 it had been reduced to just 6.6 billion TWD (28.4 billion yen).

The reduction of the technology trade deficit in these two industries amounted to 107.8 billion TWD (463.5 billion yen), which is roughly consistent with the reduction in the overall technology trade deficit. The main factor behind the shrinking of Taiwan's technology trade deficit is that imports of technology in the aforementioned two industries from overseas (particularly from the U.S.) have dropped off significantly, and exports of technology increased. These two industries, which represent Taiwan's main sources of technology exports, have made remarkable progress in terms of technological development in recent years, and it is speculated that they may be able to gradually develop their own technologies to take the place of those which are being imported today.

Table 1-9 Ratio of Technology Imports to Exports in Each Industry (2018)

Technology Imports		Technology Exports	
Electronic parts manufacturing	34.2%	Electronic parts manufacturing	44.3%
Personal computers, electronic products, and optical product manufacturing	21.3%	Power equipment manufacturing	18.6%
Non-metallurgic mineral product manufacturing	10.2%	Personal computers, electronic products, and optical product manufacturing	13.3%
Chemical products manufacturing	7.5%	Leather, fur and related products manufacturing	9.0%
Automobile and auto parts manufacturing	7.1%	Chemical materials manufacturing	3.1%
Machinery and equipment manufacturing	5.4%	Other manufacturing	2.3%
Manufacturing of other transportation tools and parts	3.5%	Automobile and auto parts manufacturing	1.8%
Chemical materials manufacturing	2.9%	Machinery and equipment manufacturing	1.5%
Other manufacturing	1.9%	Pharmaceuticals and medical chemical products manufacturing	1.1%
Basic metal manufacturing	1.2%	Manufacturing of other transportation tools and parts	1.1%
Other industries	4.5%	Other industries	3.6%

Source: Taiwan "Statistical Abstract on Science and Technology" (Table created by the authors)

1.3.6 Technology-Intensive Companies and Startups

In recent years, various Taiwanese industries have put active efforts into R&D, and as a result of applied research, technological development, and the government's efforts to promote industry-academia collaboration, Taiwan's technology-intensive companies have successfully strengthened their innovation capabilities, and many excellent new companies have emerged (Figure 1-19). To sum up the core technology-related areas these companies are engaged in, all of them, from hardware-related technologies for electronic devices, to software-related technologies such as platform systems, artificial intelligence, and block chain, are areas that currently have the potential for technological innovation in Taiwan, as well as having the common feature of being the areas mentioned earlier as receiving R&D investment and where R&D is producing results.

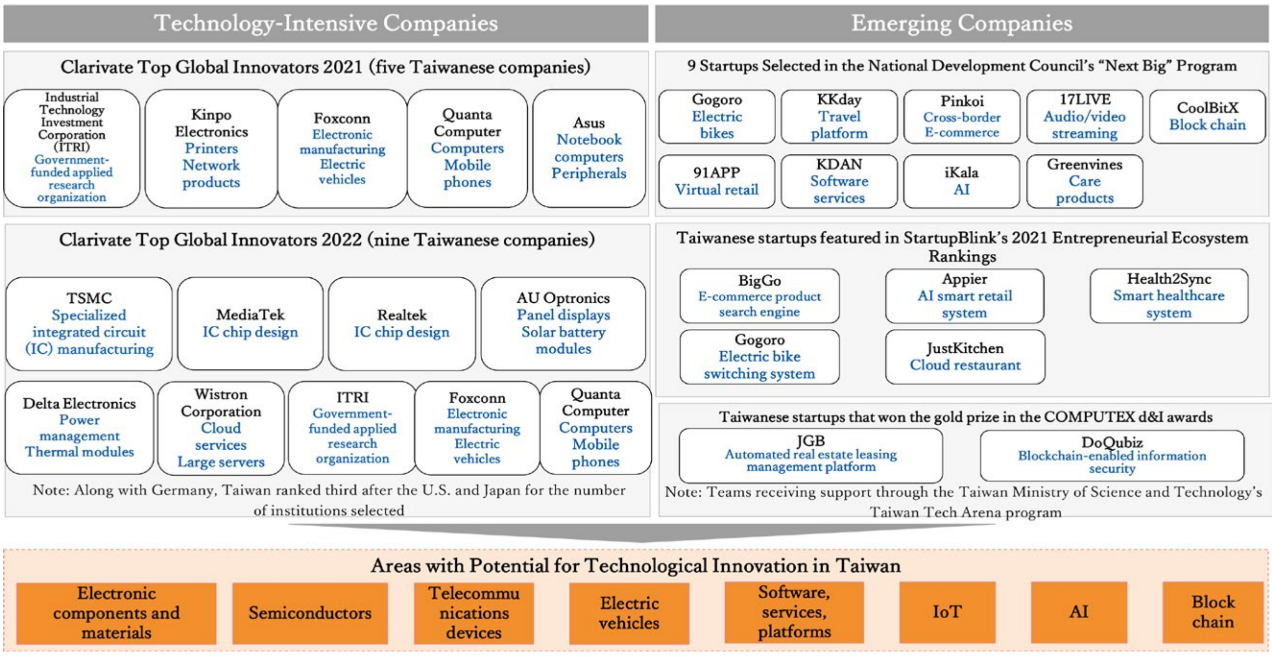


Fig. 1-19 Standout Technology-Intensive Companies and Startups in Taiwan in Recent Years

Source: Clarivate, official statistical data from the Ministry of Science and Technology (Figure created by the authors)

2 Current Status and Challenges of the Tsai Ing-wen Administration's Science and Technology Innovation Policies

2.1 Research Methodology

In order to strengthen Taiwan's technological standing in global supply chains, since 2016, the Taiwanese authorities have pushed forward a series of industrial development policies and promotion strategies. The procedure for the research on science and technology innovation policies is based on the legal grounds for STI policies in Taiwan, first analyzing the organizational and budget formation mechanisms related to science and technology policies, as well as key policy plans related to the Executive Yuan. This is followed by an analysis of the science and technology development plans related to the key policies, and clarification of the current status, challenges, and future developments of various recent science and technology policies in Taiwan through interviews with experts from various levels of industry, government, and academia and analysis of key documents issued by the regulatory authorities. The following section describes the status of policies for cooperation on science and technology based on the results of the initial analysis.

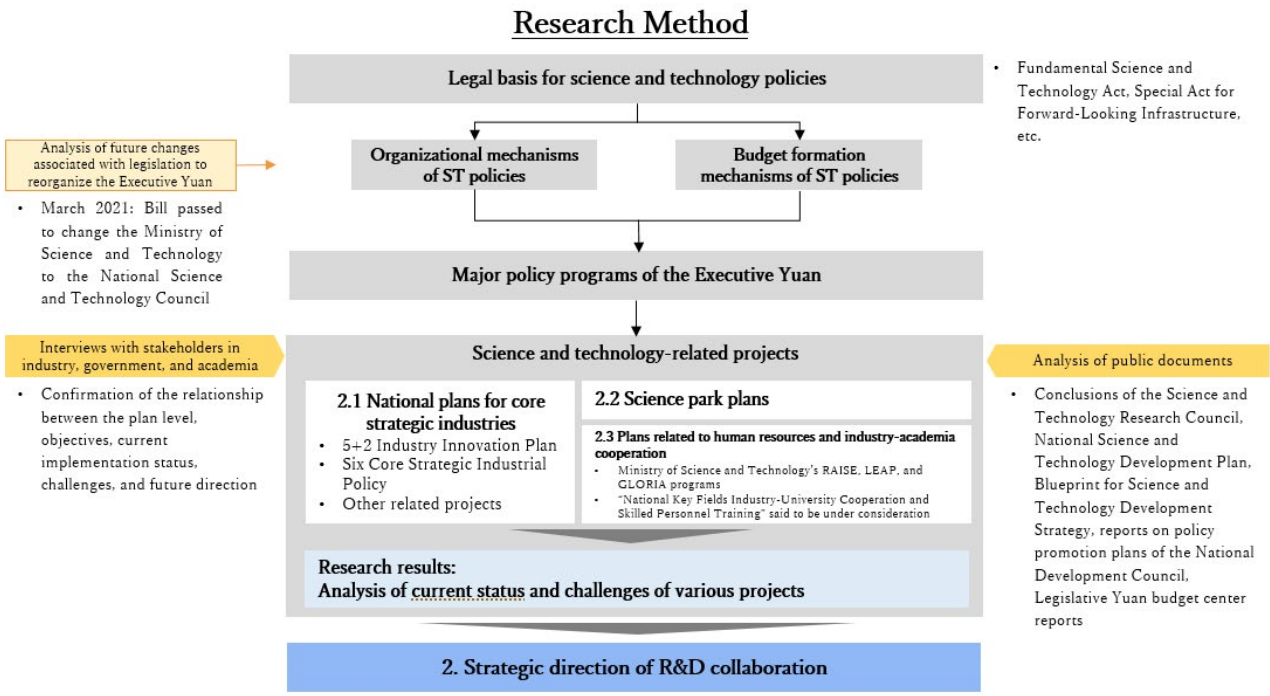


Fig. 2-1 Overview and Method of Research and Analysis for "Current Status and Challenges of the Tsai Ing-wen Administration's Science and Technology Innovation Policies"

(Figure created by the authors)

2.2 Mechanism and Formation of Organizational Structure of Taiwan's Science and Technology Policies

2.2.1 Legal Basis and Formation Mechanism for Taiwan's Science and Technology Policies

The Fundamental Science and Technology Act stipulates that a National Science and Technology Development Plan be formulated every four years. For this purpose, the Taiwanese authorities periodically hold a National Science and Technology Conference to gather input from industry, academic researchers, and experts to serve as the basis for the National Science and Technology Development Plan. Based on the National Science and Technology Development Plan, the Executive Yuan issues relevant key administrative policies and promotes related plans. In addition, each agency formulates its own science and technology development plan in accordance with the central policy and the plans for which it is responsible and corresponding to the master plan in order to promote R&D activities at universities, research institutes, and private-sector companies.

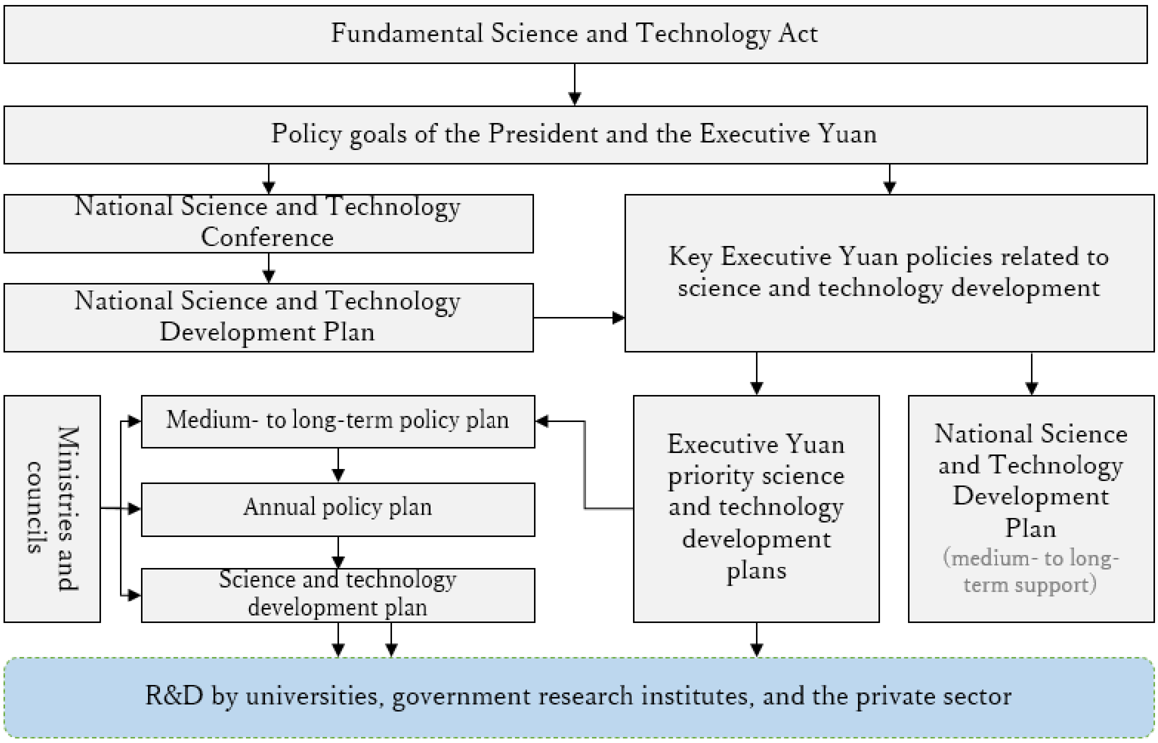


Fig. 2-2 Formation Mechanism of Science and Technology Policies in Taiwan

Source: Taiwan "White Paper on Science and Technology" (Figure created by the authors)

Taiwan's mechanism for creating annual budgets for science and technology policies allocates budgets for relevant key plans based on the Special Act for Forward-Looking Infrastructure and the Fundamental Science and Technology Act. Subsequently, the relevant agencies review and deliberate on the necessary amount of science and technology development expenditures, and finally, based on the outcome of the deliberations, the total budget for science and technology policies is prepared and allocated to the agencies involved with the Science and Technology Development Plan (Figure 2-3). As shown in Figure 2-4, a large portion of the science and technology budget is allocated to the Ministry of Science and Technology, the Ministry of Economic Affairs, and Academia Sinica, and the percentage of the budget allocated to the Ministry of Science and Technology has been increasing every year in response to Taiwan's growing needs for science and technology R&D in recent years. Therefore, the vision of the Ministry of Science and Technology and the areas of science and technology it focuses on are important in order to grasp the direction of science and technology development in Taiwan. As such, when pursuing the research for this report, interviews were conducted with officials at the Ministry of Science and Technology in order to understand the current status and future trends of Taiwan's science and technology policies.

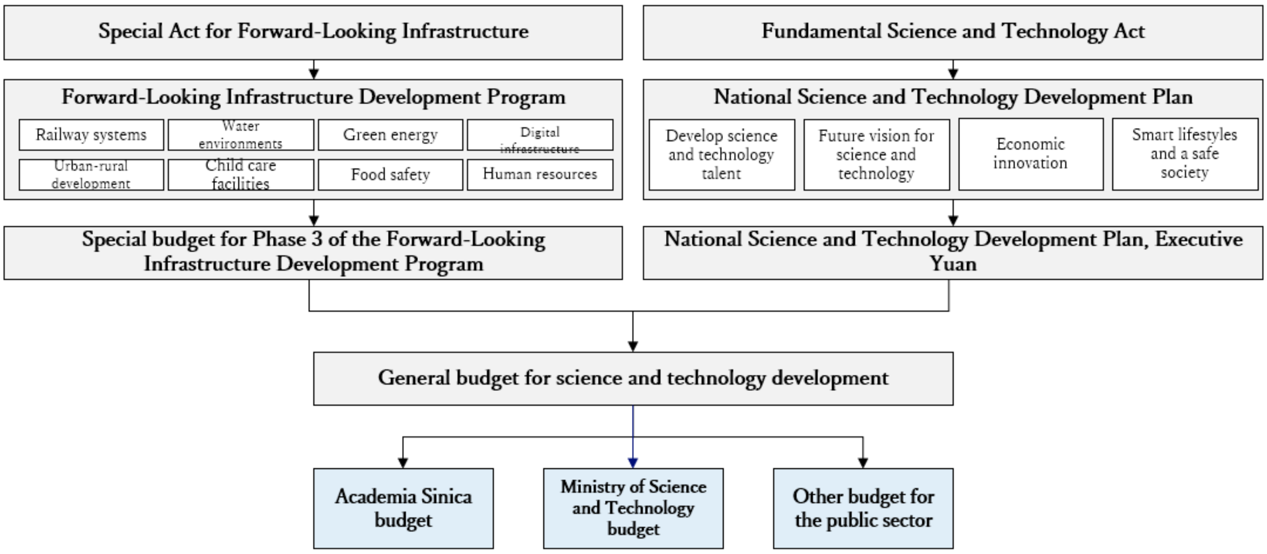


Fig. 2-3 Budget Formation Mechanism of Science and Technology Policies in Taiwan

Source: Taiwan "White Paper on Science and Technology" (Figure created by the authors)

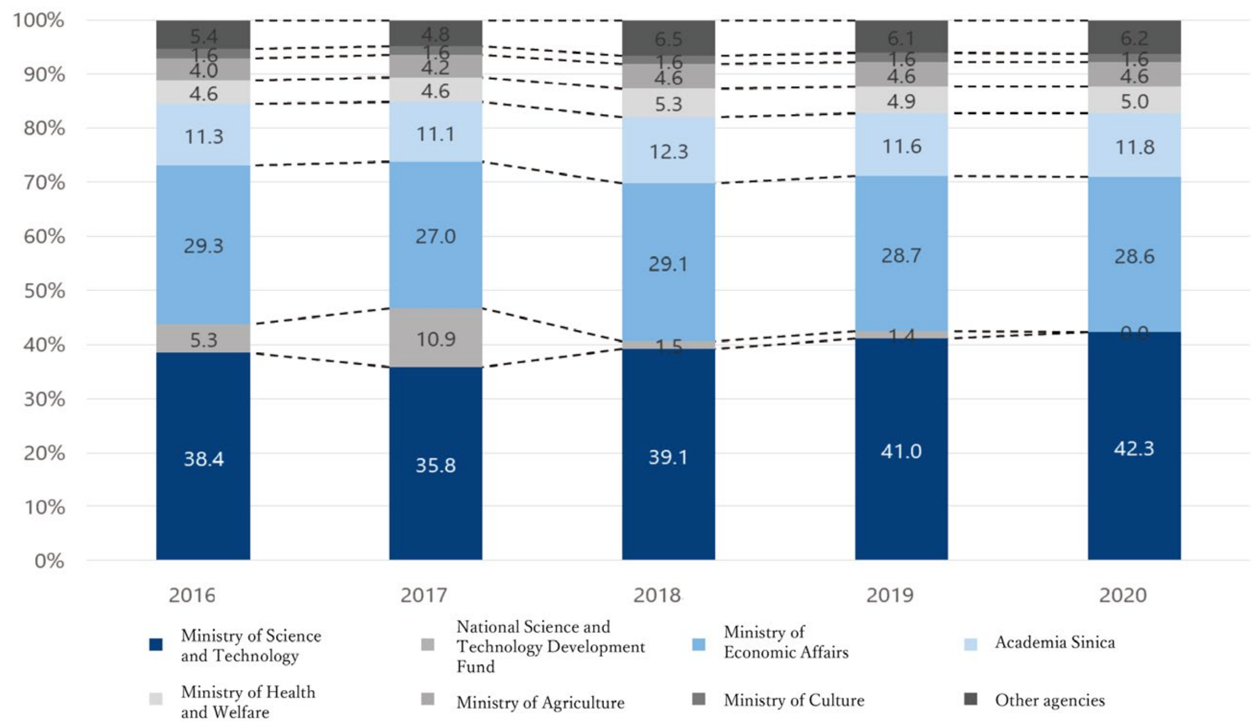


Fig. 2-4 Allocation of Science and Technology Budgets to Various Agencies in Recent Years

Source: Taiwan "Central Government Total Budget" (Figure created by the authors)

2.2.2 Development of Science and Technology Policy Organizations

(1) From the National Science Council to the Ministry of Science and Technology

In response to rapid changes in society and needs related to industrial development, the importance of top-down science and technology planning led by the Taiwanese authorities has been slowly and steadily increasing. A characteristic feature is the application of the integration capabilities of the Taiwanese authorities. The intention is to influence a deep and broad spectrum of science and technology areas, connecting society's limited resources to international and future possibilities in order to make a significant contribution to Taiwan's industrial development and social welfare. This type of science and technology policy not only has a relatively long implementation schedule and a large budget, but also targets innovation through science and technology based on a long-term vision for society, employing a cross-disciplinary and cross-agency approach. It integrates upstream, midstream, and downstream industries, the Taiwanese government, academic research resources, and human resources along both the vertical and horizontal axes of science and technology R&D, and seeks to realize its vision for society through the joint promotion of targets for science and technology innovation.

In Taiwan, top-down science and technology planning means that the Taiwanese authorities clearly define the direction of science and technology development based on future trends in science and technology development, Taiwan's potential advantages in and industry needs for application of science and technology, and then explain the direction of science and technology development to various government agencies through the National Science Council. Each agency in turn establishes a corresponding policy and action plan based on the policy direction, according to their functions as defined by law. However, the model in the science and technology development plan for

2013-2016, in which each agency participated in budgeting, tended to lack consideration from a holistic perspective, and the legal force behind the policy was weak. In addition, it was found that the division of responsibilities between agencies over a long period meant that the goals of each organization did not necessarily relate to the science and technology development goals of the Taiwanese authorities. Furthermore, the model suffered from a general lack of mechanisms for integration of and coordination between research institutes and government agencies. Overall, the top-down approach to science and technology planning resulted in a situation in which individual agencies, which are mainly responsible for practical affairs, tended to abide by their own principles and operate from their own perspectives, making it difficult to smoothly implement policies. Meanwhile, the main agency responsible for science and technology planning found it difficult to influence the other agencies, and had little leadership over them.

Amid the rapid changes in the policies of the Taiwanese authorities and in needs for industrial development, the challenges presented by this structure prevented the authorities from making any swift changes based on important factors such as changes in the international political and economic situation, social transformation, industry competition, etc., nor could they flexibly adjust budget allocation and create new types of organizations when necessary. It was also difficult to allocate resources to the relevant agencies and organizations involved in new and important themes, and to provide prompt and effective feedback on challenges and take measures to address them. In the long run, the inability to concentrate the investment of scientific and technological resources on important themes as they emerged led to a gap forming between advancements in science and technology and the actual development needs of society and industry.

To resolve the issues with the structure described above, Taiwan established the Board of Science and Technology, Executive Yuan and the Ministry of Science and Technology in 2012 and 2014 respectively. The Executive Yuan Office of Science and Technology is primarily responsible for allocating Taiwan's science and technology budget, integrating tasks related to science and technology development that span multiple agencies, and coordinating the promotion of Taiwan's overall science and technology development. Meanwhile, the Ministry of Science and Technology is tasked with the actual promotion and implementation of various science and technology plans, and is expected to strengthen cross-agency integration and coordination.

(2) From the Ministry of Science and Technology to the National Science and Technology Council

Currently, the Office of Science and Technology, an organization in the Executive Yuan, deliberates on, allocates resources to, and evaluates Taiwan's science and technology policies, and then promotes science and technology affairs in cooperation with various individual agencies. However, in 2021, the Executive Yuan submitted an amendment to the Organizational Act of the Executive Yuan that would change the Ministry of Science and Technology to the National Science and Technology Council in order to enhance the integration and promotion of science and technology affairs among agencies, which was expected to improve the effectiveness of science and technology governance (Figure 2-5). To this end, interviews were conducted with various departments of the Ministry of Science and Technology, as well as the departments relevant to the soon-to-be-established Ministry of Digital Affairs, including the Department of Information Security and Information Systems of the Ministry of Economic Affairs and digital-related departments of the National Development Council, to develop a new framework for the future management of Taiwan's science and technology policy.

Further organizational reshuffling is attributed to the fact that the Ministry of Science and Technology became an independent agency after the National Science Council was turned into the Ministry of Science and Technology through institutional reform. The Ministry of Science and Technology mainly emphasizes subsidizing academic research and implementing and managing the national science and technology budget. However, this also requires reliance on the cross-agency coordination mechanism of the Executive Yuan councils in charge of science and technology administration and its affiliated Office of Science and Technology, which weakens the cross-agency coordination capabilities of the Ministry.

The structure of the Ministry of Science and Technology organization consists of a director, deputy director, and the heads of the departments under its jurisdiction. The structure of the preceding National Science Council was based on a councilor system. The members consist of the heads of science and technology-related departments, and the National Science Council chair regularly convenes cross-agency meetings. It achieved a high level of cross-agency operational standards because it acted as an official pipeline that maintained close relationships with each agency.

As a result of the development of science and technology, many policy goals can no longer be handled by a single agency or field, and there are ever-increasing needs for R&D that spans multiple agencies, organizations, and fields. In order to strengthen the outcomes of Taiwan's science and technology policies, it has become necessary to change the Ministry of Science and Technology back from being an independent Executive Yuan agency to its former "council" format. The main difference from the former National Science Council is that in the future, the same person will serve as both minister of science and technology policy and chair of the council. In other words, the same person will be responsible for managing the allocation of budgets for science and technology and cross-agency cooperation, which will significantly strengthen the execution capabilities and cooperation of departments whose main duties are science and technology.

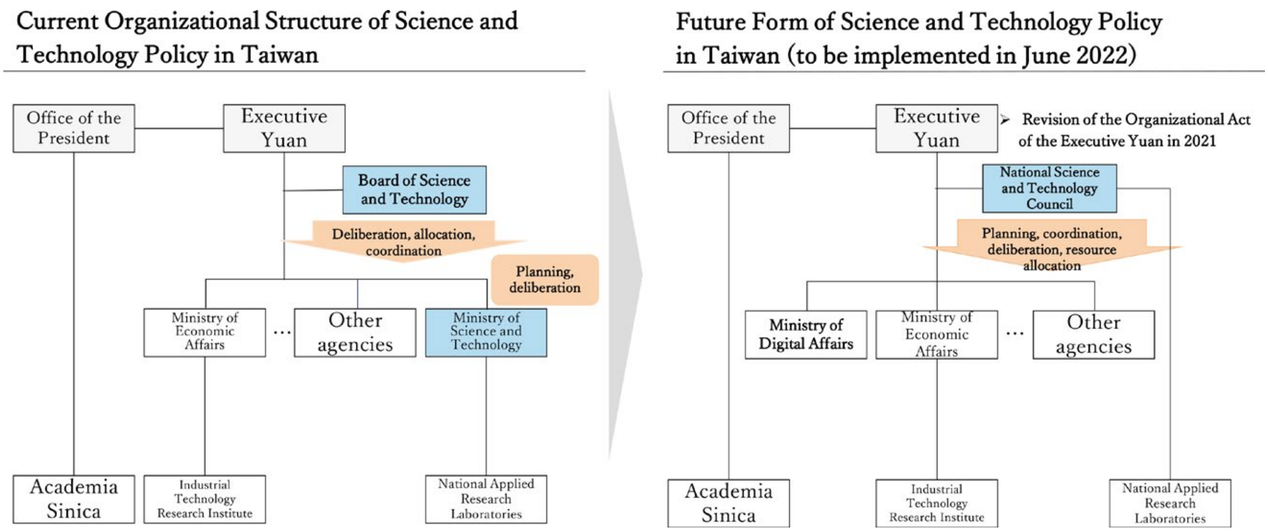


Fig. 2-5 Current and Future Organizational Structure of Science and Technology Policy in Taiwan

Note: Functions of each organization
- Board of Science and Technology:
  Planning and coordination of overall science and technology policies, and allocation of the overall science and technology budget.
- Ministry of Science and Technology:
  Planning and implementing budgets for science and technology development plans within the budget allocated to the Ministry.
- National Science and Technology Council:
  Has the functions of both the Board of Science and Technology and the Ministry of Science and Technology, i.e., formulating and coordinating overall science and technology policies, allocating the overall science and technology budget, formulating science and technology development plans within the budget allocated to the Council, and implementing the budget.

Source: Official website of the Ministry of Science and Technology (Figure created by the authors)

2.3 National Science and Technology Development Plans

Since the promulgation of the Fundamental Science and Technology Act in 1999, the National Science and Technology Conference has been held every four years in Taiwan. By asking government authorities and academic societies for their input, the current status of and development challenges in Taiwan's society, environment, economy, science and technology, and human resources are clarified, and appropriate measures are taken to address these issues as a basis for formulating future plans for the development of science and technology. This section focuses on science and technology development plans under the Tsai Ing-wen administration. The following are the main conclusions of the 10th and 11th National Science and Technology Conferences as expressed in the 2017-2020 Science and Technology Development Plan and the 2021-2024 Science and Technology Development Plan.

2.3.1 2017-2020 National Science and Technology Development Plan

The Science and Technology Development Plan for 2017-2020 (Tsai Ing-wen's first term) was formulated by the Taiwanese authorities through the 10th National Science and Technology Conference held in December 2016, based on factors such as the international situation, the social environment, the status of industrial development, and trends in science and technology at that time, gathering ideas from various fields to form a common understanding on the development of science and technology.

(1) Background and Challenges

When the 2017-2020 National Science and Technology Development Plan was enacted, Taiwanese society as a whole was facing many challenges, including the stagnating growth of the global economy, rapid development and competition from emerging markets, labor shortages due to an aging population and declining birth rate, natural disasters caused by climate change and the need for ecological and environmental protection, management and control of infectious diseases and new viruses, and food safety. It was also noted that Taiwan's science and technology R&D system also faced numerous challenges. In the past, the budget for science and technology policies had overemphasized balanced allocation, and the science and technology policy budget being too widely dispersed as a result has hampered the ability to concentrate budget funds in specific fields that are linked to important themes. This is related to the lack of mechanisms in place to link Taiwan's forward-looking science and technology investment needs with the allocation of science and technology research expenditures. The lack of such a mechanism has prevented Taiwanese authorities from responding quickly to sudden changes in the external environment and recognizing key themes as critical factors, and has made it impossible to effectively channel limited science and technology budgets into these key themes through appropriate cross-agency policy mechanisms.

In a rapidly changing external environment and with limited public resources, if budgets are allocated in a distributed manner, significant policy challenges will not receive appropriate resources. Moreover, the policy direction for many science and technology innovation programs and industrial development programs changes constantly due to personnel changes and other factors, creating a shortage of budgetary resources for science and technology in important policy challenges. In addition, many projects could not be carried out continuously over a long period of time, which was one of the reasons why Science and Technology Development Plans have not been fully effective.

The plan also points out that even with long-term science and technology budget allocations, there is a continuing problem of technology trade expenditures far exceeding revenues. This shows that there was still a gap between the investment of R&D expenditures in various industries and the improvement of the technological capabilities of the industries in Taiwan during the past period in question.

Furthermore, the agencies' dispersed allocation of R&D resources at various stages of the R&D value chain to universities and public research institutions has created a situation in which R&D budget allocation is not smoothly linked to industrial sector results due to the lack of effective feedback on the differentiated R&D investment needs that arise based on the attributes of different themes. In addition, due to differences in the nature and duties of the various government agencies to which public research institutions belong, and the lack of a mechanism for horizontal ties between agencies and research institutions, the industrial and academic spheres often have a different understanding of the direction of research and development, and there is little connection between the two. Meanwhile, the lack of understanding of the academic world's research results in the industrial sector has made it difficult to find appropriate academic research partnerships.

Academia has also had an insufficient understanding of the needs of industry. Researchers were heavily focused on academic research results, and as there was little direct linkage between research results and industrial development, academic results could not be applied for use in industry due to a lack of relevance to industrial needs. Academia R&D at this time did not effectively reflect the actual needs of all industries or of society in terms of either the direction pursued or the investment of R&D resources, which created poor R&D results.

In addition, the 2017-2020 plan points out with regard to the R&D structure that Taiwan at that time lacked a performance evaluation mechanism that took into consideration the characteristics of each type of R&D project. This made it hard to track the effects of each R&D project, and it was also difficult to accurately assess performance and determine how to allocate and coordinate resources in each scientific and technological area, and to create guidelines to serve as standards for future resource allocation. As a result, the effects that could be produced with limited resources gradually declined, impacting Taiwan's competitiveness in science and technology.

On the other hand, most of the indicators for evaluating specialized themes in academic research consist of the number of publications in international journals. The number of citations is used as a basis for evaluation, and the direction of evaluation is relatively monolithic. This makes it difficult for researchers to demonstrate their diverse talents, and fosters a tendency toward insufficient implementation of forward-looking research aimed at solving problems in many areas or social issues. It also makes it harder to display outstanding talent, and to smoothly pursue research on related important issues. Moreover, gaps in national R&D capabilities and the need for a very high level of continuity in most areas of scientific and technological development, combined with growing R&D costs and resource needs, make it difficult to achieve a variety of important R&D results based on the R&D capabilities of any single country or region. For this reason, the need for international R&D collaboration has also become increasingly important.

However, Taiwan lacks an institutionalized integration mechanism for international R&D collaboration. Although there are a variety of international collaborative efforts in Taiwan, and many universities have concluded partnership agreements with universities in other countries and regions, Taiwan lacks an institutionalized R&D collaboration network. At the same time, many of the agencies involved in science and technology policy (Ministry of Science and Technology, Ministry of Economic Affairs, Ministry of Education, Ministry of Foreign Affairs, etc.) have set up specialized departments in charge and are cooperating with companies and research institutions in international R&D collaboration through specialized plans for each project (research plans based on international collaboration, research plans based on tie-ups of the science and technology of both sides, etc.). Still, there are many problems, such as the lack of platforms or mechanisms for horizontal connections between departments and programs.

With regard to human resources, the plan points out that human resources developed through the traditional faculty-segregated educational system will have difficulty adapting to the complex and ever-changing social and industrial environment of the future. In response, the human resource development system and its functions should be modified to create a mechanism for cultivating scientific and technological human resources in related multidisciplinary fields that can respond to developments in science, technology, and society. Singapore, South Korea, China, and other countries are attracting Taiwan's top talent with high salaries, while Taiwan only exports high-caliber talent. In addition, factors such as salaries, laws and regulations, and conservative attitudes toward immigration policies make it difficult for overseas talent to flow into Taiwan. These factors have led to a shortage of high-caliber talent in Taiwan.

(2) Measures

To address the challenges in resource allocation, R&D mechanisms, and human resources described above, as well as the new development opportunities in the digital economy era, the Taiwanese authorities established four goals and perspectives in the 2017-2020 National Science and Technology Development Plan: "Revive Economic Dynamics through Innovation," "Develop Robust Smart Living Technologies and Industries," "Foster and Recruit Talent with Diverse Career Paths," and "Enhance the Innovation Ecosystem for Scientific Research."

First, regarding "Revive Economic Dynamics through Innovation," with the advent of the digital economy era, the integration of big data to provide shared services and the provision of business services related to industrial information has become an important trend in global industrial development, and in order to effectively transform Taiwan's achievements in science and technology R&D into a force that supports innovative industrial development, the Taiwanese authorities will promote the establishment of well-organized data circulation platforms to facilitate the rapid sharing and usage of large amounts of industrial, government, and consumer data to benefit the development of diversified, cross-industry innovative applications.

In addition, by strengthening intermediary mechanisms for horizontal and vertical exchanges among agencies, R&D institutions, and between industry and academia through the expansion of guidelines for the direction of R&D in industry (the 5+2 Innovative Industries Plan), each public institution and academic research institution will be able to conduct R&D that meets industrial needs. And, by utilizing a consistent R&D performance management mechanism, the Taiwanese authorities will integrate and apply the research results of each sector to ensure that the overall effects are achieved. Appropriate performance evaluation mechanisms will also be utilized to judge the research achievements of each sector based on diversified indicators to ensure the long-term development of the plan and the realization of its goals.

On the other hand, as competition is intensifying more and more due to globalization, Taiwan's innovative capability can no longer be secured solely by relying on institutional design and guidelines established by the Taiwanese authorities, and it is also necessary to improve innovation capability in specific areas. In response to this issue, the development of the Ministry of Science and Technology's science parks and the Ministry of Economic Affairs' regional industrial innovation parks and centers and industrial parks are expected to bring together various industries and human resources in these areas to achieve mutual industrial advantages, exchange, diffusion, and sharing of expertise.

New technologies and digital economic models span many domains and have a significant impact on all concerned.

However, the existing regulations have limitations. A crucial responsibility of the Taiwanese authorities is making the appropriate adjustments to existing regulations in order to facilitate the smooth development of new technologies. To this end, the demonstration test concept will be incorporated into future regulatory adjustments to create a favorable environment for industrial innovation. Measures set forth under “Revive Economic Dynamics through Innovation” aim to promote economic development by facilitating the creation of opportunities for industrial innovation. These include the promotion of innovation in specific areas to create dynamic growth by utilizing big data circulation and strengthening the linkage between science and technology R&D results and the needs of industry, relaxing related regulations, and encouraging the creation of an innovative environment.

Next, measures under “Develop Robust Smart Living Technologies and Industries” aim to apply new models to address existing challenges in each domain by adopting relevant technologies for agriculture, medicine, disaster prevention, green energy, and information security by utilizing methods such as IoT (internet of things) technology, digital technologies, and smart systems. In agriculture, for example, issues such as the safety of agricultural products and food, labor shortages in the sector and the issue of an aging population will be tackled through integrated management of upstream, midstream, and downstream R&D systems, and the development of smart agricultural production technology. In healthcare, big data available in the national health insurance database will be used to combine new medical technologies and equipment in order to develop precision medicine, aiming to solve problems such as chronic diseases suffered by the Taiwanese population, healthcare for children, and new types of zoonotic and other infectious diseases. For disaster prevention, IoT technology will be applied to improve the country’s ability to detect disasters. At the same time, big data from various industries will be linked to enhance the ability to predict and respond flexibly to risks such as the increase in torrential rainfall due to climate change, disasters in sloped areas, and earthquakes, as well as the accessibility of disaster prevention information for users.

Measures included under “Foster and Recruit Talent with Diverse Career Paths” address the problem that policies for both science and technology innovation and industrial development, as mentioned above in relation to the establishment of various innovation policies and the basic design of the Taiwanese authorities’ 5+2 Innovative Industries Plan, are based on a “digital economy,” but there is an urgent need for sufficient numbers in these areas – in other words, developing top-quality science and technology human resources is a must. In order to cultivate the human resources needed by these industries, the following four policies should be pursued: “foster interdisciplinary talent in the digital economy,” “reinforce technical expert training mechanisms for industries,” “diversify career paths to invigorate the cultivation of high-caliber scientific research professionals,” and “recruit and retain international top talent.” With regard to strengthening the capacities of incumbent staff, the mechanisms for cultivating R&D talent with doctoral degrees in various industries will be strengthened, and the gap between academic and research objectives will be reduced. In addition, diversified R&D career paths will be created for R&D human resources based on the needs of industries in and outside of Taiwan and related plans for R&D development goals. Furthermore, Taiwan will aim to attract international talents by creating a comfortable living and working environment for them.

Lastly, measures to “Enhance the Innovation Ecosystem for Scientific Research” are designed to achieve a virtuous circle of innovative ecosystems through science and technology. The goal is to create a common understanding through timely and appropriate adjustment and revision of science and technology-related laws and regulations, and increasing communication among different stakeholders from various sectors. The measures aim to create a superior environment for commercializing R&D results by promoting the development of various mechanisms and regulations necessary for innovative models of knowledge transfer through R&D and exchange between industry and academia (for example, an intermediary platform between industry and academia, provisions for acquiring shares after technology transfer, and public-school teachers and researchers concurrently serving as directors of newly established companies).

The relationship between academic research and the needs of society and industry will also be strengthened. By using diversified and upgraded systems for evaluations in higher education (e.g., establishing evaluation models and standards for different academic disciplines according to the type of R&D project), R&D capability will be made a core theme linked to social and industrial development, and partnerships with international R&D capabilities will be promoted. Enabling academic R&D capabilities to provide services that better meet the needs of society and industry will lead to investment of resources by various sectors of society with a stronger purpose, the formation of a common understanding on science and technology development, cooperation on the establishment of well-developed science and technology-related laws and regulations, and the strengthening and development of an innovative ecosystem through science and technology.

2.3.2 2021-2024 National Science and Technology Development Plan

The 2021-2024 National Science and Technology Plan is divided into four major themes: industrial innovation, science and technology, the corporate sector innovation environment, and the development of scientific research talent. The details of these themes are described below.

(1) Promotion of Industrial Innovation

In the area of industrial innovation, the ongoing 5+2 Innovative Industries Plan has produced positive results, and certain key industries (IoT and machinery) have surpassed initial government targets. Additionally, to raise awareness that the prolonged trade dispute between the U.S. and China has the potential to impact OEM (original equipment manufacturing) industries, which form the foundation of Taiwan's long-term economic growth, and in response to the trend toward restructuring of supply chains due to the Covid-19 pandemic in recent years, the Taiwanese authorities have been promoting the development of Six Core Strategic Industries, in addition to the existing plan, seeking to boost the production value of Taiwan's high-end manufacturing industry, strengthen the competitiveness of related industries, and improve Taiwan's autonomous technological capabilities.

Among the main activities outlined in the plan is strengthening Taiwan's R&D and self-supply of key semiconductor materials and equipment. In addition, the Taiwanese authorities are also focusing on the digital transformation (DX) of society and the public sector, and will step up the development of the information security industry, which is becoming increasingly important in this process. Meanwhile, in response to heightened demand for environmental protection in the international community, the Taiwanese authorities will increase investment in technology R&D in areas such as renewable energy and the circular economy, and establish demonstration areas for industrial technology business models in order to ultimately establish technologies that can meet the needs of industrial development.

(2) Promotion of Science and Technology

First, regarding investment in science and technology resources, the plan points out that while the Taiwanese authorities' technology industrialization policies and corporate sector R&D investment in recent years have focused on technological development, the ratio of the budget allocated to basic research has been decreasing year by year due to the limited science and technology budget. However, basic research is the foundation of science and technology innovation, and maintaining a certain percentage of the budget is necessary for the sustainable development of science and technology. Therefore, the plan institutionalizes grants for basic research, and states that the proportion of expenses for basic research should be returned to the long-term average level and grow in tandem with the overall budget by maintaining a fixed ratio of investment. In addition to this, the 2021-2024 plan points out that the 2017-2020 National Science and Technology Development Plan placed too much emphasis on technological development and the plan as a whole did not match the demands of society. To remedy this, Taiwan will adopt a “top-down” approach to strategic R&D going forward to encourage innovation in the corporate sector and further increase investment in applied research and basic research in order to promote innovation that develops the demands of society and industrial development, and to strengthen response to society’s demands.

Next, the plan notes that Taiwan will develop the necessary basic research in the field of science and technology, focusing on promising and important technologies based on the future demands of society. The plan predicts that the global demand for computing power will increase in the future, and since quantum computers have far superior computing power compared to conventional computers, Taiwan will reinforce its research on quantum technology in order to play an important role in the future quantum era. To support Taiwan’s future R&D capabilities in key technological areas, the Taiwanese authorities will (1) increase investment in core R&D infrastructure and services and further improve Taiwan’s science and technology-related facilities by providing support for personnel involved in the R&D for high-end equipment and detection technologies needed for academic research, and (2) establish specialized research centers based on important issues to promote groundbreaking research plans in specific specialized fields and propose innovative solutions for important social and academic challenges. Regarding the allocation of resources, a regular review mechanism will be established, and plans with outstanding performance will be selected for intensive resource subsidies, thereby gradually increasing Taiwan’s academic influence in the corresponding field.

Furthermore, the plan indicates with regard to industry-academia collaboration that current academic R&D is still focused on the publication of research papers, with little attention paid to research into technologies that are actually in demand in industry, resulting in a gap between the technologies being created in the academic sphere and industrial development. Meanwhile, from the standpoint of academia, academia is uncertain as to what technologies are in demand in the industrial sector. In order to strengthen the relationship between research papers and the demand for industrial technologies, the Ministry of Science and Technology has decided to subsidize doctoral research students in key fields that Taiwan wants to develop. This will give doctoral students the opportunity to participate in industrial training, meet actual experts in industrial R&D, and experience company operations, allowing them to pursue research on the expertise and technologies actually needed in industry and publish papers on these topics. In addition, from the standpoint of professors, by relaxing income limits on industry-academia collaborative research programs in which professors are engaged, academic research personnel engaged in basic R&D and technology patent research necessary for industry can be supported.

From the standpoint of industry, due to a lack of awareness of the current status of technology in academia, it is difficult for industry to grasp what kind of technology is available that can meet the current technological development goals. In order to provide the industrial sphere with a better understanding of Taiwan’s current technological capabilities, going forward, public research institutions will be used as a bridge between industry and academia. Public research institutions are well-versed in the competitive situation and development demands of industry and can connect with relevant contacts, which allows them to gain a deeper understanding of future trends and what needs to be developed in industry. At the same time, they can deepen their understanding of research work and interact with academics to understand the development of academic research capabilities and the potential value of research results in terms of applications. To this end, the Taiwanese authorities will provide support to public research institutions to conduct evaluations and analysis of research results in key areas of academia in order to identify the most promising opportunities for commercialization and analyze strategies for industries with potential applications in the future. In addition, leveraging the R&D capabilities of public research institutions will increase the value of using still-immature research results from academia, and promote the value of using patents, thereby upping the rate of patent usage.

(3) Corporate Sector Innovation Environment

In addition to the difference in the direction of R&D between the academic and industrial spheres mentioned above, in reality, in the process of pursuing the commercialization of their academic research results, academics are often unable to accurately gauge the commercialization potential of their own R&D results due to the lack of practical knowledge and experience in industry in the academic world. As a result, in many cases the most suitable industry or manufacturer for the application of the research results is not found, and resources necessary for commercialization are not sufficiently secured. In addition, in the initial stages of R&D technology becoming a new business, the business model may not be mature enough or the market demand may not be stable, resulting in the new business facing the problem of insufficient resources and possibly failing while still in the middle of its development.

To address these issues, the plan recommends that a mechanism first be established that would allow industrial experts to participate in the academic R&D process in order to identify outstanding R&D results. In addition to providing guidance on the direction of R&D in related technologies, experts should also use their specialized actual industrial experience to assess the future commercialization potential of each R&D result, identify themes with particular potential among many R&D results, and utilize their own industry contacts to promote outstanding R&D results to industrial investors. In order to support new businesses, if R&D technology becomes the basis for launching a new business in the form of technology transfer or by independently starting up a company, the Taiwanese authorities will provide sufficient funding along with overseas startup experience for the new businesses by inviting Taiwanese entrepreneurs or overseas investors (for example startup investors from Silicon Valley in California, U.S.A.) and providing public investment funds, ensuring that new businesses are able to grow steadily after they get off the ground.

In addition, the environment for translating R&D into new businesses is still deficient in many areas, especially in terms of legal regulations. Although many of Taiwan's top professors and researchers are affiliated with public universities, the current regulations impose many restrictions on public university professors and researchers engaging in business activities. For instance, professors are not allowed to hold any positions in venture companies. However, these restrictions have significantly reduced the participation of Taiwan's outstanding professors and researchers in activities to commercialize R&D technologies. In order to further facilitate the R&D to startup development process in Taiwan's key science and technology fields, and to enable a large number of top R&D personnel to participate in this process, the plan therefore relaxes legal regulations related to startups. For example, new businesses will be allowed to utilize the resources of public universities, and restrictions on professors at public universities holding positions or shares in overseas venture companies will be eased.

(4) Development of Scientific Research Talent

Amid the rapid development of digital science and technology and the digital economy, the trend in various industries to use more semiconductors, and the demand for medical science and technology brought about by the pandemic, the plan notes that there is a continuing shortage of human resources in smart devices, biomedicine, green energy, IoT, IC design, image displays, information security, and digital content and materials. To resolve these issues, the Taiwanese authorities have submitted the "Act for National Key Fields Industry-University Cooperation and Skilled Personnel Training" and its related plan to cultivate highly skilled science and technology human resources in key science and technology fields. Going forward, the inter-agency council will first select the key fields, establish the application conditions for public universities and conditions for cooperating private companies, after which public universities and private companies will cooperate to establish research institutes in key fields, strengthen personnel exchanges between academia and industry, and build long-term cooperative relationships in the process.

In addition to the shortage of talent in key fields, the internationalization of human resources is still considered to be a problem, with a low ratio of international personnel, insufficient internationalization of domestic personnel, and little active participation in international scientific research activities. This shows that Taiwan may not be able to obtain technological resources and R&D experience from the international community, which could slow the pace of its technological development. In order to promote the internationalization of R&D personnel, the Taiwanese authorities, through relevant programs for industry-academia cooperation, provide scholarships to international personnel and waive employment restrictions to attract international personnel to Taiwan and promote the STEM disciplines (science, technology, engineering, and mathematics) and key science and technology fields (5+2 industries, AI, IoT, semiconductors, and information security). As for the internationalization of human resources in the region, the authorities encourage doctoral research students to intern at research institutes and companies in the U.S., France, Israel, and other countries, and provide students with the necessary funds to do so. In addition to this, the Taiwanese authorities also encourage research teams to actively participate in international scientific research programs (e.g., the EU's Horizon Europe, which promotes the development of international scientific research).

2.4 Industrial Innovation Plans

The Taiwan authorities launched the 5+2 Innovative Industries Plan in 2016, followed by the enactment in 2020 of the Six Core Strategic Industries , which is based on the 5+2 Industries, to promote the development of key industries.

2.4.1 5+2 Innovative Industries Plan

With the advent of the smart era and fierce competition in global industries, the Taiwanese government has been actively promoting the 5+2 Innovative Industries Plan since 2016, seeking to advance the transformation and upgrading of Taiwan's industries and cultivate renewed momentum for Taiwan's economic development. The plan aims to shift away from the traditional OEM-based model, which was based on a cost reduction-oriented economic growth model, to a new economic development model centered on the principles of innovation, employment, and equitable distribution.

To this end, the Taiwanese authorities targeted seven core areas where there are industrial needs: smart machinery, Asia Silicon Valley, green energy, biomedicine, national defense, new agricultural industry, and the circular economy.

The plan also promotes industrial development based on three key strategies. The key strategies are as follows.

1. "Links to the Future" promotes the development of Taiwan's industrial value chain from hardware manufacturing to application services and system integration that link software and hardware.

2. "International Links" promotes technological partnerships between Taiwan's industrial value chain and developed countries such as Europe, the U.S., and Japan, as well as links and alliances with industries in Southeast Asian countries through the "New Southbound Policy."

3. "Local Links" pursues well-balanced development in northern, central, and southern Taiwan during the development process. By applying the industrial cluster approach, local supply clusters will be transformed into innovative ecosystems in partnership with industry, government, academia, and research institutions. The central government's Forward-Looking Infrastructure Development Program will contribute to improving the local investment climate and help implement partnerships with industries both within and outside the region. Local governments provide experimental fields and improve innovation capacity by linking industry and academic research capabilities. The promotion policies of each industrial plan are as follows. Local governments provide experimental fields and boost innovation capacity by linking industrial and academic research capabilities. The promotion policies of each industrial plan are as follows.

(1) Smart machinery

Create a smart machinery ecosystem linking the smart technology and precision machinery industries to promote smart manufacturing in the digital information, metal machinery electronics, information services, and consumer chemical industries, among others.

(2) Asia Silicon Valley

Bring about economic growth through innovative startups by relaxing laws and regulations, developing top talent, and supporting innovative industries, facilitate industrial transformation and upgrading through the IoT industry, and use Taiwan's advantages to promote partnerships with industries in and outside the region.

(3) Green energy

Centered mainly around energy generation, energy storage, energy conservation, and system integration. The development of distinctive industries and an end-to-end infrastructure based on domestic needs for green energy will strengthen energy security and independence and create a new green economy. By introducing large investments from within and outside the region and increasing the number of excellent job opportunities, Taiwan's green energy technology and industry will make a quantum leap forward and go one step further in its ties with international markets.

(4) Biomedicine

Promote the integration of resources in the biomedical industry. Develop market niche items consistent with the goals of the plan and link them to smart technology-operated products to cultivate international markets.

(5) National defense

Develop made-in-Taiwan manufacturing capabilities such as superior design, manufacturing, assembly, and technologies that are key elements tied to defense needs and linked to related industries, including self-manufacturing capabilities for military equipment and battleships among military ships. This program will also cultivate a civilian market, train information security personnel, strengthen information security capabilities, and enhance the development of information security-related industries.

(6) New agricultural industry

A new model of agriculture will be established. Achieve the continued goal of a compatible environment and feasible agriculture by building a system for agricultural safety and improving marketing capabilities in agriculture.

(7) Circular economy

Ensure a permanent source of goods and raw materials. Achieve full circulation and zero waste of goods through the creation of a green consumption model, appropriate revisions of relevant laws and regulations, and enhancement of recycling and reuse technologies.

2.4.2 Six Core Strategic Industries

The 5+2 Innovative Industries Plan, enacted in 2016, has already begun to show initial results. It has stimulated Taiwan's IoT and machinery industries, with production value surpassing 1 trillion TWD (4.3 trillion yen, converted at TWD 1 = 4.3 JPY), and many leading international companies such as Google, Amazon, and AWS have established R&D innovation centers and data centers in Taiwan. International offshore wind power companies and system integrators have successfully promoted the development of wind farms in Taiwan. Furthermore, Taiwanese companies have succeeded in researching, developing, and manufacturing fighter aircraft for training purposes in order to improve their own defense capabilities.

Based on the initial results of industrial innovation, Taiwan has made further progress in its development. Meanwhile, a trend of supply chain surfaced in the wake of U.S.-China trade friction and the outbreak of a new infectious disease, COVID-19. On May 20, 2020, President Tsai Ing-wen declared the promotion of "six core strategic industries," namely information and digital industries, the cybersecurity industry, the precision health industry, the green and renewable energy industry, national defense and strategic industries, and strategic stockpiling industries, and on December 10, 2020, the Executive Yuan approved the "Six Core Strategic Industries." Through the Ministry of Economic Affairs, the Ministry of Science and Technology, the Ministry of Transportation, the Ministry of Health and Welfare, the National Development Council and other related agencies, the country hopes to preemptively take advantage of the opportunity presented by the restructuring of global supply chains in a post-pandemic Taiwan, and to become a key player in the global economy in the future.

(1) Information and digital industries

Vision: Taiwan will become a base for digital technology contributing to global prosperity and security.

Policy: Research and develop semiconductor technologies for a new generation and expand the fields for application of AI and IoT. Maintain Taiwan's leadership in information and communications (ICT) technology by integrating domestically produced 5G Open Ran (open network architecture) solutions. Also, export AIoT solutions and participate in the development of international telecommunications equipment and system integrators.

(2) Cybersecurity industry

Vision: Create a globally trusted information security system and industrial chain.

Policy: Develop solutions in fields such as 5G R&D, semiconductor and other security technologies, AIoT, and healthcare, and enhance the protection of emerging areas and build high-level fields for actual operations through offensive and defensive cybersecurity approaches and establishment of international partnership mechanisms.

(3) Precision health industry

Vision: Make Taiwan a benchmark area for infection prevention through global health-related technologies.

Policy: Establish a big data databank using genetic and national health insurance records, and develop precision prevention, diagnosis, and medical care systems. Develop precision epidemic prevention products and expand international biomedicine business opportunities, and present a successful model of epidemic prevention to the world under the Taiwan brand.

(4) National security and strategic industries

Vision: Independently develop the defense industry and make Taiwan an important supply chain region for the global aerospace industry.

Policy: Promote the establishment of F16 maintenance centers. Develop self-maintenance capabilities for military aircraft, pursue R&D in core technologies in the aerospace industry, and complete the defense industry supply chain. Develop low-Earth orbit satellites and ground equipment in the aerospace industry, and establish and market Taiwan's brand as an aerospace nation.

(5) Green and renewable energy industry

Vision: Create a green energy model for the Asia-Pacific region in Taiwan.

Policy: Break into the wind power industry value chain in the Asia-Pacific region and export Taiwan's offshore wind power industry by creating dedicated renewable energy industrial zones and R&D bases, build a sound system for participating in green energy, and create a national team for offshore wind power.

(6) Strategic stockpiling industries

Vision: Build a civilian and emergency response industry sufficient to ensure the supply of critical commodities.

Policy: Stabilize the five supply chains (energy, food security, key materials for people's livelihood, medical resources, disaster relief, and procurement of gravel and cement), and grasp the relevant science and technology and raw materials and ensure independent supply of items such as semiconductor materials and equipment, vehicle batteries, pharmaceutical ingredients, and 15 important industrial materials.

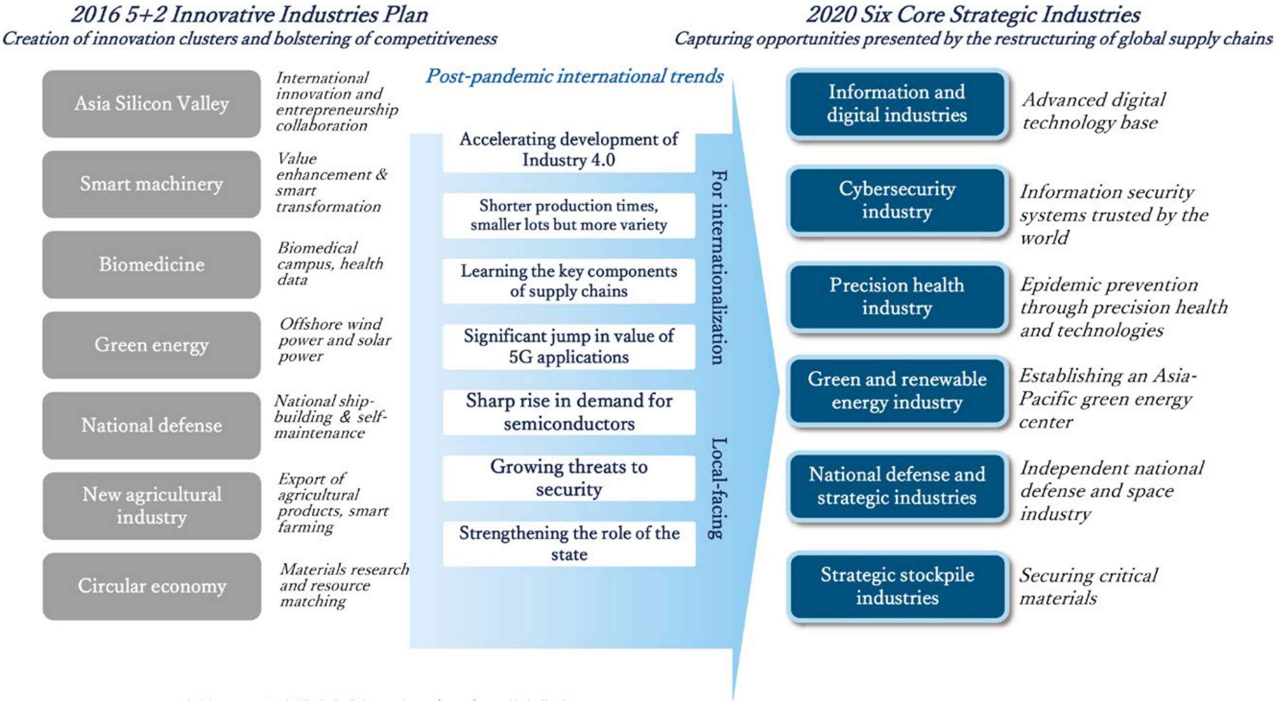


Fig. 2-6 The 5+2 Innovative Industries Plan and the Six Core Strategic Industries

Source: 5+2 Innovative Industries Plan, Six Core Strategic Industries, etc. (Figure created by the authors)

2.4.3 Forward-Looking Infrastructure Development Program

The forward-looking infrastructure development program was approved in 2017, and is based on the principles of permanence and area balance, with an eye to the future, and supports the implementation of infrastructure development in eight areas: railway systems, water environments, green energy, digital infrastructure, urban-rural development, child care facilities, food safety, and human resources.

"Railway systems" promotes safe, convenient, speedy, and smooth transportation and tourism. "Water environments" targets construction that addresses climate change, and water supply security, while "green energy" promotes environmental sustainability and encourages public and private sector investment in renewable energy. "Digital infrastructure" emphasizes digital architecture with digital services and information security, with a focus on developing an ultra-broadband network society. "Urban-rural development" aims to strengthen balanced development among regions and actively develop infrastructure in remote towns and villages to improve the quality of life of urban and rural populations. In addition, programs for "child care facilities," "food safety," and "human resources" are also being implemented.

The program is being implemented with the budget divided into 3 phases for the 2017-2022 period (the overall schedule is 8 years, from 2017-2024). The budget for Phase 1 (2017-2018) was 107.1 billion TWD (460.5 billion yen), Phase 2 (2019-2020) was 222.9 billion TWD (958.5 billion yen), and Phase 3 (2021-2022) was 229.8 billion TWD (988.1 billion yen). The program is expected to boost real GDP by 975.9 billion TWD (4.1964 trillion yen). In addition, the program will generate 36,000 to 45,000 job opportunities and 1.7777 trillion TWD (7.6441 trillion yen) in public and private investment through a budget of approximately 882.5 billion TWD (3.7948 trillion yen) from the Taiwanese authorities, with digital architecture and green energy the two most important areas.

2.4.4 AI Scientific Research Strategy

In 2017, the Taiwanese authorities enacted an AI scientific research strategy. Its objective is to create an AI ecosystem by establishing the human resources, technologies, fields, and industries to set up a basic environment for AI R&D. The plan builds on Taiwan's leading edge in the global ICT industry and aims to achieve its goals through five policies. The specific policies are as follows:

1. Building the "main machine" for AI: Share a large-scale, high-speed computing environment, enhance in-depth learning, and build technology for big data analysis
2. Establishing AI innovation research centers: Develop AI technology over a 5-year period, and train AI personnel
3. Establishing an intelligent robot innovation base: Conduct R&D of robot technology over 4 years
4. Semiconductor moonshot project: Over 4 years, strengthen semiconductor manufacturing processes and wafer system R&D in view of the future AI edge, develop into next-generation memory design, and eventually conduct R&D on cognitive computing and AI chips to develop AR and VR.
5. Increase people's awareness of AI and encourage participation in relevant programs in society.

2.4.5 Digital Nation & Innovative Economic Development Program (DIGI+) (2017-2025)

Aiming to achieve industrial transformation and innovation in response to the cloud computing, big data, ultra-broadband, IoT, and digital network era, in 2017 the Executive Yuan approved the Digital Nation & Innovative Economic Development Program (DIGI+) (2017-2025). By 2025, Taiwan's digital economy is expected to have expanded rapidly, with an increased penetration rate for digital lifestyle services and people's basic rights to use broadband internet service guaranteed. Taiwan is also expected to move up in the international rankings for information capabilities. This project is scheduled to be carried out over a 9-year period, aiming to upgrade broadband and digital infrastructure to benefit industrial innovation. It has six main focuses: Constructing a beneficial infrastructure for digital innovation, Digital economy, Network Society and Smart Government, Intelligent Cities, Fostering interdisciplinary digital talents, and Researching and developing cutting-edge digital technology. The program aims to apply the power of innovation to industry through steady implementation of participatory democracy and balanced area development.

2.4.6 National Cyber Security Program (2017-2020)

In order to create a safe and reliable digital country and to perfect, the Taiwanese authorities set forth four strategies in this program: completing the cyber security infrastructure, constructing a national united defense system in cyber security, increasing the self-development energy of the cyber security industry, and nurturing excellent talents in the field of cyber security. By promoting these strategies, laws related to information security in Taiwan will be perfected, overall cybersecurity defense capabilities will be improved, the cybersecurity industry will be developed to meet national defense needs, from which human resources involved with cybersecurity will be developed and self-defense capabilities will be established.

2.5 Science Parks

To promote the development of high-tech industries, Taiwan established the Hsinchu Science Park, the Southern Taiwan Science Park (STSP), and the Central Taiwan Science Park (CTSP) in 1979, 1995, and 2002, respectively. Over the last 30 years, Taiwan has steadily built up experience in industrial innovation, which has had a ripple effect on various industries. By concurrently promoting the transformation of its industrial structure, Taiwan has successfully earned an important position in the international high-tech industry.

To meet the need for land required for the development of the semiconductor and optoelectronics industries, the Taiwanese authorities are proactively developing land for science parks and attracting related companies for technological exchange and cooperation. In recent years, the U.S-China trade conflict has led many Taiwanese companies to come back from China and invest in Taiwan, and the National Development Council is actively developing land in southern Taiwan under the government's "New Southbound Policy" to promote the development of green energy, biotechnology, marine engineering, semiconductors, circular economy, etc. To this end, we also conducted interviews with the Southern Taiwan Science Park Bureau of the Ministry of Science and Technology to understand the direction of Taiwan's science park policy.

In 2020, the total turnover of firms at the three major science parks reached 3 trillion TWD (12.9 trillion yen). The main industries are the semiconductor and integrated circuit (IC) industry (approximately 2.2 trillion TWD, or roughly 9.46 trillion yen) and the optoelectronics industry (478.7 billion TWD, or roughly 2.0584 trillion yen). Of these, the Hsinchu Science Park's main growth areas are IC design and wafer fabrication and computer network communications, while CTSP's main growth areas are 5G, high-performance computing (HPC) chips, and semiconductor wafers with a 7-nanometer manufacturing processes. The main growth area at STSP is semiconductor wafers based on a global state-of-the-art 5-nanometer process.

Taiwan bases its approach to science park development on the development goals and characteristics of each area, aiming to attract corresponding enterprises to form industrial clusters and encourage business investment. This also leads to the growth of companies in the local vicinity in a mutually complementary manner. At the same time, the system also supports providing added value to industries by providing substantial public support, for example matching for industry needs, setting up R&D centers, developing specialized R&D areas and demonstration fields, subsidizing industry-academia collaboration, and cooperating in obtaining important certifications.

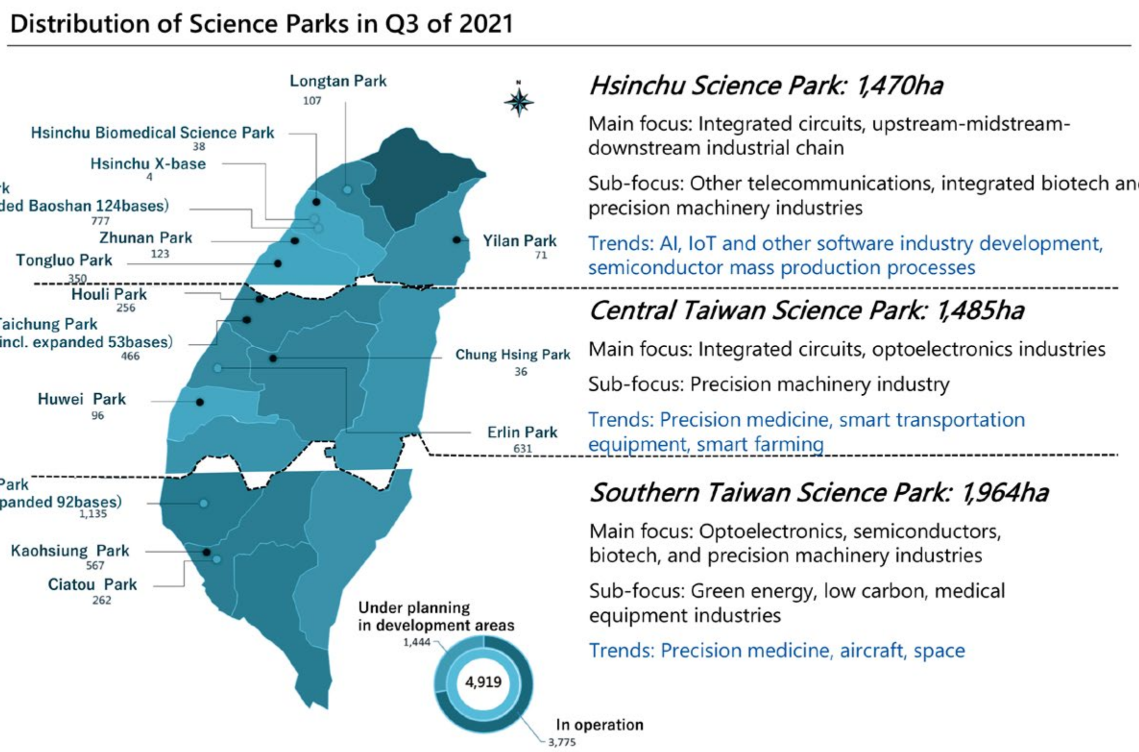


Fig. 2-7 Distribution of Science Parks in Taiwan in 3Q of 2021

Source: Official website of the Ministry of Science and Technology (Figure created by the authors)

2.6 Human Resource Development and Industry-Academia Collaboration Programs

In recent years, the Taiwanese authorities have been hoping to strengthen Taiwan's industrial competitiveness, which can only be attained by cultivating a large number of high-caliber human resources and facilitating breakthroughs in industrial technology. However, since most Taiwanese companies are small and medium-sized enterprises and have focused primarily on R&D of manufacturing processes, it is not easy for them to bear the huge investment needed for the process of R&D of key basic industrial technologies alone. Therefore, the Taiwanese authorities have launched a series of industry-academia collaboration plans that utilize government grants for academic researchers and enterprises, and by leveraging the R&D capabilities of academia and the resources of the public and corporate sectors, they are supporting the development of key industrial technologies in the industries themselves, gradually cultivating high-level R&D personnel in the process, and driving Taiwan's continued industrial development. Below is a description of various programs implemented since 2017 and recent developments.

2.6.1 Forward-Looking Industry-Academia Collaborative R&D Program

To strengthen industry-academia collaboration, Taiwan's Ministry of Science and Technology has launched a forward-looking university-industry collaborative R&D program. This project will enable Taiwanese universities to develop promising and important technologies together with companies from both inside and outside the region. There are three types of projects, which are mainly divided into cooperative objectives, cooperative targets, and cooperative models.

The first type is projects for research and development of promising technologies. The main objective of this type of project is for universities and Taiwanese companies to cooperate in the research and development of promising key technologies, with the aim of gradually developing R&D personnel in the future key technologies in the course of the research and development. In this type of project, based on the direction for the technological R&D submitted by industry, the Ministry of Science and Technology subsidizes the academic researchers and the Ministry of Economic Affairs subsidizes the companies (bearing part of the R&D risk), allowing academic researchers to use the funds invested by companies to conduct cooperative research in specific fields.

Next are projects that involve university-industry R&D centers. The main objective of this type of project is to establish a long-term cooperative R&D relationship between universities and companies in and outside of Taiwan, and to reduce companies' R&D expenditure through the application of internationally competitive technologies currently possessed by the research industry in the center in question and the grants provided to the academic researchers and companies by the Ministry of Science and Technology. Ultimately, it is hoped that long-term, mutually complementary interaction of corporate participation and academic R&D will produce internationally competitive technologies and cultivate a large number of high-quality industrial human resources.

The third type are projects with a university-industry R&D consortium model. The main objective of these projects is to set up an R&D consortium between universities and Taiwanese companies to strategically develop the necessary technology and high-caliber R&D human resources in key industrial domains. Unlike the two types of projects described above, these projects focus more on key domains and human resource development, and are divided into different subgroups based on the key domains set by the government (for example, the semiconductor field selected as a key domain by the Taiwanese authorities in recent years is divided into three subgroups: IC design, IC manufacturing, and testing and packaging)). The monthly salary for top R&D personnel who participate in these projects is directly subsidized. This will be utilized to nurture high-caliber human resources and technology in Taiwan's key industrial domains and facilitate improved industrial competitiveness.

A comparison of the three types of projects reveals that in terms of R&D, all of these projects are led by the industrial sector, which submits the directions and themes for the R&D, after which the academic sector conducts cooperative research accordingly. As for funding, government grants are used for part of the expenses, and the companies cover the rest (which should not be less than the amount subsidized by the authorities). In addition, in-house R&D personnel participate in the program as temporary staff. Meanwhile, the most significant differences lie in the amount and the coverage of the subsidies. Projects pursuing R&D of promising technologies receive the largest amount of funding and are subsidized over the longest period, capable of receiving more than 40 million TWD (172 million yen) annually, with an implementation period of 3 to 5 years. The purpose is to provide long-term funding to support high-risk but promising technology development. University-industry R&D center projects also receive a lot of funding for a long period of time, reaching more than 20 million TWD (86 million yen) a year, with an implementation period of 3 to 5 years. The purpose of these types of projects is to establish a long-term and stable cooperative relationship between academia and industry by supplying sufficient funds. University-industry R&D consortium projects are subsidized for relatively small amounts and shorter periods of time, amounting to about 2 million yen or more, with a period of 1 to 3 years. The main reason for this is that these projects are primarily strategic in nature, based on government demand, and provide a flexible way to train doctoral-level personnel in key domains and assist industries in technological R&D. The following are some examples of actual cooperation.

(1) Collaborative Research and Development by TSMC and National Taiwan University

TSMC and National Taiwan University (NTU) have a long history of abundant cooperation on R&D of promising semiconductor technology. Beginning with the predecessor of university-industry collaborative projects on promising technologies (the Industry -Academia Grand Alliance Project, implemented in 2013), and continuing through the current project, a system for collaboration has been established up to this day. Up to now (2022), two projects have been implemented that have produced very good research results. In the course of implementing the two projects (2013-2017 and 2018-2022), 120 patents have already been obtained and more than 500 master's and doctoral students in the semiconductor field have been trained.

The NTU research team began research on 7-5 nanometer semiconductor technology nodes in 2013 and developed a new process technology to replace FinFET called GAAFET (Gate-all-around FET) technology. This technology has advanced semiconductor manufacturing by lowering the voltage of semiconductor chips and increasing transistor density. In the second phase of the plan in 2018, the NTU team continued to work on future-proof semiconductor technology research to develop chips beyond 3 nanometers. In 2021, a joint research project with the Massachusetts Institute of Technology (MIT) jointly announced that bismuth, a new material for semiconductor manufacturing, can solve the challenges of semiconductor materials of the past, and in the future, the team will be able to realize the concept of atomic-level transistor manufacturing at 1 nanometer or less. The results of this research have already been published in the international academic journal *Nature*. In the future, next-generation chips with low power consumption and high computing speed will be available, which can be applied to the latest scientific technologies such as AI, electric vehicles, and accurate disease prediction, thereby significantly advancing the economic development of society. For these two projects, the Ministry of Science and Technology has already contributed as much as 490 million TWD (2.107 billion yen) in subsidies to support investment in the latest equipment and personnel needed in the process of R&D. This backing has not only facilitated success in various aspects of semiconductor technology research (front-end parts, back-end connectivity, and new materials), but has also strengthened industrial competitiveness and contributed to building a long-term, stable model for industry-academia collaboration between National Taiwan University and TSMC.

(2) Other Examples of Collaborative R&D

In addition to cooperation in the field of semiconductors, there is a wide range of other R&D areas being explored in collaborative university-industry projects for promising technologies, ranging from high value-added steel manufacturing to green science and engineering, to 5G wireless communication technology, targeting both small and large companies. For example, in the field of green science and engineering, a research team from National Tsing Hua University (Taiwan) has teamed up with Changchun Petrochemical Group to implement a new generation green chemical industrial technology based on recycled raw materials. The main objective is to use renewable methods such as biomass and green processes in place of the petrochemical materials on which the chemical industry depends and to reduce the carbon dioxide emissions and water consumption of chemical industry products. From 2014 to the present, the Ministry of Science and Technology has provided a total of 385 million TWD (1.6555 billion yen) in grants to National Tsing Hua University (Taiwan) and Changchun Petrochemical Group to complete the two phases of the project from 2014 to 2021. In terms of R&D achievements, National Tsing Hua University (Taiwan) and Changchun Petrochemical Group have implemented a total of 37 projects related to new generation green chemical industrial materials and smart manufacturing, and have applied for a total of 101 key patented technologies. The most significant achievement of the projects was the improvement of CO_2 capture technology, which will enable the capture of 99% of CO_2 at the industrial level. Moreover, this technology is already in use at the chemical plants of Changchun Petrochemical Group and Formosa Plastics Group, and has enabled the industry to increase its CO_2 capture rate by 10%, reduce energy consumption by 30%, and reuse the captured CO_2 for production of formaldehyde, polyurethane, and other chemical industry products.

2.6.2 Doctoral Training Programs

The Taiwanese authorities have realized that the reasons why the number of doctoral students is decreasing every year are the gap between the research being conducted by Taiwan's doctoral personnel and industrial development needs and the difficulty doctoral students have in finding jobs after graduating. In response, the authorities created the following two systems to solve the aforementioned problems, and by utilizing projects, doctoral students' research on the technology and expertise needed by industry is strengthened, stimulating industry demand for doctoral personnel in the course of the projects, while simultaneously improving the doctoral students' R&D capabilities. The purpose of these projects is to contribute to industry and increase the value of industrial technology.

(1) High Level Industrial Professionals Cultivation Program (renamed from the RAISE Program)

The goal of the High Level Industrial Professionals Cultivation Program is to have doctoral students go to Taiwan as apprentices to participate in actual corporate R&D projects, allowing them to use their own research experience and abilities to solve R&D problems faced by companies. This is intended to help them understand the R&D needs of the industrial sector and the impact of industry characteristics and business models on R&D operations starting from actual research, and to acquire the necessary research skills. The program operates by having research corporations and universities in Taiwan be in charge of the training department, which serves as an intermediary platform between companies and doctoral students, connecting doctoral students with companies in need of R&D personnel and providing them with one year of on-the-job training. The contents of the training program supplement the skills required by the doctoral students by providing a relevant industrial curriculum, with the exception of industrial on-the-job training of 6 months or longer. As for subsidies, the Ministry of Science and Technology will contribute a salary of 60,000 TWD (258,000 yen) per person per month during the training course, with a total subsidy expenditure of 1.05 million TWD (4.515 million yen) per person (including doctoral salary, materials and equipment usage fees, and administrative costs to the training department).

(2) X Talent Program for Overseas Internship of Industry Innovation Talent (renamed from the LEAP program)

While the aforementioned program mainly targets apprenticeships in Taiwanese companies, this program targets apprenticeships in overseas companies. The program dispatches qualified doctoral-level personnel to well-known companies and venture businesses in the U.S., France, Israel, etc., and provides them with a grant of 1.5 million TWD (6.45 million yen) for a one-year fellowship. The main purpose of the program is to send top talent to companies in fields such as digital transformation (DX), precision medicine, the space industry, and kinetic science and technology to learn relevant cutting-edge technologies and obtain international business development experience, becoming multidisciplinary talents in technology and business through the training course, and to bring back relevant technologies, knowledge, and abilities to Taiwan in order to contribute to the development of the relevant industries.

2.6.3 Platform for S&T Industrialization

In most of the university-industry collaboration projects described above, one company and one university research team join up to conduct research, top companies develop the necessary technology, and through technology transfer, patents for the related technology are provided to the company for its use, and the research team can obtain government grants, patent transfer income, and related bonuses provided by the company for its involvement in the project. However, as Taiwanese industries become more sophisticated, it is necessary not only to deepen the development of specific technologies needed by existing industries, but also to integrate the various technological developments and overall solutions needed to support the vision of emerging industry development. The platform for science and technology industrialization was created for precisely this purpose.

Unlike the previously described university-industry collaboration projects, the S&T industrialization platform focuses on key areas of future industrial development. A science and technology consortium of several universities is formed in order to integrate each school's R&D capabilities and patent resources in specific fields, providing a "one-stop" technology R&D membership service to a number of companies. The operating model has the university consortium clarify the status of R&D and results of research currently being conducted at each university, and then find the optimal products for commercialization among the ongoing research. At the same time, an "Industrial Liaison Center" is established, and industry veterans and experts with venture capital experience are convened as members of the center in order to serve as intermediaries between corporate demand and the university consortium's R&D capabilities. Through the Industrial Liaison Center, companies can find a university consortium that is related to their industrial field and conduct joint research. By becoming a member of the consortium and paying a membership service fee, the company can also take advantage of the long-term R&D services offered by the university consortium. Ultimately, the hope is that each participant will benefit and come to each other's aid, creating an autonomous operating platform and reducing the expenditure on subsidies provided by the Ministry of Science and Technology from year to year.

As an actual example, the "Great South S&T Industrialization Platform" led by National Cheng Kung University, a university consortium formed by 12 universities, formed partnerships with as many as 800 companies between 2011-2020, and obtains nearly 5 billion TWD (21.5 billion yen) a year in university-industry collaborative research funding. In 2021, it was announced that the platform had successfully developed products for the smart medicine field, and it has produced a number of technological products. For example, the platform developed seven products including a 24-hour heart rate detector, a wireless urinalysis system, and a smart neural training device, and simultaneously launched new businesses and successfully commercialized products.

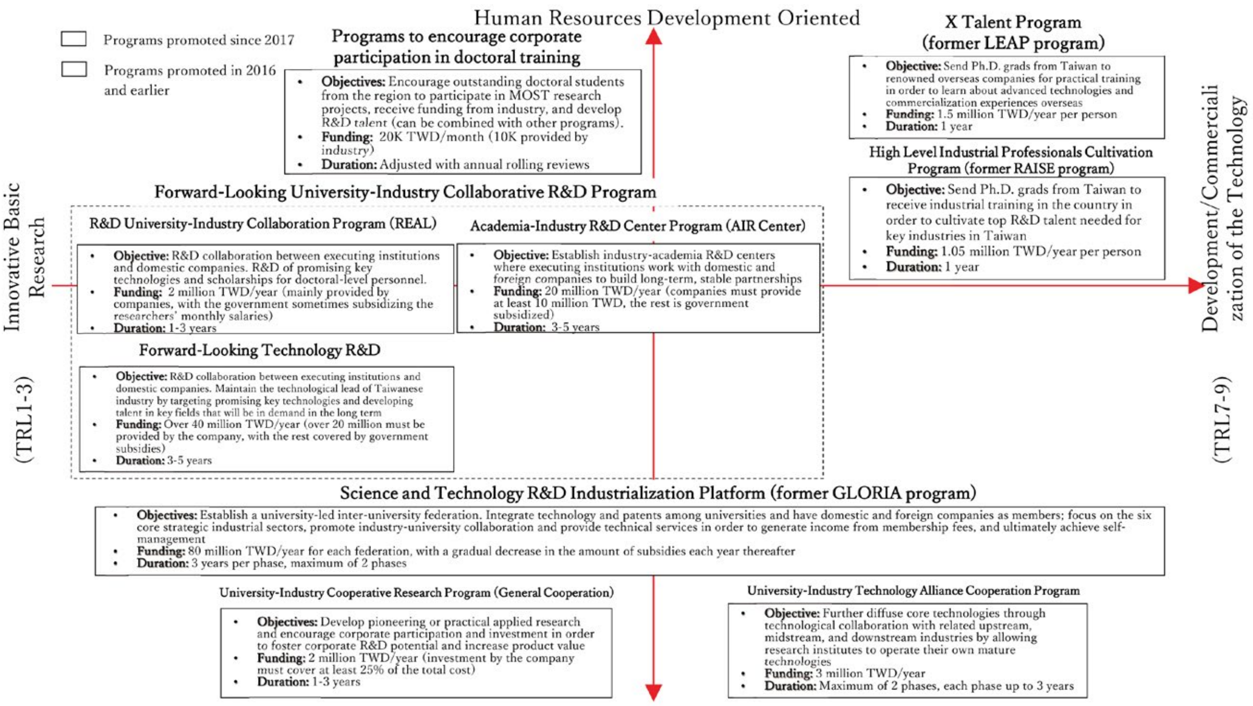


Fig. 2-8 Human Resources and Industry-Academia Collaboration in Taiwan

Source: Official website of the Ministry of Science and Technology (Figure created by the authors)

2.6.4 National Key Fields Industry-University Cooperation and Skilled Personnel Training Act

With the development of Taiwan's key industrial sectors, there is a continuing shortage of relevant human resources. In order to address the lack of top talent in key fields, the Taiwanese authorities proposed the National Key Fields Industry-University Cooperation and Skilled Personnel Training Act in May 2021, which was jointly deliberated by various agencies (Ministry of Education, National Development Council, Ministry of Economic Affairs, Ministry of Science and Technology, the Executive Yuan Directorate-General of Budget, Accounting, and Statistics, etc.) and experts from the industrial and academic spheres. At the meeting, the five key fields were defined as semiconductors, artificial intelligence, smart manufacturing, circular economy, and finance. Then, research institutes in these five areas were established in universities that met the requirements. By relaxing the rules for university personnel, organization, finance, and purchasing, the Act aims to deepen mechanisms for university-industry exchange and increase industry's motivation to invest resources and cultivate high-quality talent in many important fields by involving companies in the management of the cooperative industry-academia efforts in public universities. As of January 2022, five universities have already set up research institutes. They consist of National Taiwan University's Graduate School of Advanced Technology, National Tsing Hua University (Taiwan)'s College of Semiconductor Research, National Cheng Kung University's Academy of Innovative Semiconductor and Sustainable Manufacturing, National Yang Ming Chiao Tung University's International College of Semiconductor Technology, and National Sun Yat-sen University's College of Semiconductor and Advanced Technology Research. At all of these institutes, the theme of the main direction being taken at this point in time is "semiconductors."

These research institutes are positioned as specialized graduate schools for master's and doctoral programs, and they differ from ordinary graduate schools in that, under the norms of the National Key Fields Industry-University Cooperation and Skilled Personnel Training Act, the institutes are not subject to conventional university-related legal norms such as the University Act, Degree Conferral Act, Budget Act, Government Procurement Act, and the National Property Act. In other words, the main purpose of the Act is to relax some of the existing restrictions on the higher education system and to allow companies to play a greater role in the university-industry collaboration process.

Specifically, in terms of organization and personnel, institutes will be able to more flexibly select their presidents and instructors according to industry demand, and the rule regarding university teaching certification will no longer be mandatory. In addition, recruitment of instructors will be decided by an “industry-university association” and will not be influenced by a teacher evaluation committee. The institute will also have the right to confer degrees to research institute personnel. In terms of finances, institutes will have autonomous organizing and budgeting authority, and can freely adjust students’ tuition fees. Institutes are also free from many legal restrictions on the management and procurement of property, and can provide research assets to companies for development and management. In addition, the income from institutes’ research results is allocated in proportion to the salaries of professors, and the costs of equipment and maintenance of the university.

Companies entering the realm of universities certainly strengthens the links between industry and academia, accelerates the development of human resources in the key industrial fields where they are actually needed, and solves the problem of a shortage of top talent. However, this approach also raises a new issue of increasing corporate control over university development and undermining universities’ autonomy. Even if the aforementioned problems were not as significant as they may seem, industry-university associations have only a limited ability to oversee the institute, and since the potential technological capabilities of the companies cannot be clearly evaluated, there is a possibility that companies with sufficient funds but no promising technologies will participate in a research institute. In addition, the inability of companies that have promising technologies but do not have sufficient funds to participate may make it difficult for these institutes to achieve the goal of cultivating top-tier R&D personnel and cutting-edge technologies. Therefore, while this initiative has positive aspects, its operating model still has some issues that need to be addressed, and its actual effectiveness needs to be monitored continuously going forward.

In conclusion, the concept that led to the establishment of recent university-industry collaboration programs and regulations is to bring the R&D capabilities of academia into industry in order to support the further development of industrial technology. And by bringing more industrial resources into the academic sphere, academia can use these abundant resources to support promising, deep, and diverse R&D, and in the process, cultivate high-quality R&D talent in key fields at the same time. The government’s role in terms of funding is to provide the necessary funds in the early stages of university-industry collaboration through the utilization of these programs, so that both industry and academia can smoothly navigate the uncertain first half of the R&D phase, when the effects of R&D are uncertain. In addition, if academia’s R&D capacity is improved in subsequent phases and industry is able to stably generate R&D effects, the government subsidies can be gradually reduced in providing R&D investment, eventually forming a self-sustaining industry-academia collaboration model. On the regulatory side, the government should identify the current demands of industry and academia along with the regulations that impose restrictions in the process of industry-academia collaboration, and at the same time, in consideration of the impact of regulatory adjustments, begin trials of small-scale regulatory adjustments and establish relevant organizations to realize the goals.

2.7 Challenges in the Implementation of National Science and Technology Plans

Based on the evaluations in the 2020 and 2021 Legislative Yuan budget center reports on the National Science and Technology Plan for 2017-2020 and the results of interviews with senior officials of various departments of the Ministry of Science and Technology, the following four main challenges were identified with regard to the execution of Taiwan's National Science and Technology Plan in recent years. (1) Effective metrics for the outcomes of S&T projects have not been established; (2) the degree of integration of S&T project execution by each agency is insufficient; (3) the effects of collaborative industry-academia projects on industry are insufficient; and (4) there is a lack of rational evaluation and feedback mechanisms. These challenges are explained below.

(1) Effective metrics for the outcomes of S&T projects have not been established

According to the results of the evaluation and the interviews with senior officials, the Taiwanese authorities have not set optimal metrics to evaluate the outcomes of the relevant S&T development plans. Since many planning indicators are set by the agencies as OKRs (objectives and key results) for the plans they are in charge of, in situations where effective supervision and management mechanisms are lacking, the indicators set by each agency, which are based on standard conventional outcome metrics, are used. Examples include "number of projects subsidized by relevant agencies," "number of personnel and research teams trained," "number of papers and related reports published," and "number of promotional activities conducted." However, due to the low level of difficulty in achieving these metrics and their low relevance to the long-term effects of the plans, many plans have achieved the targets that were initially set by the agencies, but have failed to produce good outcomes, and the primary objectives of the Taiwanese authorities have not been realized.

The report notes that industrial technology development plans are currently being evaluated in terms of metrics such as "number of papers published" and "number of patent applications," but in the future, agencies should be asked to increase the number of metrics that relate to specific revenue generated and actual benefits to industry, such as "patent utilization rate," metrics related to "industrial service vitality," and "monetary amount of technology transfer" to ensure that the effects of the plan serve to promote industrial development. In addition, for social development plans, the relevant agencies should set quantitative indicators for the actual needs of important social groups in the plan objectives that relate directly to their well-being.

(2) The degree of integration of S&T project execution by each agency is insufficient

According to the results of the evaluation and the interviews with senior officials, government agencies do not have a sufficient degree of integration when implementing the same type of plan. The operational approach of many S&T programs is based on the long-term strategic policy submitted by the Office of the President and the Executive Yuan, with various agencies sharing responsibility for projects in different phases of technology R&D and social implementation. For instance, the Ministry of Science and Technology is mainly in charge of basic and applied research, focusing on work at TRL (technology readiness levels) 1-5. In addition, research-oriented administrative agencies (Industrial Technology Research Institute, National Science and Technology Center for Disaster Reduction, etc.) under each agency focus on applied research and technological development in accordance with to the needs of the agency in charge, and are responsible for operations at TRL 5-9. Finally, each agency and the executive bodies under it are responsible for the implementation of the relevant policies in society. This kind of implementation system also ensures that there is a relevant organization in charge of the corresponding tasks in each process of social implementation or industrial development of its own technology R&D, and that there are relevant KPIs to ensure the completion of the tasks at each stage. However, there are challenges, such as the inability to effectively continue the same type of plan and ensure that it stays relevant.

Since all plans and tasks are carried out separately by each agency, and plans are implemented based on long-term organizational goals, even though the overall vision is the same, agencies do not properly communicate with each other, and S&T budget allocation and management authority is mostly determined by each agency on its own. As a result, problems such as lack of impetus, duplicated investment, inefficient execution, and lack of continuity can easily arise in "top-down" type S&T plans. For example, the reality is that in quite a few cases, basic technologies researched and developed under Ministry of Science and Technology plans are lost with the end of the plans, and subsequently the development and commercialization of these technologies are taken over by related agencies or industries. On the other hand, in the process of executing policies, the organizations doing so are often faced with the challenge of not being able to grasp the current technological capabilities and lack the necessary degree of technological development. Overall, the problem is that although the policy vision is the same, the organizational goals at the various agencies are different and budgetary resources are dispersed. As a result, when implementing related plans, horizontal links lack support for mutual exchange of resources, while vertical links lack the feedback necessary for continuity of work and actual technological development, leading to a lack of critical resources in the process of implementing the plan, and stagnation of the plan, creating a gap between the direction of R&D and actual demand. In addition, after a plan is executed, the plan is sometimes terminated due to lack of support from other agencies.

In order to resolve the issues described above, senior officials at the Ministry of Science and Technology say that the Taiwanese authorities should strengthen the integration of "top-down" type S&T plans, ensure that each agency and plan is implemented under the same framework, and strengthen cooperation among all parties involved. In addition, the report also notes that the comprehensive evaluation mechanism for the outcomes of collaborative industry-academia research plans should be strengthened, the subsequent results of technologies and new projects produced by the plans should be continuously tracked using relevant metrics, and feedback should be provided in order to shape the direction for future policy implementation plans.

(3) The effects of collaborative industry-academia projects on industry are insufficient

With regard to this issue, the report indicates that although many S&T plans already incorporate the concept of technology readiness level (TRLs) and apply them in the plan implementation, in many cases the concept of MRLs (manufacturing readiness levels) has not been taken into account, resulting in the quality and progress of many technological developments lagging behind international standards and failing to meet actual demand in manufacturing or other industries. Meanwhile, the direction of R&D that has been implemented for some time does not factor in an overall strategic plan for future commercial application, resulting in many technologies created in S&T programs reaching the TRL 5-7 stage but not being effectively promoted, despite the fact that many have the potential for commercialization, or due to the limitations of the technology itself and constraints related to actual market demand, the technology is not developed to the later stages of TRL and is not commercialized.

In other words, the Taiwanese authorities have been implementing a number of programs for industry-academia collaboration to promote industrial development, harnessing the expertise and technology of academia and applying them in industry. However, in the actual implementation of these plans, excessive emphasis has been placed on technological development goals rather than the goal of industrial application of technology, resulting in a situation in which some technologies fail to bring benefits to industry after their research and development. In the case of green energy, which the Taiwanese authorities have placed great emphasis on in recent years as one of the “5+2 Industries”and “Six Core Strategic Industries,” the valid indicators of many related R&D plans have been set as “technology transfer grants” and “number of patents,” which are related to university-industry collaboration and technology transfer. However, these metrics have little relevance to the Taiwanese authorities’ green energy development goals of energy conservation, energy creation, energy storage, system integration, and industrial development through green energy. In addition, according to the report, many technologies related to solar power generation, energy storage systems, and batteries for power storage may not reach the final TRL stage, and budgetary resources are occupied by plans without scientific and technological capabilities.

To address these issues, the report suggests that before initiating R&D plans, relevant management agencies should first formulate a plan with an “R&D to commercialization” roadmap, and infer the appropriate R&D direction and process based on the final demand for commercialization. At the same time, a plan for exit mechanisms should be prepared, and R&D for unattainable technological development goals should be halted to ensure the effectiveness of fund distribution.

(4) There is a lack of rational evaluation and feedback mechanisms

According to interviews with senior officials of the Ministry of Science and Technology, many MOST-led plans are aimed at promising basic research and long-term human resource development, and do not produce results immediately after resources are invested. Therefore, it is difficult to calculate the time required for the effects of implanting such plans to appear, and it is also difficult to quantify and evaluate the outcomes. As a result, there is a lack of valid criteria for evaluating plan outcomes, appropriate pre-, mid-, and post-implementation evaluation models, and mechanisms for providing feedback on evaluation results for the next program’s cost allocation. However, since the budget rules related to science and technology state that “plans must produce results for verification,” it is difficult to continue plans that were invested in but have yet to produce results, and coupled with the problems of changes in policy directions and indicators due to changes of administration, the situation does not lend itself to effective implementation and management of science and technology plans. This has also been a factor in the gradual shift of science and technology policy toward industrialization in recent years, and in the declining ratio of basic research expenditures.

3 Basic Research Trends

3.1 Research Methodology

The analytical framework for basic research trends in Taiwan (Figure 3-1) is broadly divided into two main sections.

The first is an analysis of the status of basic research investment. This consists of an analysis of the current growth of basic research investment as a whole based on various R&D investment metrics, and also clarifies the current strength and direction of government support for basic research through an analysis of relevant government policies. In addition, the Government Research Bulletin (GRB) is used to analyze data on specific R&D areas to provide a better understanding of where Taiwan's investment in basic research is concentrated.

Next, an analysis of basic research outputs was conducted in collaboration with a team from National Taiwan University in which the ESI and Web of Science databases were used to conduct a detailed analysis of scientific fields (including international coauthored papers) in which Taiwan has strengths in basic research. In addition, using appropriate selection criteria, leading research institutions and notable researchers in each field with outstanding basic research achievements were identified, and on-site interviews were conducted with scholars and experts to understand current research directions and challenges, and explore opportunities for collaborative research with Japan.

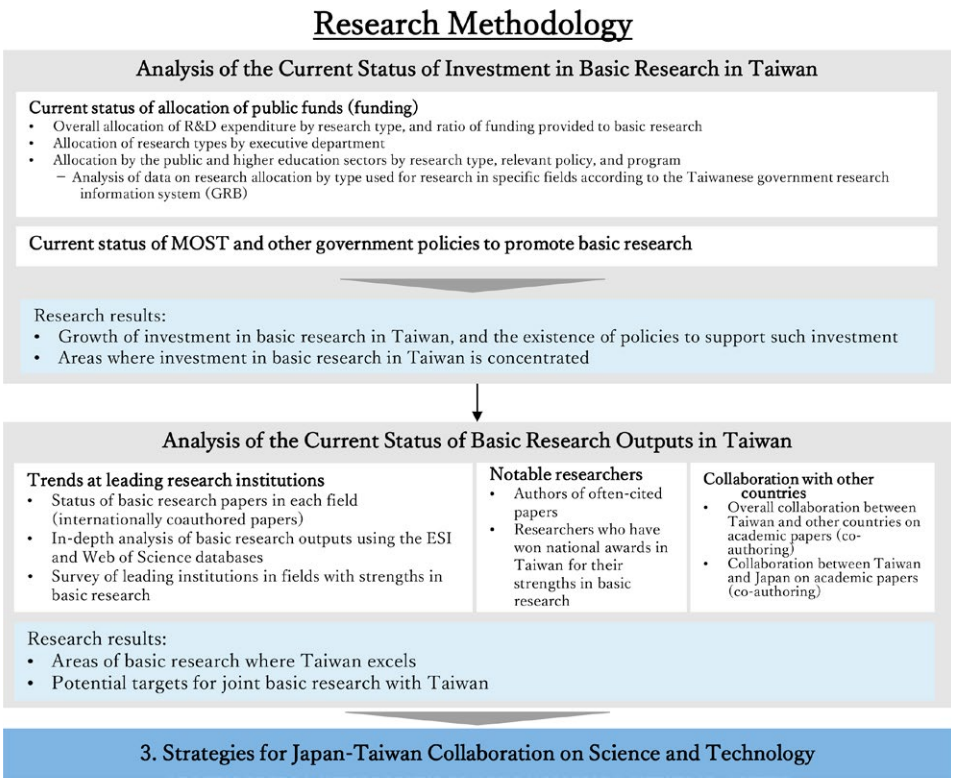


Fig. 3-1 Overview and Method of Research and Analysis for "Basic Research Trends"

(Figure created by the authors)

3.2 Current Status of Policies to Promote Basic Research

In order to strengthen the innovative development of basic research and develop outstanding research talent, the Taiwanese authorities have launched a series of basic research support programs designed in accordance with the state and purpose of the basic research and the eligible recipients of the support (qualifying age, academic track record), aiming to cultivate basic research human resources and facilitate advancements in pioneering research.

3.2.1 Development of Talent for Basic Research Programs

Many basic research programs in Taiwan are primarily aimed at groundbreaking basic research and human resource development. With the passage of time, the form of assistance and targets of Taiwan's basic research programs have changed. In the past, the main form of basic research programs was the "general specialized subject research program" that did not specifically limit the research area. In recent years, however, Taiwan has enacted a number of basic research grant programs that differ from the past, mainly targeting young scholars and supporting top-level young researchers to conduct groundbreaking scientific and technological research by providing sufficient funding support over a long period of time. Examples include the Einstein Program and the Columbus Program, launched in 2018, and the Shackleton Program, launched in 2019.

While the main goal of both the Einstein Program and the Columbus Program is to develop young basic researchers, the methodology for awarding grants differs between the two programs. The Einstein Program emphasizes innovation and originality in research and development, and targets postdoctoral fellows under the age of 32. Researchers are also required to put together multidisciplinary research teams based on their research goals to address important unresolved problems in science or society, plan R&D projects, and conduct innovative research through the research team that is not limited to scientific fields. The plan provides each research project with a grant of 5 million TWD (21.5 million yen, at a rate of 4.3 yen per TWD) each year, and in principle 50 projects are eligible to receive the grant each year. Meanwhile, the Columbus Program emphasizes the importance and originality of research on unresolved problems in science and society, as well as the exchange and cooperation between the researchers and overseas laboratories or research centers. To be eligible for the grants, the applicant must hold a doctorate degree, be under 35 years of age and must have held an important position in an international academic society or international professional society. The program provides grants of 10 million TWD (43 million yen) per year for each research project, and in principle, 30 projects are eligible to receive the grant each year.

On the other hand, the main purpose for the enactment of the Shackleton Program is to encourage outstanding scholars to lead research teams to push the limits of science and technology by providing sufficient financial support over a long period, to foster internationally acclaimed research teams, strengthening the international influence of Taiwan's science and technology. The program mainly targets researchers who are under 45 years old, have won international honors in the past (official overseas medals, international journal editorships, and international awards for excellence in scholarly contributions), and whose research achievements are very outstanding. The program provides grants of 15 million TWD (64.5 million yen) per year for each research project, and in principle, 15 projects are eligible for the grant each year.

The general specialized subject research programs enacted in the past subsidized individual researchers, and were based on a model in which small grants were awarded to a large number of projects. In contrast, the newly enacted programs of the past few years tend to provide larger grants to a smaller number of projects, and emphasize research team development and plan direction. This shows that the Taiwanese authorities recognize that it is more advantageous for groundbreaking scientific and technological research to concentrate R&D resources on exceptionally talented researchers, to set up scientific research personnel and research teams, and to provide these researchers with long-term, stable, and sufficient research resources.

The aforementioned Einstein Program and Columbus Program faced many challenges in the process of implementation. For example, many scholars at the time questioned the programs' age limits. Many scholars were already over the age limit by the time they had completed their doctoral studies and obtained their teaching credentials, and as such the actual number of qualified candidates was quite small, which resulted in the actual effectiveness of these two programs being low. Many other excellent research results were produced by the "middle generation" of researchers with extensive research experience and a steady stream of publications, and not by the "new generation"of researchers who were the target of this program's grants. In addition, because the Taiwanese authorities were attempting to implement these programs only with new generation researchers at the time, it may have led to a lack of support from middle generation researchers, reducing the effectiveness of the final research outputs. Moreover, the grant funds for these programs came out of the special budget for the Forward-Looking Infrastructure Development Program, which was inadvisable for cultivating young scientific researchers because the subsidy expenditure was not stable depending on the annual budget.

In order to solve these problems, the Ministry of Science and Technology merged the three existing programs, revised the eligibility and method of providing grants, and submitted the 2030 Cross-Generation Young Scholars Program in 2021. Unlike the past programs, this grant funds for this program come from a stable general science and technology budget, allowing young scientific research personnel to obtain sufficient long-term funding to conduct their research. In addition, the program has relaxed the age and background restrictions on applications, giving more researchers the opportunity to apply. The program's grant recipients are divided into three types: emerging young scholars, excellent young scholars, and international outstanding young scholars. The differences among the three types are primarily in the required qualifications for application, grant expenditure, and method of support (see Table 3-1 below for details).

However, some researchers have advised against the 2030 Cross-Generation Young Scholars Program. For example, in the current Ministry of Science and Technology talent development plan for basic research, the number of researchers aged 50-60 is quite small and they are being ignored, even though the research capabilities of researchers in that age group are at the peak of their lives. There is also the concern that the program's stipulation that "a researcher who receives a grant through this program may not apply for a grant through another program at the same time" restricts opportunities for young researchers to collaborate with researchers involved in other programs and fields. There is also the issue that after the program ends, the researcher may face a situation where he or she has to discontinue the research assistance because of possible problems in linking to another grant program. In response, the Ministry of Science and Technology responded that it will readjust the program content in the future to ensure that all scholars "between 30 and 60 years old, from average to excellent" receive the most appropriate program support.

Table 3-1 Details of 2030 Cross-Generation Young Scholars Program Grants

Scope of grant eligibility	Emerging young scholars	Excellent young scholars	International outstanding young scholars
Age limit	None	Under 45 years old	Under 45 years old
Required qualifications	Academic background of 5 years or less, or within 5 years of earning their Ph.D.	Holder of MC qualification for MOST research programs	Must already have an independent research team at home or abroad and have participated in international teams, etc.
Grant expenditure	5 million TWD annually (21.5 million yen, at a rate of 1 TWD = 4.3 JPY j	–	10 million TWD annually (43 million yen, at a rate of 1 TWD = 4.3 JPY)
Number of grants	25 a year	To be determined on the basis of grant screening results	15 a year
Total expenditure	1.8 billion TWD (7.74 billion yen, at a rate of 1 TWD = 4.3 JPY)		

Source: Official website of the Ministry of Science and Technology (Table created by the authors)

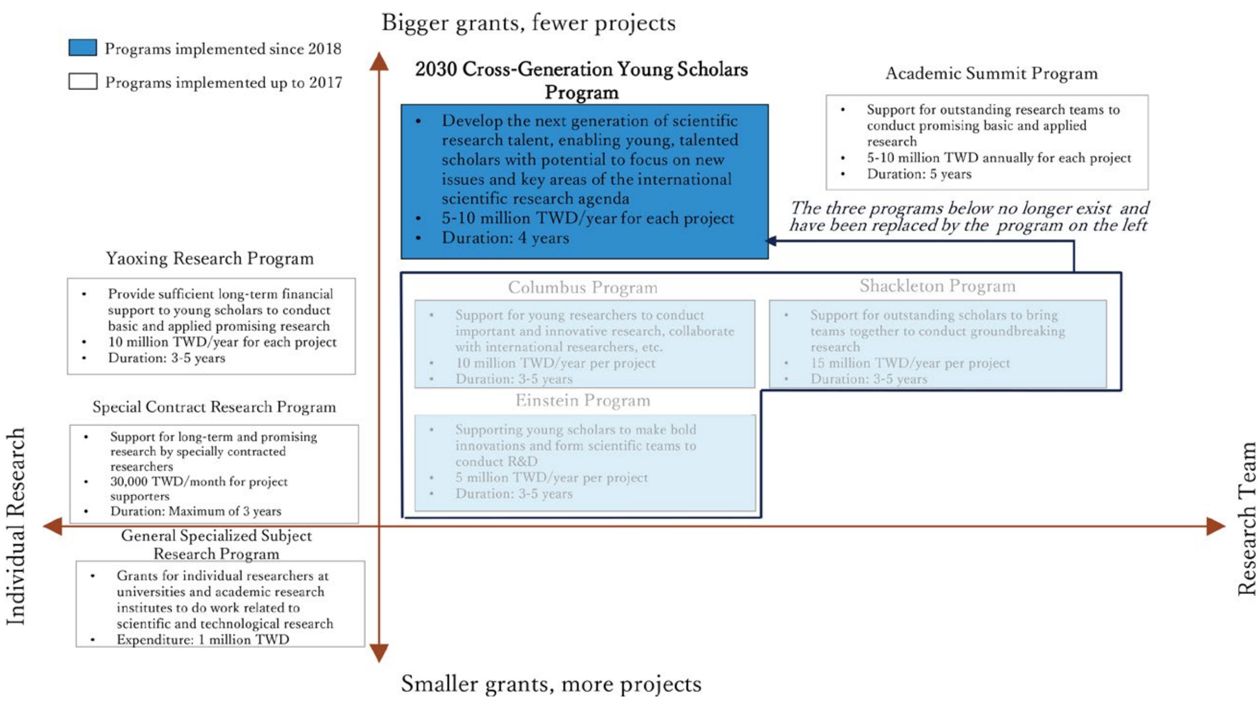


Fig. 3-2 Overview of Basic Research Programs

Source: Official website of the Ministry of Science and Technology (Figure created by the authors)

3.2.2 Technology Research and Development for Basic Research Programs

In addition to basic research programs that focus on developing human resources, Taiwan has basic research programs in many important scientific fields. The following is a description of representative programs.

(1) Angstrom Semiconductor Initiative (an angstrom (Å) is equal to 0.1 nanometer)

Semiconductors represent an extremely important industry for Taiwan. According to Taiwan Semiconductor Industry

Association (TSLA) statistics, Taiwan's semiconductor industry had a production value of 148 billion USD in 2021, accounting for 17% of Taiwan's GDP. In addition, the demand for semiconductors will continue to grow due to continuous advancements in big data, AI, and IoT. Considering the importance of the semiconductor industry as a driver of Taiwan's economy and the future potential of the semiconductor industry, the Ministry of Science and Technology established the Angstrom Semiconductor Initiative in September 2020, aiming to solve the current challenges of semiconductor technology and continue Taiwan's leading position in the semiconductor industry. A current issue for semiconductor technology is the possibility that developments in chip miniaturization may have already reached a physical limit, and it is uncertain whether the technology can continue to be developed further in the future. If significant progress is not made in the technology, future semiconductor technology will not be able to further reduce power consumption per unit, and as a result, various computation needs will not be met and the manufacturing cost will not be reduced. This means that semiconductor manufacturers will be less willing to invest, and the energy driving the development of the semiconductor industry will disappear.

This program is part of the Six Core Strategic Industries, and its main objectives are to promote early-stage research on the equipment, materials, and state-of-the-art process testing technologies that Taiwan's semiconductor industry will need over the next decade, and to find solutions for the key problems facing the latest semiconductor industry technologies by 2030. There are two specific R&D directions: Angstrom-scale key semiconductor detector technology, and development of key technologies for sub-nanometer semiconductor parts and chips.

The program description points out that there are currently no solutions for the physical limitations of developing sub-nanometer semiconductor technologies, and the academic community is encouraged to propose out-of-the-box solutions unlike any existing technologies. In addition, considering the program's high-risk nature, the method of evaluating its results will not be limited to whether the quantified technology standards presented by the program have been achieved, but will instead use many technology-related indicators in order to maintain flexibility in the R&D process, so that many R&D routes can be secured when necessary and can proceed simultaneously. In terms of expenditure, the program provides each research project with 25 million TWD (107.5 million yen) in research funding each year for a total of four years (November 2021-October 2025). As for the requirements for R&D proposals, the Ministry of Science and Technology will require points such as the relationship between the proposal and the technological standards in the program's goals, a projected technological development plan for each year, how the technology will be applied to industry, the basis of the technological theory, and a distribution plan for key patents.

(2) R&D Program for Critical Technology for Next-Generation Telecommunications Systems

Considering the revolutionary technological changes that the advent of 6G (sixth generation technical standard for wireless communications) will usher in, such as high-speed transmission, wide-area coverage, and multi-functional communications, Taiwan is following the international R&D schedule for B5G (beyond 5G) and 6G, aiming to research and develop promising B5G/6G technologies that will be needed in Taiwan's future telecommunications industry. The program calls for early-stage research on innovative 6G technologies to develop the advanced technologies needed in the competition for international 6G standardization in 2025, cooperate with international 6G R&D teams, and continue to participate in 3GPP telecommunications standardization activities to boost Taiwan's international influence in the telecommunications sector, while also developing the next generation of telecommunications science and technology R&D talent. The program provides each project with annual funding of

10 million TWD (43 million yen) for a total of four years (June 2021-May 2025). The main direction of R&D is "R&D of promising technologies for B5G/6G," which will include wireless and antenna technology, telecommunication and transmission technology, network technology, and communication software. Another direction is "participation in conferences on 3GPP standards and related research."

(3) Executive Yuan New-Generation Quantum Phase –Academia Sinica's Quantum Science Research Base

Given the fact that countries around the world have been investing heavily in the research and development of quantum science and technology, along with dramatic advancements in the field in the last few years, it is clear that quantum computers with vast computing power could have a significant impact on areas such as information security, finance, and national security. In response to these issues, the Executive Yuan, together with Academia Sinica, the Ministry of Science and Technology, the Ministry of Economic Affairs, and other agencies, has formed a project team for quantum development in Taiwan, and will invest 8 billion TWD (34.4 billion yen) over the next five years (2022-2026) and build a quantum research base in Shalun Science Park in Tainan. The objectives and strategy of this policy is to collaborate with Academia Sinica to build a core facility for state-of-the-art R&D and advanced manufacturing lab at the base in Tainan, to strengthen the integration of Taiwan's quantum technology talent and resources, to eliminate the software/hardware roadblocks Taiwan is currently facing in quantum technology R&D, and to develop a multidisciplinary quantum technology research base.

With regard to hardware for quantum computers and quantum communication technology, Taiwan is focusing its efforts on quantum materials, quantum bits (qubits), cryoelectronic circuit systems, quantum optics and detectors, and chips for quantum communication. As for software technology, Taiwan will establish a joint development platform to develop quantum algorithms, quantum software design, and quantum encryption and a quantum communication protocol. In addition, the Ministry of Science and Technology, in cooperation with the Ministry of Economic Affairs, plans to establish a platform for exchanges with local industries, and is also planning to leverage the strengths of the semiconductor industry and other sectors to develop key parts for quantum devices. Ultimately, Taiwan hopes to establish an important position in the global quantum science and technology industry in 2030.

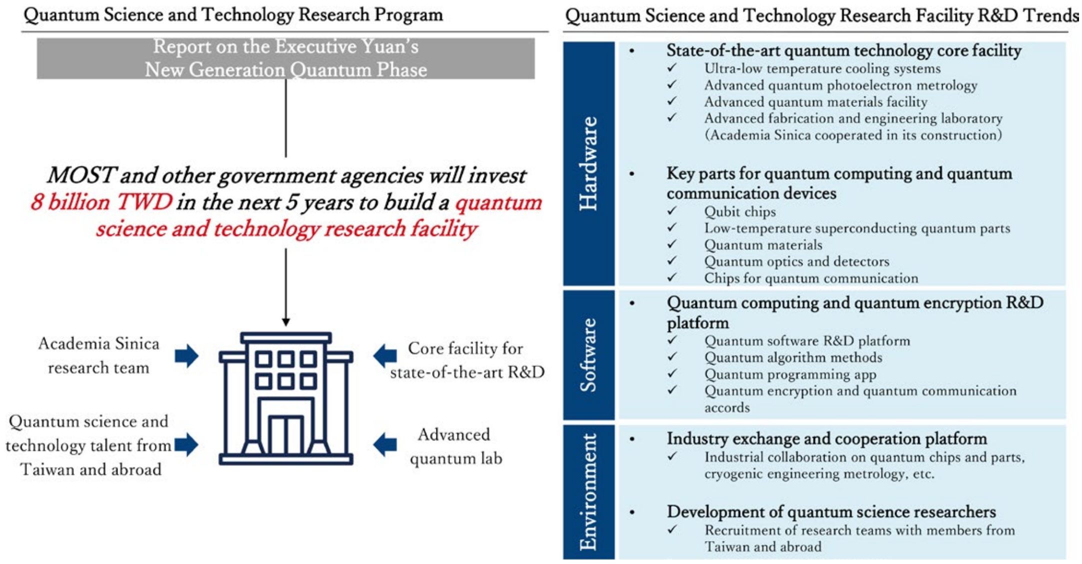


Fig. 3-3 Taiwan's Quantum Science and Technology R&D Program

Source: Official website of the Ministry of Science and Technology (Figure created by the authors)

Taiwan's programs for basic research through technological development mainly focus on key development fields/industries with high future growth potential. Looking at the relevant basic research in recent years, the technology fields expected to develop further through the programs are semiconductors, green energy, telecommunications, quantum, humanities and social sciences, AI, cybersecurity, virtual reality integration, human-machine collaboration, and defense, as well as Taiwan's 5+2 Industries, and it can be seen there is a strong link to the key fields specified in the Six Core Strategic Industries. As such, going forward the Taiwanese authorities are expected to launch more basic research programs for science and technology development centered on these important industries. Meanwhile, the annual subsidy expenditure for each program will be determined by the degree of importance the authorities attach to the development of the technology, which is related to the future application potential of the technology and the opportunity for Taiwanese industry to take control of the technology. The latter impacts the current technology development base of Taiwanese industry, and the annual subsidized expenditures per project for each of the aforementioned programs are highest for semiconductors, green energy, and telecommunications, at 25 million, 15 million, and 10 million TWD per year, respectively (corresponding to 107.5 million, 64.5 million, and 43 million yen respectively). All other programs are budgeted for under 8 million TWD a year (34.4 million yen), indicating that not only is there ample potential for future technological development in these three fields, but also that Taiwan has many basic areas of industrial technological development.

3.3 Current Status of Allocation of Public Funds (Funding)

3.3.1 Overall Allocation of Basic Research Expenditure

(1) Trends in Basic Research Expenditure

As shown in Figure 3-4, in Taiwan, basic research receives the smallest ratio of funding among the three types of R&D (basic research, applied research, and technology development), decreasing from 10.5% in 2010 to 7.0% in 2019.

In addition, Taiwan's ratio of investment in basic research is well below the international level when compared to the ratios overseas. Furthermore, a breakdown of R&D expenditures by sector in 2019 (Fig. 3-5) shows that the corporate sector hardly invests in basic research at all, accounting for only 8.6% of the total, while public research institutions and the higher education sector are the main performers of basic research, accounting for nearly 91%.

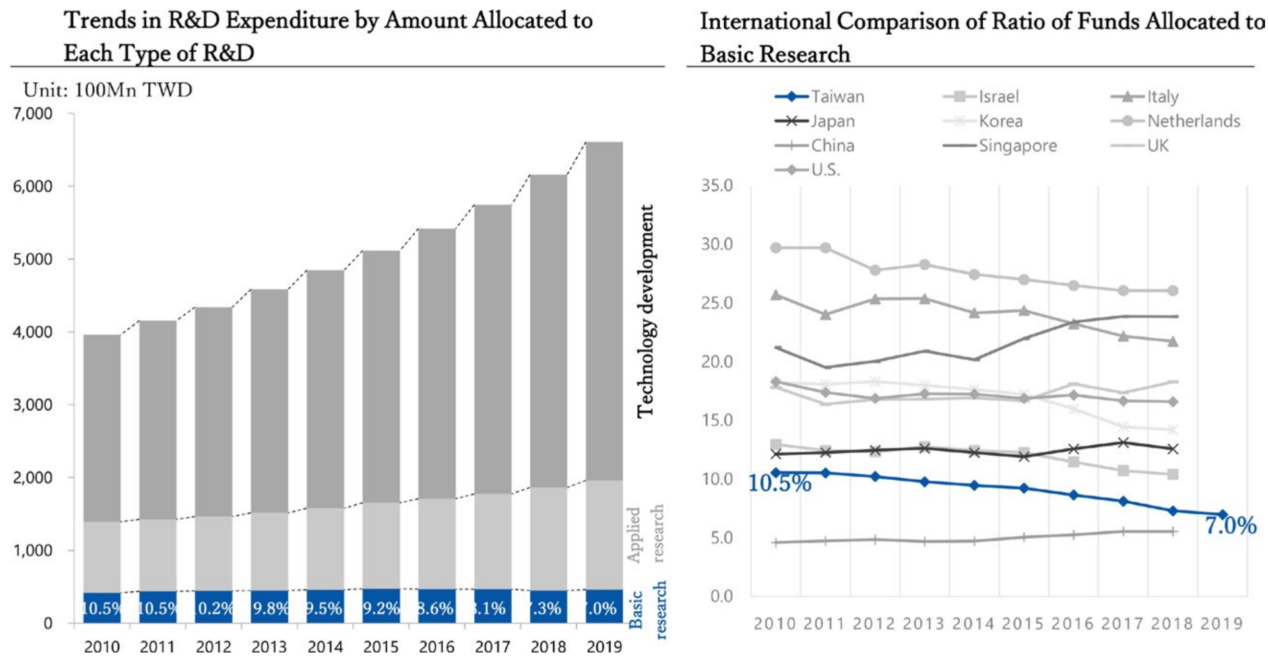


Fig. 3-4 Ratio of Funds Allocated to R&D in Taiwan and International Comparison

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

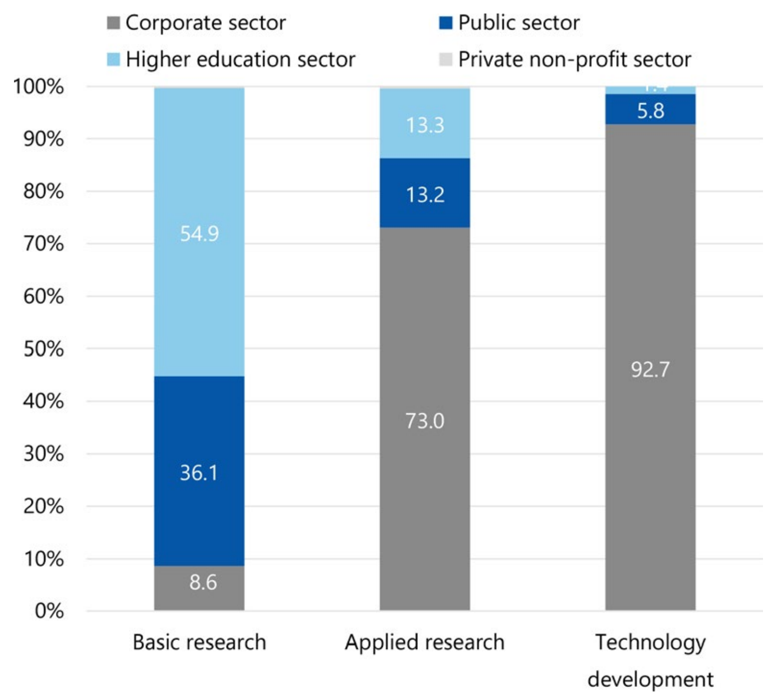


Fig. 3-5 Allocation of R&D Expenditure by Sector (2019)

Source: Taiwan "Statistical Abstract on Science and Technology" (Figure created by the authors)

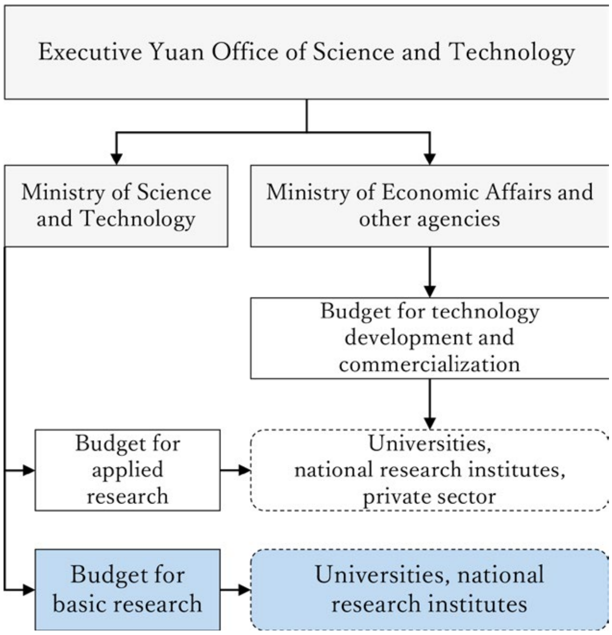


Fig. 3-6 Mechanism for Allocation of Public Funds for Science and Technology

Source: Taiwan "White Paper on Science and Technology" (Figure created by the authors)

(2) Investment in Basic Research by the Public Sector and the Higher Education Sector

Figure 3-7 shows that the amount of investment in basic research by the public sector and the higher education sector in Taiwan was increasing from 2010 to 2015, but the ratio of investment in basic research by both sectors declined significantly after 2016. The main reason for this is that the recent government policy of strengthening industry-academia collaboration has resulted in the launch of many collaborative industry-academia projects to promote the application of university and research institution technologies in industry. As a result, part of the budget for basic research has been transferred to technology development.

However, the Taiwanese authorities are also aware of the problem of insufficient investment in basic research, and have introduced a basic research support program aimed at increasing the ratio of basic research expenditures to at least 10% of total research expenditures over the next five years.

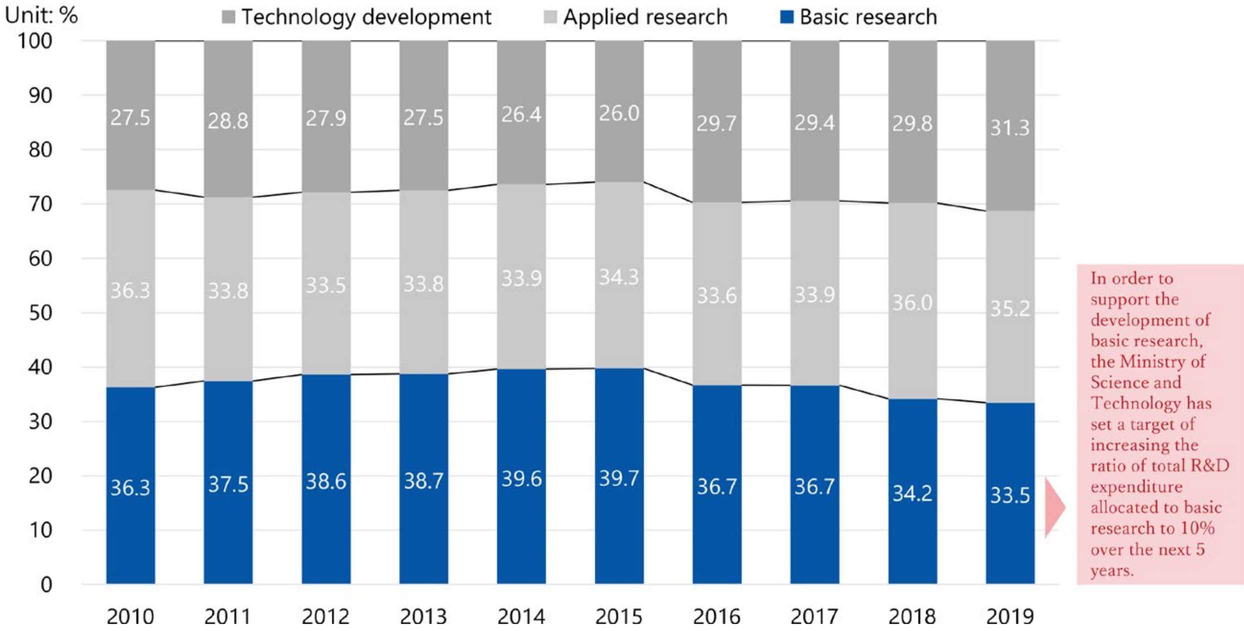


Fig. 3-7 Changes in the Ratio of R&D Expenditure in the Public and Higher Education Sectors

Source: Taiwan "Statistical Abstract on Science and Technology," (Figure created by the authors)
Official website of the Ministry of Science and Technology (Figure created by the authors)

3.3.2 Status of the Government's Management of Basic Research Funds

The following section uses the Government Research Bulletin (GRB), a government information system established by the Ministry of Science and Technology, to provide information on the Taiwanese government's investment in the academic research sector over the last five years (2017-2021), broken down into the six major fields defined by the GRB database (science, engineering, medicine, agriculture, humanities, and social sciences). An analysis was also performed for the top three fields in each of the six major fields.

(1) Number of Basic Research Projects

Looking at the changes in the number of basic research projects (Table 3-2) in the six major fields over the past five years, the number of projects as a whole has been growing year by year, but dropped sharply in 2021. In terms of individual fields, science, medicine, and engineering have been the top three fields every year, with science ranking first in 2017 and numbering over 2,000 projects each year. Next is the field of medicine, which was the basic research field with the largest number of projects in 2018-2021, with around 3,000 projects each year. Meanwhile, the field with the lowest number of planned projects each year is agriculture, with less than 500 projects.

Table 3-2 Number of Basic Research Projects in the Six Major Fields during 2017-2021

Six Major Fields	2017	2018	2019	2020	2021
Science	2,010	2,192	2,269	2,215	1,021
Engineering	1,530	1,750	2,041	1,303	1,126
Medicine	1,748	2,726	3,177	3,313	1,945
Social Studies	1,886	2,024	2,200	2,909	950
Humanities	1,177	1,128	1,234	1,277	539
Agriculture	292	327	371	413	233
Total	8,643	9,972	11,082	11,239	5,630

Notes: 1. Data was retrieved on January 20, 2022.
2. Calculation method: (a) Collaborative projects in different fields, calculated once in field A and once more in field B; total figures are calculated based on once. (b) All project numbers are taken from the GRB database. (c) Calculation method for basic research ratio is "number of basic research projects in the field/total number of research projects in the field."

Source: GRB database (Table created by the authors)

Looking at the number of research projects in the main subfields for basic research (Figure 3-8), clinical medicine and basic medicine in the medical field and linguistics in the humanities had the most projects. In the field of science, mathematics was the largest subfield in 2017, but lost its place to physics in 2018. In the field of engineering, IT and software had been the major subfield, but medical engineering had the most projects in 2021. Food science and technology continued to be the most common subfield in the field of agriculture in 2018, as residents of Taiwan have become more concerned about food safety in recent years. The social science fields of management and education have their own strengths, and both are relatively more prevalent.

Overall, clinical medicine has the largest number of research projects, followed by basic medicine. Note that in 2021, the number of projects decreased in almost all basic research subfields, and only medical engineering increased. This indicates that medical engineering-related research was emphasized in the wake of COVID-19.

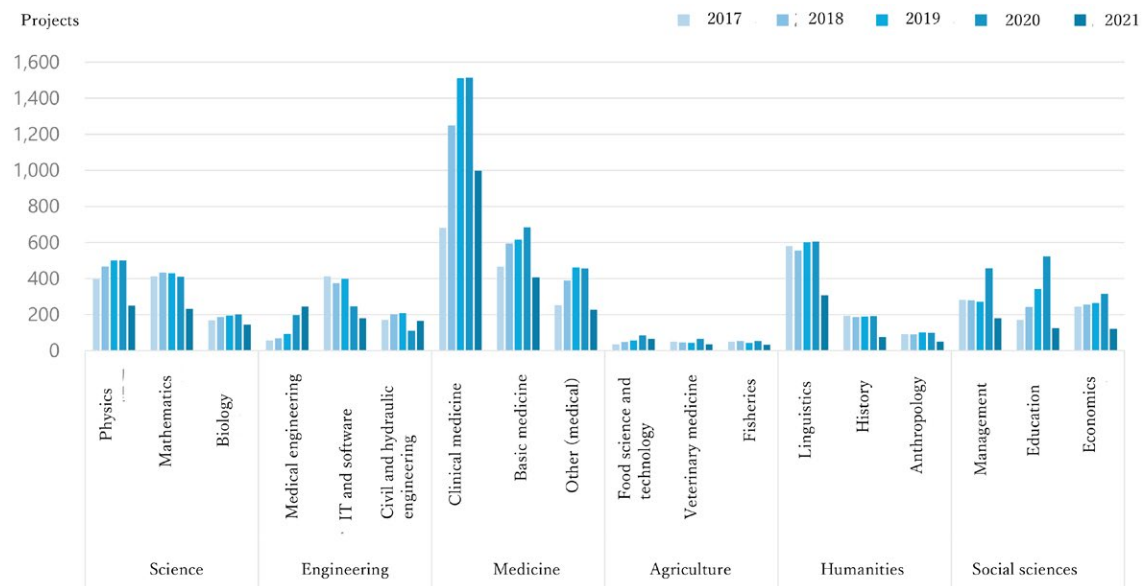


Fig. 3-8 Estimated Top 3 Fields in Number of Projects in Each Basic Research Subfield in 2017-2021

Notes: 1. Data was retrieved on January 20, 2022.
2. Calculation method: (a) Collaborative projects in different fields, calculated once in field A and once more in field B.
(b) All project numbers are taken from the GRB database.

Source: GRB database (Figure created by the authors)

(2) Basic Research Expenditures

Looking at the basic research expenditures in the six major fields (Figure 3-3), the most investments are made in the field of science each year, hovering around 10 billion TWD (43 billion yen) annually. The next two fields are engineering and medicine, with the engineering field showing the largest increase, with basic research expenditures in 2020 approximately double those of a year earlier. The lowest amount of expenditure is in agriculture and the humanities.

Fig. 3-3 Estimated Basic Research Expenditures in the Six Major Fields in 2017-2021 (10K TWD)

Six Major Fields	2017	2018	2019	2020	2021
Science	1,046,281	1,039,251	1,098,726	1,097,901	923,432
Engineering	319,423	370,460	422,771	883,403	861,190
Medicine	537,388	386,800	495,607	509,501	526,280
Social Studies	200,459	204,966	294,108	231,020	183,666
Humanities	74,828	80,162	85,650	98,789	35,515
Agriculture	79,045	82,947	98,349	102,859	83,252

Notes: 1. Data was retrieved on January 20, 2022.
2. Data calculation method: (a) Collaborative projects in different fields, calculated once in field A and once more in field B.
(b) Because the GRB database does not have statistical data on basic research expenditures for all fields, APRC calculated the estimate using the range of scales of GRB projects.
3. 1 TWD is roughly 4.3 JPY.

Source: GRB database (Figure created by the authors)

Basic research expenditures as a percentage of public research expenditures (Figure 3-9) are highest in the sciences, at 60-80%. The field of humanities is next, but the percentage dropped to just over 20% in 2021. The medical field has the second highest share of basic research from 2021, maintaining around 40-50% each year. The engineering field, on the other hand, is clearly dominated by applied research or technological development expenditures, with basic research accounting for a very small share, albeit showing significant growth in 2021, climbing to about 20%.

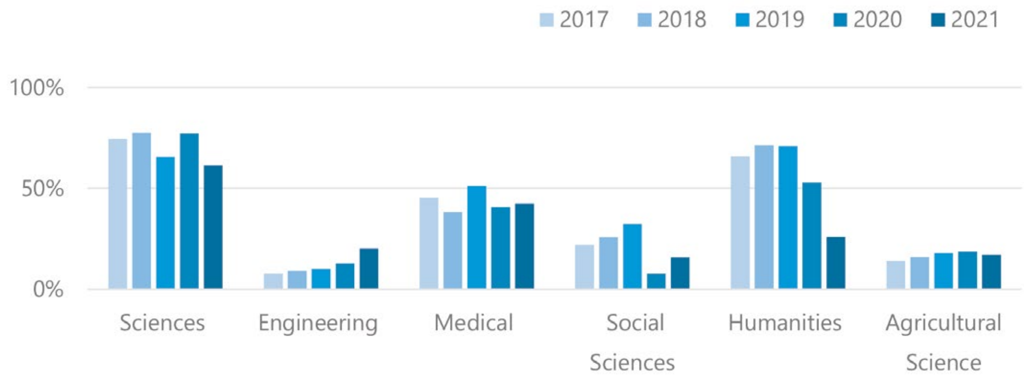


Fig. 3-9 Basic Research Expenditures in the Six Major Fields in 2017-2021 as a Percentage of Public Research Expenditures

Notes: 1. Data was retrieved on January 20, 2022.
2. Data calculation method: Collaborative projects in different fields, calculated once in field A and once more in field B.
3. Data adoption: Because the GRB database does not have statistical data on basic research expenditures for all fields, APRC calculated the estimate using the range of scales of GRB projects.

Source: GRB database (Figure created by the authors)

Looking at basic research expenditures by subfield (Figure 3-10), the largest research expenditures to date have been in the fields of biology and oceanography in the sciences, indicating that Taiwanese authorities are making long-term and continuous investments in basic research in these two research fields. The top three subfields in engineering are IT and software, electronics and electrical engineering, and optoelectronics, all of which shot up dramatically in 2021. This is related to the increased emphasis on semiconductors and information and telecommunications-related technologies in Taiwan's Six Core Strategic Industries.

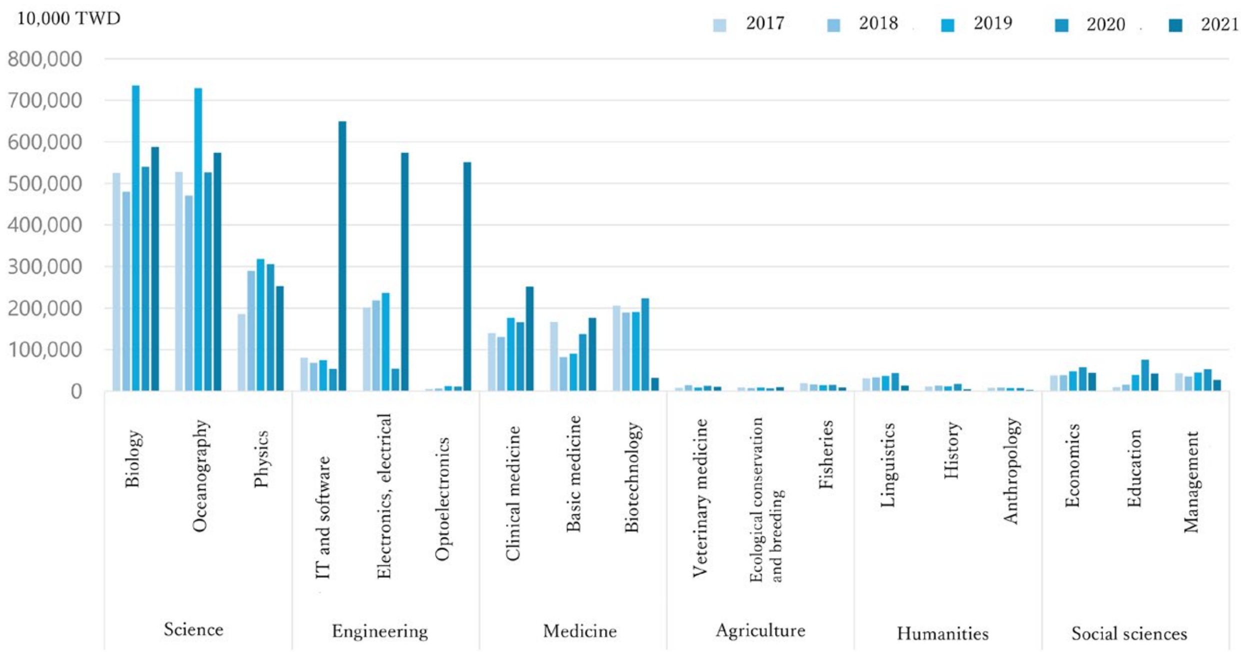


Fig. 3-10 Estimated Top 3 Fields in Expenditures in Basic Research Subfields in 2017-2021

Notes: 1. Data was retrieved on January 20, 2022.
2. Data calculation method: Collaborative projects in different fields, calculated once in field A and once more in field B.
3. Data adoption: Because the GRB database does not have statistical data on basic research expenditures for all fields, APRC calculated the estimate using the range of scales of GRB projects.

Source: GRB database (Figure created by the authors)

3.4 Status of Cooperation with Foreign Countries

3.4.1 Current Status of Taiwan's Cooperation with Foreign Countries in Basic Research

Based on the number of international co-authored papers shown in Table 3-4, the country with the most international academic cooperation in Taiwan in 2012 was the U.S. (12%), followed by China (11%) and then Israel (4%). In 2013, the U.S. and China each accounted for 12%, followed by Israel at 4%. Starting in 2014, China had the most cooperation with Taiwan, and the ratio has increased rapidly since. In particular, China accounted for about 30% of the total in 2020. The U.S. and China have the most active academic exchange with Taiwan, both accounting for over 10% of co-authored papers each year. Note that there is not much change in the percentages of countries other than China.

Table 3-4 Main Countries and Regions Collaborating with Taiwan on Academic Papers in 2012-2021

Year	1st		2nd		3rd		4th		5th	
	China		U.S.		Israel		Japan		UK	
	Number of papers	Ratio	Number of papers	Ratio	Number of papers	Ratio	Number of papers	Ratio	Number of papers	Ratio
2012	3,675	10.53%	4,136	11.86%	1,332	3.82%	1,179	3.38%	947	2.71%
2013	4,210	11.82%	4,318	12.13%	1,424	4.00%	1,126	3.16%	880	2.47%
2014	5,025	13.92%	4,507	12.48%	1,450	4.02%	1,060	2.94%	967	2.68%
2015	5,926	16.70%	4,773	13.45%	1,598	4.50%	1,273	3.59%	1,133	3.19%
2016	7,018	19.13%	5,012	13.66%	1,678	4.57%	1,463	3.99%	1,251	3.41%
2017	8,238	22.61%	5,244	14.39%	1,723	4.73%	1,642	4.51%	1,366	3.75%
2018	9,718	25.83%	5,516	14.66%	1,746	4.64%	1,759	4.68%	1,518	4.04%
2019	11,846	29.05%	6,028	14.78%	1,864	4.57%	1,968	4.83%	1,757	4.31%
2020	13,144	29.55%	6,147	13.82%	1,892	4.25%	2,209	4.97%	1,806	4.06%
2021	13,106	28.78%	5,876	12.90%	1,946	4.27%	2,047	4.50%	1,916	4.21%
Total	81,906	21.35%	51,557	13.44%	16,653	4.34%	15,726	4.10%	13,541	3.53%

Note: Listed in order of the number of papers in 2021.

Source: WOS database (Table created by the authors)

3.4.2 Taiwan's Joint Research Programs in Science and Technology with Other Countries

With the growing difficulty and scale of science and technology research and the gradual increase in the importance of international joint papers, the Ministry of Science and Technology has signed many agreements with overseas government agencies and scientific research institutions and implemented various programs for science and technology exchange in order to raise the level of Taiwan's science and technology. The share of total publications in Taiwan accounted for by international joint papers has increased from 19.0% in 2000-2004 to 41.1% in 2019, and has continued to climb in recent years. This indicates that international collaborative research in Taiwan has become increasingly important over time.

In response to this trend, Taiwan has been promoting joint research programs together with Japan. For example, Taiwan has recently been pursuing joint research with the National Institute for Materials Science (NIMS) in fields including functional materials, energy and environmental materials, magnetic and spin materials, quantum materials, structural materials, and the latest ICT and energy materials. Taiwan also collaborates with RIKEN (National Institute of Physical and Chemical Research) in the fields of precision machinery and medicine, biomedicine, next-generation compound semiconductors, applications of AI and social issues, and earth sciences such as those related to the SDGs.

In addition to cooperation with Japan, Taiwan has also implemented joint research programs in science and technology with other countries and regions, including China, the United States, the European Union, the United Kingdom, and France. The model for collaboration is that the Ministry of Science and Technology (MOST) and research institutions in these countries and regions sign a joint research agreement, formulate related plans, and then MOST solicits, reviews, and selects the implementers of the plans. The following is a list of the most recent joint research projects between Taiwan and other countries. The following is a list of recent joint research plans with major countries and regions. MOST then provides the research funds needed by the Taiwanese participants to initiate the science and technology joint research between Taiwan and other countries. The following is a list of recent joint research programs with major countries and regions.

Table 3-5 Taiwan's Joint Research Programs with Other Countries and Regions

Country or region	Cooperating Institutions or Programs	Program	Areas of Cooperation
China	Ministry of Science and Technology of the People's Republic of China	Cross-Strait Science and Technology Exchange	Disaster prevention, food safety, etc.
U.S.	National Science Foundation (NSF)	GEMT collaborative research program	Geoscience
Japan	National Institute for Materials Science (NIMS)	MOST-NIMS joints research program	Materials science
	RIKEN (Institute of Physical and Chemical Research)	MOST-RIKEN joint research program	Biomedical science, semiconductors, AI, etc.
Israel	Ministry of Innovation, Science, and Technology (IMST)	Taiwan-Israel joint research program	Digital medicine, aquaculture, marine biotechnology
UK	National Environment Research Council (NERC)	MOST-NERC joint research program	Natural environment
EU	EU Horizon Europe Program	International group science and technology innovation program enabling participation by non-EU countries	-
	EU NEURON Program	EU international joint neuroscience research program	Neuroscience

Source: Official website of the Ministry of Science and Technology (Table created by the authors)

3.5 Analysis of Basic Research Outputs in Taiwan and Direction for Japan-Taiwan Collaboration

3.5.1 Overall Outputs of Taiwan's Basic Research

With the implementation of the aforementioned basic research programs, Taiwan has produced a large number of international papers in various science and technology fields. The following is an analysis of the results of those papers using the ESI database to determine Taiwan's dominance in various fields of science and technology.

(1) Current Status of Basic Research Outputs

Basic research outputs were evaluated based on the quality and quantity of the papers. The quality of the papers has a strong relationship to the originality and impact of the final research results. Meanwhile, the number of papers has ramifications with respect to the repleteness of related research capabilities, for instance the ability to find appropriate partners for collaboration, to continue subsequent research successfully, and to explore opportunities for further expansion. Since both of these factors are important, the following section evaluates basic research outputs in each science and technology field in Taiwan by analyzing the quality and quantity of papers in field, broken down into "average number of papers cited" and "percentage of international papers published." (Supplementary explanation: The calculation method for the average number of citations of papers is "total number of citations of published papers/ total number of published papers" for the last 10 years, while the calculation method for percentage of international papers published is "total number of Taiwan-published papers/total number of international published papers" for the last 10 years.)

Using the above-described metrics for the quality and quantity of papers, 22 science and technology fields can be classified (plotted by the average value of each metric) to determine the science and technology fields in which Taiwan currently has an advantage and potential in R&D. First, the upper right-hand corner (quadrant 1) of the graph (Figure 3-11) below reveals that Taiwan has produced excellent basic research outputs in the fields of space science, materials science, physics, clinical medicine, and chemistry. The number of papers in these fields accounts for a large proportion of the number of international papers, and the average number of times papers are cited is also high. This means that there are many outstanding researchers in these fields, and these fields should be prioritized and strengthened in future international joint research.

Aside from the upper right, the lower right (quadrant 4) and upper left (quadrant 2) of the coordinates also show fields to pay attention to. Although these fields only fared well with one of the two evaluation metrics, they have sufficient R&D potential in themselves, given the continuous development of science and technology, and could well become dominant science and technology fields for Taiwan's R&D in the future, regardless of whether or not they receive continuous government or private subsidies or investments. Therefore, these fields can also be considered to be possible fields for collaboration that have R&D potential.

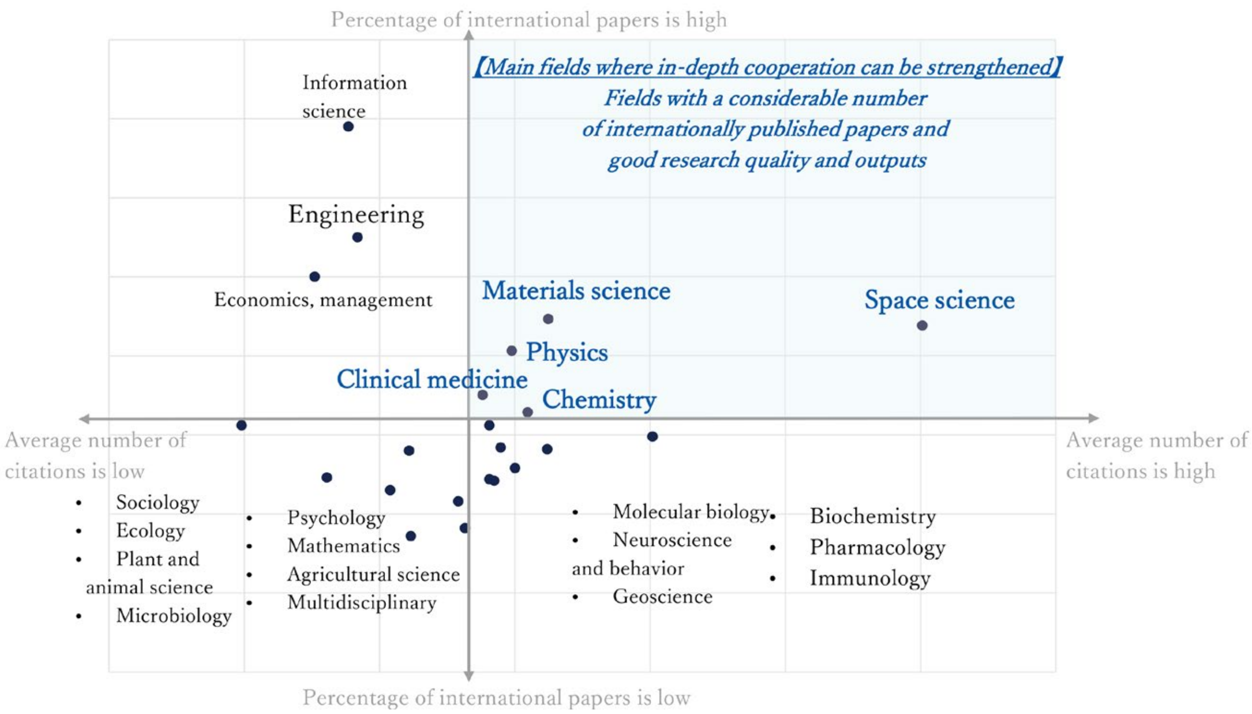


Fig. 3-11 Results of Analysis of Basic Research Outputs in Taiwan

Source: ESI database (Figure created by the authors)

(2) Public Sector Investments and the Impacts Produced by Science and Technology

As described previously, continuous investment by companies and the government in a particular scientific and technological field will lead to the development of research in that field and the generation of more and better research results. For those fields that have more mature R&D and sufficient research capacity, the field's own R&D potential is sufficient to continually encourage companies and the government to invest resources in these fields. These fields also raise the visibility of R&D by presenting academia-related industrial knowledge and R&D directions, and by guaranteeing future patenting and industrialization. Furthermore, by using the existing stable R&D infrastructure, many talented researchers are able to obtain sufficient research funds and invest them in research areas that have potential for future development, allowing them to conduct long-term, groundbreaking basic research, which will ultimately facilitate the improvement of the quality of publications in specific scientific and technological fields.

On the other hand, economic development impacts certain scientific and technological fields, and new technological issues worth studying will emerge. Government departments are increasingly willing to invest in these "new fields" that have not received much attention in the past, and are investing in technological research in these science and technology fields by enacting related policies. And while these science and technology fields are still in the early stages of development and do not have sufficient R&D potential, a large volume of social resources are being invested in them over long periods of time as support associated with the authorities' key field development policies. Relevant scientific and technological personnel are brought in to participate in R&D programs related to these emerging fields, thereby increasing the number of publications in specific science and technology fields faster than in other countries and regions, building up Taiwan's R&D capabilities.

To further validate this point, this section first summarizes and breaks down the investment to date in related industries in Taiwan, including industrial R&D investment, government R&D subsidies, and science and technology outputs, and then replaces these industries with related science and technology fields to determine which fields public sector investment has actually contributed to the development of. The aggregated results are then analyzed in combination with long-term data from actual papers to objectively determine whether there is a clear difference in research outcomes in these science and technology fields. The results of our analysis are as follows.

First, the 5+2 Industries launched by the Taiwanese authorities in 2016, followed by the six core strategic industries, can be summarized as investments in related industries in the figure below (Figure 3-12, left side). A deeper look reveals that the Taiwanese authorities' investments in key fields are actually divided into two categories: investments in emerging strategic industries that the authorities want to see develop, and investments that the authorities are making to maintain their current dominance in that industry and to further develop the technology.

On the other hand, a look at the amount of R&D investment in various industries in Taiwan and the scientific and technological outputs of each industry shows that the investment of R&D resources and the R&D outputs produced by the industrial and academic sectors are all concentrated in industries in which Taiwan already has an advantage. Examples include electronic components, electronic and optical products, semiconductors, and chemical material products. This means that most of the R&D investment in Taiwan's industries has gone to industries that are already mature and have sufficient R&D capabilities, and less R&D investment has been made in emerging industries.

Because the development of key industries is closely related to the R&D outputs of related science and technology fields, interviews were conducted with experts on Taiwanese industry for this research report to determine whether the relevant industries for R&D investment and science and technology outputs are related to policy investment, industrial investment, or science and technology outputs, by grouping them together under related science and technology fields, and to determine which science and technology fields were primarily related to which industries.

The results, shown on the right side of the figure below, were that the Taiwanese authorities are focusing on seven new science and technology fields: space science, pharmacology, molecular genetics, immunology, biochemistry, geoscience, and neuroscience and behavior. Meanwhile, the six fields that already have sufficient R&D capabilities are clinical medicine, materials science, engineering, chemistry, physics, and information science. Based on the aforementioned existing R&D capabilities and the effects of industry-academia R&D investment, all of the scientific and technological fields related to these two categories should have improved their research results compared to other scientific and technological fields. Next, we analyzed the status of research outcomes in these fields using data on actual papers produced.

Field	Related Industries	Related Science and Technology Fields
Policy investment (5+2 industries, Six Core Strategic Industries)	Green energy power generation	Geoscience, materials, chemistry, engineering
	Energy storage, power grid and energy management	Geoscience, materials, chemistry, engineering
	Biotechnology and pharmaceuticals	Clinical medicine, pharmacology, immunology, molecular genetics, neuroscience and behavior, chemistry
	Medical devices	Clinical medicine, materials, engineering
	Aircraft and shipbuilding	Space science, engineering
	Electronic components	Engineering, materials
	Machinery and equipment	Engineering, information
	Semiconductor industry	Engineering, materials, physics, chemistry
	Telecommunications services industry	Information, engineering
Industrial investment (R&D expenditure)	Electronic components	Engineering, materials, chemistry
	Personal computers, electronic and optical products	Engineering, materials, chemistry, information
	Telecommunications services industry	Information, engineering
	Pharmaceutical and medical chemical products	Clinical medicine, pharmacology, chemistry
Science and technology outputs (Number of patents, technology trade value)	Electronic machinery and equipment	Engineering, materials, chemistry, information
	Computing technology	Information, engineering
	Semiconductor industry	Engineering, materials, physics, chemistry
	Optical instruments	Engineering, materials, physics, chemistry
	Chemical materials manufacturing	Chemistry, materials, engineering

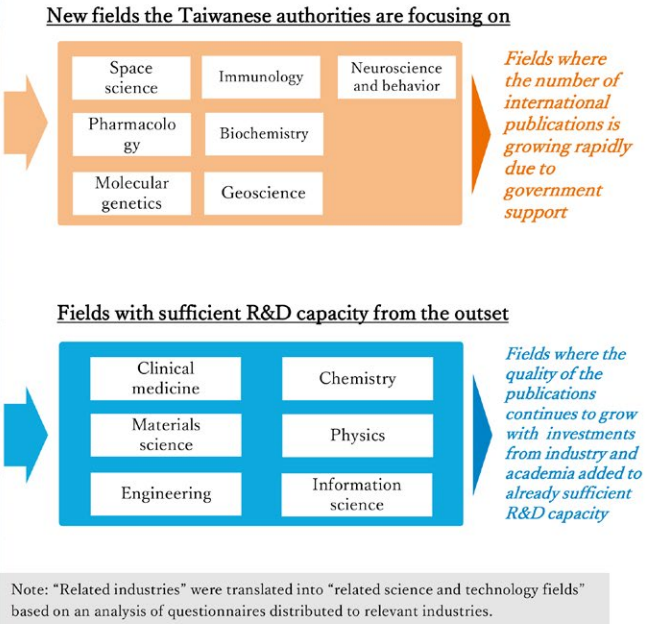


Fig. 3-12 Industries and Science and Technology Fields Related to Policy and Industry R&D Investment

Note: "Related industries" are converted into "related science and technology fields" based on the results of an analysis of questionnaires distributed to relevant industries.
Source: ESI database (Figure created by the authors)

Looking at the new fields that Taiwanese authorities have focused on in recent years, according to the results of the paper data analysis, from 2012 to 2016 (before the implementation of the 5+2 Innovative Industries Plan and the Six Core Strategic Industries), the ratio of international publications in these fields was similar to the situation in other science and technology fields, indicating that these fields received less attention and investment of R&D resources during that period. However, from 2016 to 2021, the ratio of international papers of these seven science and technology fields clearly changed, with the share of the number of international papers in these fields rising markedly since 2017 and remaining high, exceeding the degree of increase in the share of the other fields. This shows that the key industry development policies implemented by the Taiwanese authorities since 2016 have steadily promoted the research and development of related scientific and technological fields and that these fields have continued to accumulate and grow their R&D capabilities. Given that the Taiwanese authorities launched the Six Core Strategic Industries, based on the 5+2 Industries, in 2020, and the key industries that the two policies focus on are almost the same, it can be concluded that R&D in these fields will continue to develop in the future as well.

As for fields with sufficient R&D capacity from the outset, the results of the data analysis for the period of 2012-2021 show that the average number of citations of papers in these fields has grown quite steadily, while the average number of citations for other fields over the same period was unstable. The reason for this difference is that the science and technology fields with sufficient R&D capacity have many excellent researchers, and their average R&D capacity is high overall. This has resulted in a high willingness to invest in R&D in these industries, and as companies have acquired important technologies relevant to their own development and the authorities have also been willing to support these fields, earning them a certain standing amidst the international competition. With continued investment from industry and academia, fields with sufficient R&D capacity will be able to further enhance their research resources and make long-term investments in talented researchers to conduct R&D in related fields. In addition, this process also cultivates a large number of human resources and leads to a consistent increase in the quality of publications in the science and technology fields in question.

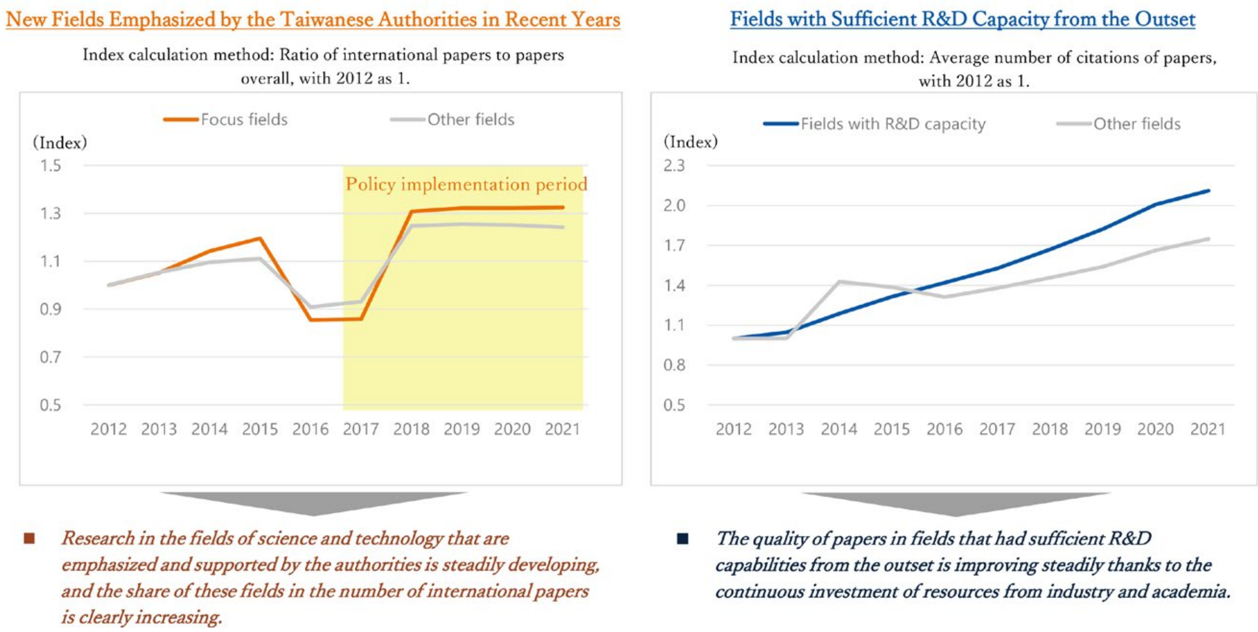


Fig. 3-13 Basic Research Outputs in Science and Technology Fields in Different Circumstances

Source: ESI database (Figure created by the authors)

From the above, it can be said that the authorities' emphasis on certain scientific and technological fields and the use of methods to reinforce the investment of resources will facilitate the development of R&D in these fields and rapidly increase the number of papers, while scientific and technological fields that have sufficient R&D capacity from the start will improve the quality of their R&D through continuous investment and participation in R&D by industry and the authorities. If this analysis is combined with the results of the previous analysis of basic research outputs in Taiwan (Figure 3-11), the upper half of the figure (quadrants 1 and 2) are science and technology fields (aside from space science) with sufficient R&D energy, and the quality of papers in these fields may continue to improve in the future, and the position of each field's coordinates may move to the right.

Meanwhile, the lower right corner of the figure (quadrant 4) and space science are the science and technology fields that the Taiwanese authorities have been focusing on in recent years, and these fields may continue to grow in terms of the number of papers and move the position of each field's coordinates upward by implementing more R&D projects as they receive support from the Taiwanese authorities. In other words, the science and technology fields originally located in the upper left (quadrant 2) and lower right (quadrant 4) may move toward the upper right in the future, and may become science and technology fields that produce top-caliber outputs in terms of both quality and quantity, thus becoming candidates for future expansion of joint research with Japan.

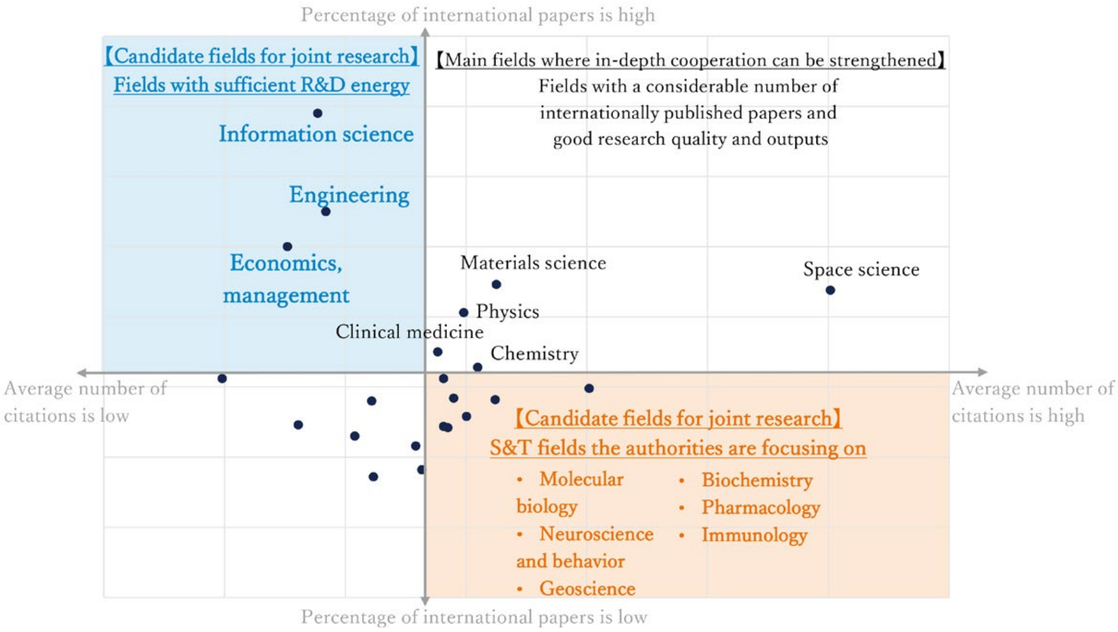


Fig. 3-14 Optimal Fields for Pursuing Joint Japan-Taiwan Research

Source: ESI database (Figure created by the authors)

3.5.2 Status of Academic Collaboration Between Japan and Taiwan

The Table below (Table 3-6) shows the number of joint Japan-Taiwan academic papers in the last decade. In 2012, there were 1179 joint papers, which has increased to 2047 in 2021. The ratio of academic papers in Taiwan that are joint papers has risen from 3.38% to 4.50%, most notably during the past five years (2017-2021), in which the ratio of joint papers has been consistently over 4%. In 2020, the ratio of joint papers reached a record high of 4.97%, just short of 5%.

Table 3-6 Overall Numbers of Joint Japan-Taiwan Academic Papers in 2012-2021

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Taiwan's total number of papers	34,887	35,610	36,107	35,483	36,694	36,443	37,617	40,775	44,476	45,539	383,631
Joint Taiwan-Japan papers	1,179	1,126	1,060	1,273	1,463	1,642	1,759	1,968	2,209	2,047	15,726
Ratio of papers	3.38%	3.16%	2.94%	3.59%	3.99%	4.51%	4.68%	4.83%	4.97%	4.50%	4.10%

Note: 1. Listed according to the 2021 data.

Source: WOS database (Table created by the authors)

The number of co-authored papers produced through Taiwan-Japan joint research has been climbing steadily, notching up by about 100-200 papers each year. 2019-2020 saw the largest increase of 241 co-authored papers. The number of coauthored papers in 2012-2014 was on a downward trend, but began to increase from 2015 and exceeded 2000 coauthored papers in 2020. In 2020-2021, the number of coauthored papers decreased (by 162 papers), presumably due to the constraints on coauthorship caused by the COVID-19 pandemic. However, in view of the trend up until now, the number of coauthored papers this year (2022) is likely to remain at the current level or even increase.

Furthermore, looking at the status of cooperation between Japan and Taiwan by field (Table 3-7), the field with the largest number of co-authored papers is clinical medicine, with nearly 400 co-authored papers in recent years. Physics comes next, followed by chemistry, space science, and materials science. The number of coauthored papers in the five main fields of Japan-Taiwan collaboration has been growing little by little every year since 2014. In terms of co-authorship by field in a broader sense, most of the areas of close cooperation between Taiwan and Japan fall under medicine or science, indicating that Japan and Taiwan have strong R&D capabilities in these fields.

Table 3-7 Fields of Japan-Taiwan Collaboration in 2012-2021

Year	1st		2nd		3rd		4th		5th	
	Clinical Medicine		Physics		Chemistry		Space Science		Materials Science	
	Co-authored papers	Total no. of papers	Co-authored papers	Total no. of papers	Co-authored papers	Total no. of papers	Co-authored papers	Total no. of papers	Co-authored papers	Total no. of papers
2012	176	6,937	239	2,667	109	3,446	69	261	28	1,931
2013	149	6,669	177	2,617	109	3,387	61	241	53	2,638
2014	143	6,862	165	2,540	125	3,716	64	264	62	2,647
2015	205	7,214	239	2,272	119	3,573	82	294	70	2,601
2016	250	7,294	298	2,455	157	3,726	91	326	72	2,643
2017	306	6,752	270	2,491	153	3,830	125	362	80	2,736
2018	342	7,850	286	2,445	182	4,080	136	381	82	3,003
2019	387	8,001	307	2,472	175	4,040	168	388	113	2,901
2020	397	7,369	259	2,528	200	3,616	142	376	122	3,017
2021	365	6,831	252	2,445	152	3,411	146	326	105	2,990
Total	2,720	71,779	2492	24,932	1,481	36,825	1,084	3,219	787	27,107

Notes: 1. Listed according to the number of co-authored papers in 2021.
2. Only the top 5 fields in terms of the number of co-authored papers are shown.

Source: WOS database (Table created by the authors)

3.5.3 Research Institutions with the Most Japan-Taiwan Collaboration

(1) Japanese Research Institutions with the Most Collaboration with Taiwan

Table 3-8 shows the Japanese universities or research institutes with the most collaborative research with Taiwan in the last 10 years (2012-2021). Among these, the University of Tokyo ranks first among Japanese universities and research institutes for the most collaborative research with Taiwan during this period, followed by Kyoto University. These two universities have consistently occupied the first and second places through the last decade. In third place are Tokyo Institute of Technology in the first half of this time period, and Nagoya University in the latter half. Nagoya University has had an increasing trend in the number of coauthored papers, especially since 2016, and after overtaking Tokyo Institute of Technology, has remained stable in third place. The total number of papers at the top five Japanese universities and research institutes with the most coauthored papers with Taiwan was lowest in 2014 at 830 and peaked at 1342 in 2019. There have been over 1200 coauthored papers every year between 2018 and 2021, which shows the recent degree of closeness between Japanese and Taiwanese research institutions.

Table 3-8 Japanese Universities and Research Institutions with the Most Collaboration with Taiwan in 2012-2021

Year	1st		2nd		3rd		4th		5th	
	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers
2012	University of Tokyo	321	Kyoto University	215	Waseda University	210	University of Tsukuba	203	Tokyo Institute of Technology	202
2013	University of Tokyo	233	Kyoto University	165	Tokyo Institute of Technology	158	Nagoya University	155	Waseda University	148
2014	University of Tokyo	221	Kyoto University	172	Tokyo Institute of Technology	153	Nagoya University	145	Osaka University	139
2015	University of Tokyo	294	Kyoto University	214	Tokyo Institute of Technology	192	Nagoya University	181	Kyushu University	179
2016	University of Tokyo	341	Kyoto University	243	Nagoya University	221	Tokyo Institute of Technology	200	Osaka University	194
2017	University of Tokyo	370	Kyoto University	223	Nagoya University	188	Osaka University	179	Kyushu University	165
2018	University of Tokyo	385	Kyoto University	288	Nagoya University	208	Osaka University	208	University of Tsukuba	200
2019	University of Tokyo	403	Kyoto University	288	Nagoya University	236	Osaka University	213	University of Tsukuba	202
2020	University of Tokyo	398	Kyoto University	256	Nagoya University	201	Osaka University	199	Tokyo Institute of Technology	176
2021	University of Tokyo	363	Kyoto University	264	Nagoya University	226	Osaka University	200	Tokyo Institute of Technology	182

Notes: 1. Listed according to the 2021 data.
2. Only the top five Taiwanese institutions in terms of the number of co-authored papers are listed.
Source: WOS databas(Table created by the authors)

(2) Taiwanese Research Institutions with the Most Collaboration with Japan

Table 3-9 reveals that the number of coauthored papers with Japan has been increasing at Academia Sinica and National Taiwan University in the last 10 years (2012-2021), averaging over 300 coauthored papers a year. The number of coauthored papers is also increasing year by year, with National Taiwan University surpassing 400 coauthored papers with Japanese institutions in 2019, surpassing Academia Sinica to take first place. National Yang Ming Chiao Tung University, National Tsing Hua University (Taiwan), National Cheng Kung University, and National Central University followed with the largest number of papers coauthored with Japan, each of them producing 100-200 coauthored papers so far. The total number of coauthored papers produced by the top five universities and research institutes in Taiwan for co-authored papers reached 694 in 2014 as the lowest, and 1413 in 2020 as the highest. From 2018 to 2021, the total number of co-authored papers has been consistently over 1000, revealing the close collaboration between Taiwanese and Japanese research institutes in recent years.

Table 3-9 Taiwanese Institutions that Closely Collaborated with Japan in 2012-2021

Year	1st		2nd		3rd		4th		5th	
	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers	Institution	Co-authored papers
2012	Academia Sinica	320	National Taiwan University	222	National Yang Ming Chiao Tung University	93	National Central University	84	National Cheng Kung University	65
2013	Academia Sinica	285	National Taiwan University	233	National Yang Ming Chiao Tung University	79	National Central University	77	National Cheng Kung University	67
2014	Academia Sinica	257	National Taiwan University	208	National Yang Ming Chiao Tung University	87	National Cheng Kung University	79	National Central University	63
2015	Academia Sinica	333	National Taiwan University	255	National Tsing Hua University	142	National Yang Ming Chiao Tung University	110	National Cheng Kung University	90
2016	Academia Sinica	358	National Taiwan University	315	National Tsing Hua University	196	National Yang Ming Chiao Tung University	136	National Cheng Kung University	90
2017	Academia Sinica	356	National Taiwan University	348	National Tsing Hua University	196	National Yang Ming Chiao Tung University	168	National Cheng Kung University	118
2018	Academia Sinica	423	National Taiwan University	379	National Tsing Hua University	200	National Yang Ming Chiao Tung University	173	National Cheng Kung University	116
2019	National Taiwan University	406	Academia Sinica	394	National Tsing Hua University	205	National Yang Ming Chiao Tung University	199	National Cheng Kung University	141

2020	National Taiwan University	476	Academia Sinica	378	National Yang Ming Chiao Tung University	222	National Tsing Hua University	205	National Cheng Kung University	132
2021	National Taiwan University	450	Academia Sinica	399	National Yang Ming Chiao Tung University	205	National Tsing Hua University	194	National Cheng Kung University	113

Note: 1. Listed according to the 2021 data. 2. Only the top five Taiwanese institutions in terms of the number of co-authored papers are listed.

Source: WOS database (Table created by the authors)

3.5.4 Direction for Japan-Taiwan Collaboration in Science and Technology

The top five fields in terms of joint Japan-Taiwan research papers are materials science, space science, chemistry, physics, and clinical medicine, which collectively make up 50-60% of all joint research papers in these fields in Japan and Taiwan (Figure 3-15). Notably, when combined with the results of the analysis of basic research outputs in Taiwan (Figure 3-11), the five main fields in which Japan and Taiwan are currently collaborating are precisely the science and technology fields in which Taiwan is producing favorable research results, indicating that the current Taiwan-Japan cooperation in science and technology is already on track. Therefore, there are two directions for future collaboration between Japan and Taiwan in science and technology research. The first is to pursue continued and deeper cooperation in the current main fields for joint research, not only to maintain the current status of joint research, but also to explore long-term cooperation, find more talented researchers to conduct joint research in these fields, and combine the supply and demand for scientific and technological cooperation on both sides in order to promote the development of science and technology in those fields together. The second direction is to expand into other science and technology fields with research potential. In Figure 3-16, the upper left corner (quadrant 2) includes information science and engineering, while the lower right (quadrant 4) includes molecular genetics, biochemistry, neuroscience and behavior, immunology, and geoscience. The reason to expand cooperation in these two groups of science and technology fields is that they represent fields that already have sufficient R&D capacity and emerging fields that the authorities in Taiwan are currently focusing on. As mentioned earlier, the research outputs of these fields are expected to continue to grow in the future thanks to the virtuous cycle of R&D capacity and investment in industry and the support of the Taiwanese authorities.

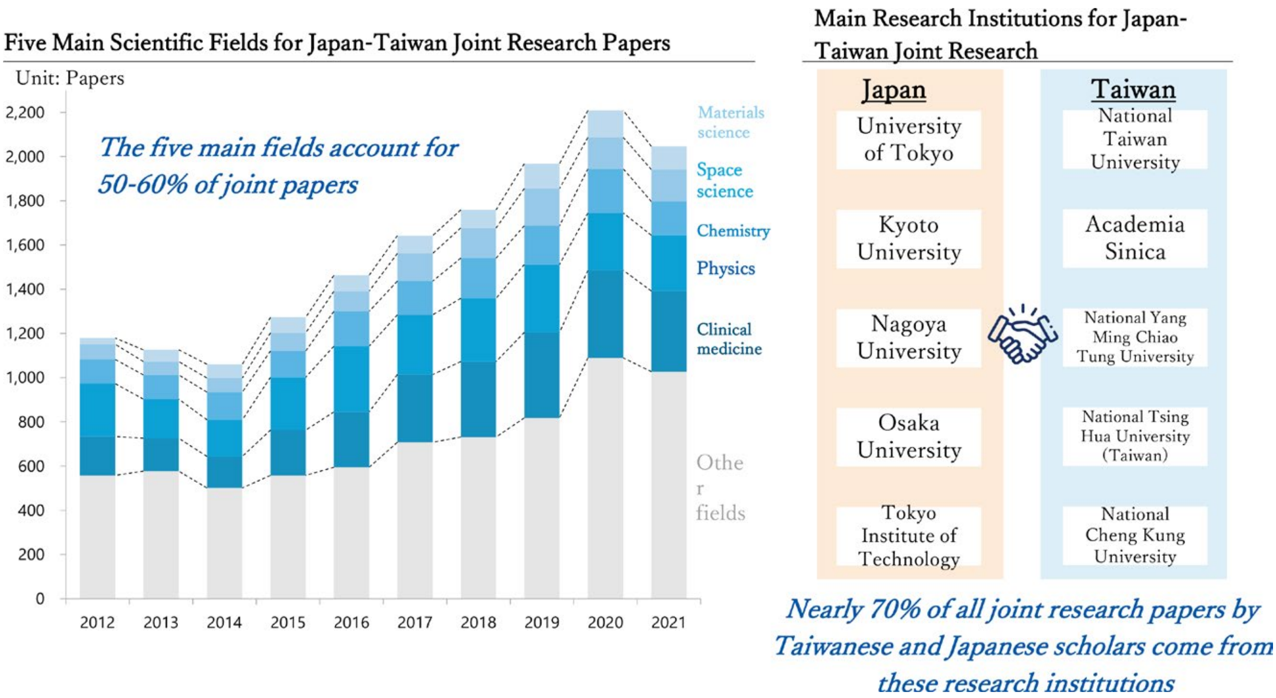


Fig. 3-15 Five Main Fields for Japan-Taiwan Joint Research Papers and Main Research Institutions

Source: WOS database (Figure created by the authors)

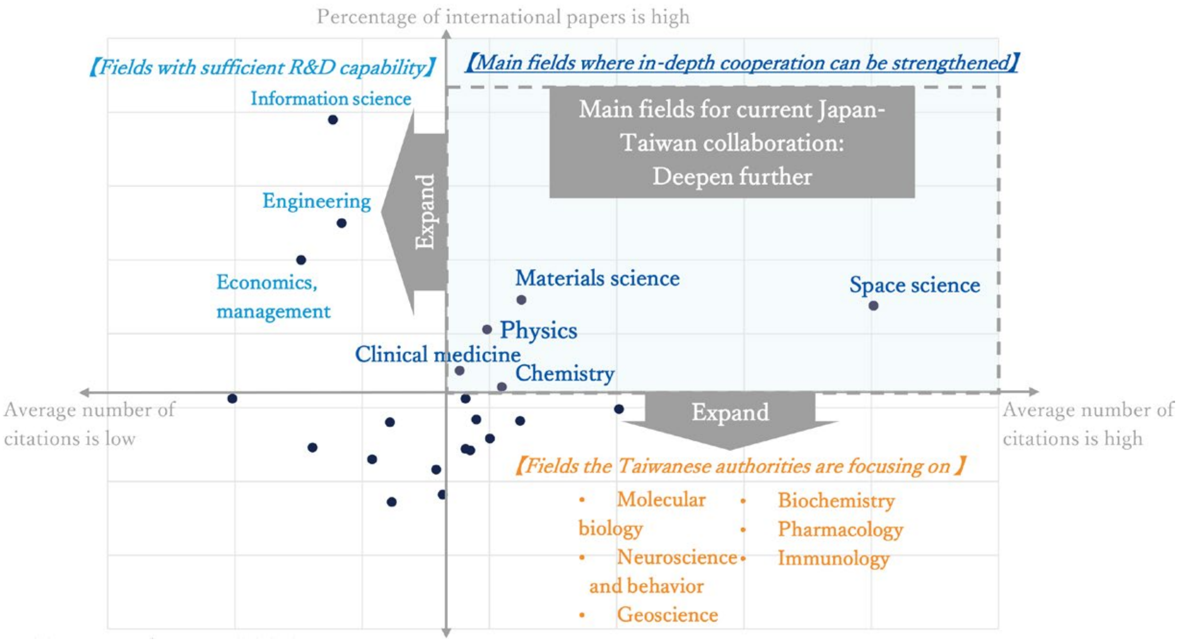


Fig. 3-16 Direction for Promising Fields for Future Japan-Taiwan Collaboration

Source: ESI database (Figure created by the authors)

3.5.5 Methods of Japan-Taiwan Collaboration in Science and Technology Fields

In order to increase and deepen Taiwan-Japan collaboration in science and technology, it is necessary to consider the methods of joint research. To this end, we will summarize interviews with highly cited Taiwanese researchers who have relevant experience, summarize key points, related issues, and countermeasures in the process of joint research, and discuss methods related to Taiwan-Japan joint research methods.

There are two ways to strengthen international collaborative research: to strengthen the establishment of the foundations for a cooperative relationship, and to support the implementation of collaborative research projects. After summarizing and analyzing the interviews, we found that building the foundations for cooperative relationships has three components: the establishment of an exchange fund, networking among researchers, and long-term collaboration. These three items form the basis for creating opportunities for joint research and facilitating its smooth progress. Professors with collaborative research experience point out that trust and tacit understanding among researchers has an impact on the smoothness of the research process and the quality of the research. Therefore, all of their collaborators are researchers who know their counterparts well, and they are reluctant to collaborate with researchers that they do not know well. The professors also point out that most of the opportunities for them to get acquainted with researchers from different countries and regions are through activities such as international seminars and overseas conferences for the presentation of research papers. Interactions at these types of events is where they learn about other researchers' expertise and become friends. To this end, Japan and Taiwan are actively engaging in joint academic exchange activities, bringing together researchers in specific fields of science and technology to give them an understanding of current R&D trends and the main research interests of both sides, and providing opportunities for deeper interactions between Taiwanese and Japanese researchers, thereby promoting joint research between the two countries. In addition to networking, mutual benefit and complementarity in the division of roles in joint research is key to long-term cooperation, as it influences the relationship between researchers and both sides' attitudes toward cooperation and their level of contribution to the research. Therefore, in order to strengthen the long-term relationship between Taiwan and Japan, the authorities in both countries should pay special attention to these areas during the review and post-evaluation of international collaborative projects, and continue to collect feedback on the projects from Taiwanese and Japanese researchers in order to understand the effectiveness of Taiwan-Japan cooperation, which can serve as a basis for future policy adjustments.

On the other hand, implementing a collaborative project has four components: obtaining of research subjects, confirmation of solutions, cooperation of research students, and securing funds for the project. The first three components are areas that the researchers must strengthen by themselves. In order to do so, researchers must strive to independently enhance their research expertise and develop their judgment of important R&D trends. In the research process, researchers can also improve their overall research capabilities by cultivating their own teams of talented research students, which will create stronger complementarities in international joint research and lead to more opportunities for cooperation. Meanwhile, the Japanese and Taiwanese governments can also provide researchers with information on the latest international R&D trends to help them better understand the current state of R&D and find the most appropriate targets for collaboration. It is also important for researchers to secure project funds, which will enable Japanese and Taiwanese researchers to participate in joint research and pay for necessary expenses such as research facilities and salaries for researchers. Thus, in the science and technology fields where future cooperation will deepen and expand (such as the aforementioned materials science, chemistry, information science, and engineering), a Taiwan-Japan joint research program can be developed to provide assistance to researchers and cooperating institutions for research expenses and resources. In summary, through these two strategies, we can further increase opportunities for future Taiwan-Japan joint research and, with the support of relevant policies and programs, improve the complementarity of research to make cooperation more effective and sustain collaboration over the long term.

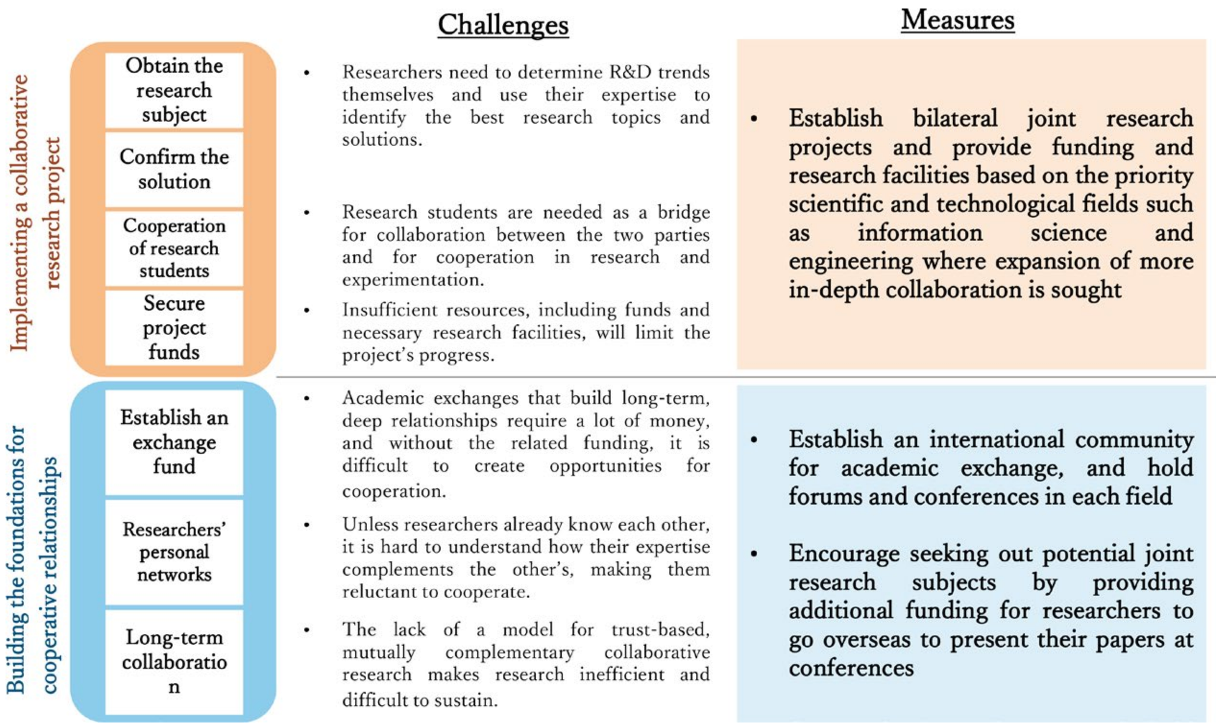


Fig. 3-17 Components, Challenges, and Measures in International Joint Research

Source: Interviews with National Taiwan University professors (Figure created by the authors)

3.6 Academic Research Trends at Major Research Institutions

According to the analysis of university rankings in section 1.2.2, the top-ranking universities in Taiwan in order are National Taiwan University, National Tsing Hua University (Taiwan), National Yang Ming Chiao Tung University, and National Cheng Kung University. THE Ranking puts Taipei Medical University and China Medical University at the top of its list. Aside from universities, Academia Sinica is the highest academic research institution under the jurisdiction of the Taiwanese authorities. Therefore, this section mainly analyzes Academia Sinica, National Taiwan University, National Tsing Hua University (Taiwan), National Yang Ming Chiao Tung University, and National Cheng Kung University, while at the same time examining the distinctive fields of other research institutions to analyze the academic research advantages of Taiwan's key research institutions.

3.6.1 Research Institutions with Outstanding Results in Each Field

The ESI database on research papers in regularly published journals is divided into 21 fields of academic research, and Table 3-10 shows the three best Taiwanese research institutions in these 21 fields in terms of the number of papers published and ranking (based on the number of publications by each academic institution worldwide in the ESI statistical database). It shows that National Taiwan University ranks first in all fields except for computer science, engineering, mathematics, neuroscience and behavior, pharmacology and toxicology, and space science, revealing National Taiwan University's significant influence on academic research in Taiwan. As to the aforementioned areas of Taiwan-Japan cooperation, the leading institution in the space field is Academia Sinica, as it is a research field related to the policies of the Taiwanese authorities. Other areas in which Academia Sinica has an advantage include physics, geosciences, biochemistry, and molecular biology and genetics. National Yang Ming Chiao Tung University ranks first in computer science, with National Cheng Kung University first in engineering. National Tsing Hua University (Taiwan) is also rated very highly in the field of chemistry. National Sun Yat-sen University is the strongest in mathematics, while National Yang Ming Chiao Tung University and China Medical University, both of which are strong in medicine, placed first in neuroscience and behavior and pharmacology and toxicology, respectively. These institutions are worthy of attention when further deepening Japan-Taiwan joint research in the future.

Table 3-10 Taiwan's Top 3 Performers in Each Field in 2012-2021

	Year	1st			2nd			3rd		
		National Taiwan University			National Chung Hsing University			China Medical University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Agriculture Science	2012	1,549	121	0.26%	-	-	-	-	-	-
	2013	742	61	0.32%	637	77	0.27%	338	189	0.15%
	2014	1,003	93	0.30%	791	136	0.24%	453	255	0.14%
	2015	1,068	88	0.30%	809	144	0.23%	523	238	0.15%
	2016	1,106	94	0.29%	823	156	0.22%	584	234	0.16%
	2017	1,124	103	0.28%	813	172	0.21%	628	243	0.16%
	2018	1,086	126	0.26%	600	280	0.14%	758	222	0.18%
	2019	1,087	131	0.25%	716	253	0.16%	626	292	0.14%
	2020	1,111	149	0.24%	719	284	0.15%	649	317	0.14%
	2021	1,134	166	0.23%	690	331	0.14%	674	337	0.14%
Biology and Biochemistry	Year	National Taiwan University			Academia Sinica			National Yang Ming Chiao Tung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	1,549	121	0.26%	1,237	182	0.21%	777	314	0.13%
	2013	1,567	116	0.27%	1,248	176	0.21%	770	318	0.13%
	2014	1,724	167	0.27%	1,434	219	0.22%	870	390	0.14%
	2015	1,893	155	0.28%	1,566	205	0.23%	981	365	0.15%
	2016	1,974	155	0.28%	1,613	206	0.23%	1,020	367	0.15%
	2017	2,035	159	0.28%	1,650	213	0.23%	1,038	375	0.14%
	2018	2,110	158	0.28%	1,728	218	0.23%	1,064	398	0.14%
	2019	2,102	165	0.28%	1,726	226	0.23%	1,070	417	0.14%
	2020	2,079	186	0.26%	1,712	248	0.22%	1,053	442	0.13%
	2021	2,108	202	0.26%	1,721	264	0.21%	1,464	330	0.18%

	Year	National Taiwan University			National Tsing Hua University (Taiwan)			Academia Sinica		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Chemistry	2012	4,403	40	0.34%	2,765	94	0.21%	2,442	127	0.19%
	2013	4,467	40	0.34%	2,809	98	0.22%	2,486	122	0.19%
	2014	4,779	56	0.34%	2,981	146	0.21%	2,371	210	0.17%
	2015	4,971	58	0.34%	3,115	145	0.21%	2,510	207	0.17%
	2016	5,144	60	0.33%	3,221	151	0.21%	2,642	203	0.17%
	2017	5,563	64	0.33%	3,502	160	0.21%	3,095	192	0.19%
	2018	5,635	71	0.33%	3,486	180	0.20%	3,138	202	0.18%
	2019	5,599	79	0.31%	3,397	194	0.19%	3,141	219	0.18%
	2020	5,699	84	0.31%	3,433	209	0.18%	3,201	229	0.17%
	2021	5,769	92	0.30%	3,422	224	0.18%	3,263	237	0.17%

	Year	National Yang Ming Chiao Tung University			National Cheng Kung University			National Taiwan University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Computer Science	2012	1,445	21	0.51%	1,123	42	0.40%	1,210	35	0.43%
	2013	1,447	22	0.50%	1,177	40	0.41%	1,258	32	0.44%
	2014	1,653	43	0.50%	1,423	58	0.43%	1,517	51	0.46%
	2015	1,706	43	0.50%	1,522	53	0.45%	1,577	48	0.46%
	2016	1,731	44	0.50%	1,581	51	0.46%	1,582	50	0.46%
	2017	1,750	44	0.50%	1,628	52	0.46%	1,549	56	0.44%
	2018	1,717	45	0.49%	1,623	52	0.46%	1,495	63	0.43%
	2019	1,721	48	0.46%	1,578	64	0.42%	1,504	66	0.40%
	2020	1,702	61	0.42%	1,506	76	0.37%	1,452	82	0.36%
	2021	1,761	69	0.40%	1,423	109	0.32%	1,386	112	0.31%

	Year	National Taiwan University			Chang Gung Memorial Hospital			Chang Gung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Clinical Medicine	2012	8,295	78	0.37%	4,675	181	0.21%	4,821	175	0.21%
	2013	8,552	76	0.38%	4,684	187	0.21%	5,207	162	0.23%
	2014	8,905	108	0.39%	7,491	134	0.33%	6,185	179	0.27%
	2015	9,220	110	0.39%	8,113	128	0.34%	6,736	171	0.28%
	2016	9,749	114	0.39%	8,412	134	0.34%	7,290	171	0.29%
	2017	10,222	120	0.39%	9,000	140	0.34%	8,110	164	0.31%
	2018	10,618	125	0.39%	9,558	144	0.35%	8,801	160	0.32%
	2019	10,905	135	0.38%	10,142	147	0.36%	9,293	165	0.33%
	2020	11,278	151	0.38%	10,781	159	0.36%	9,776	182	0.33%
	2021	11,793	159	0.37%	11,439	165	0.36%	10,292	190	0.33%

	Year	National Taiwan University			National Chengchi University			-		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Economics and Business	2012	542	96	0.30%	-	-	-	-	-	-
	2013	595	82	0.32%	-	-	-	-	-	-
	2014	-	-	-	-	-	-	-	-	-
	2015	-	-	-	-	-	-	-	-	-

	2016	881	96	0.37%	-	-	-	-	-	-
	2017	904	100	0.35%	-	-	-	-	-	-
	2018	941	103	0.35%	702	168	0.26%	-	-	-
	2019	961	106	0.34%	743	168	0.26%	-	-	-
	2020	964	121	0.32%	765	193	0.25%	-	-	-
	2021	991	134	0.31%	805	202	0.25%	-	-	-
Engineering	Year	National Cheng Kung University			National Taiwan University			National Yang Ming Chiao Tung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	5,084	11	0.56%	4,517	18	0.50%	3,908	27	0.43%
	2013	5,216	10	0.57%	4,622	18	0.50%	3,973	27	0.43%
	2014	5,680	21	0.60%	5,008	30	0.53%	4,313	41	0.46%
	2015	5,956	22	0.59%	5,220	28	0.52%	4,436	44	0.44%
	2016	6,136	24	0.57%	5,365	35	0.49%	4,480	47	0.41%
	2017	6,248	26	0.54%	5,425	42	0.47%	4,421	54	0.38%
	2018	6,128	34	0.50%	5,320	48	0.43%	4,353	65	0.35%
	2019	6,015	43	0.45%	5,248	60	0.39%	4,260	85	0.32%
	2020	5,824	61	0.40%	5,189	78	0.35%	4,243	104	0.29%
	2021	5,678	80	0.35%	5,127	93	0.32%	4,329	118	0.27%
Environment Ecology	Year	National Taiwan University			National Cheng Kung University			Academia Sinica		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	1,144	59	0.38%	516	209	0.17%	217	491	0.07%
	2013	1,137	61	0.37%	524	220	0.17%	230	490	0.08%
	2014	1,221	99	0.37%	610	269	0.18%	309	529	0.09%
	2015	1,319	106	0.36%	680	262	0.19%	350	526	0.10%
	2016	1,337	118	0.34%	724	269	0.19%	364	556	0.09%
	2017	1,408	127	0.33%	787	276	0.19%	393	583	0.09%
	2018	1,502	130	0.32%	824	303	0.18%	440	622	0.10%
	2019	1,598	129	0.31%	873	328	0.17%	467	667	0.09%
	2020	1,770	138	0.31%	918	367	0.16%	505	710	0.09%
	2021	1,980	144	0.31%	998	396	0.16%	561	745	0.09%
Geosciences	Year	National Taiwan University			Academia Sinica			National Central University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	1,231	81	0.40%	822	158	0.27%	839	153	0.27%
	2013	1,318	79	0.42%	846	158	0.27%	895	143	0.29%
	2014	1,553	115	0.44%	1,039	193	0.29%	1,037	194	0.29%
	2015	1,701	113	0.45%	1,114	200	0.29%	1,135	194	0.30%
	2016	1,785	119	0.44%	1,204	199	0.30%	1,191	204	0.30%
	2017	1,890	126	0.45%	1,280	202	0.30%	1,244	210	0.29%
	2018	1,971	136	0.44%	1,387	210	0.31%	1,294	231	0.29%
	2019	2,076	145	0.44%	1,466	220	0.31%	1,325	251	0.28%
	2020	2,165	148	0.43%	1,526	225	0.30%	1,356	266	0.27%
	2021	2,260	157	0.42%	1,581	242	0.29%	1,380	288	0.26%

	Year	National Taiwan University			Chang Gung Memorial Hospital			Chang Gung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Immunology	2012	377	155	0.29%	-	-	-	-	-	-
	2013	393	149	0.30%	-	-	-	-	-	-
	2014	807	150	0.38%	435	288	0.20%	458	272	0.22%
	2015	913	138	0.40%	580	249	0.25%	541	263	0.24%
	2016	981	140	0.41%	625	249	0.26%	604	263	0.25%
	2017	1,000	141	0.40%	664	254	0.27%	652	261	0.26%
	2018	1,054	146	0.41%	717	250	0.28%	707	255	0.27%
	2019	1,100	152	0.41%	784	239	0.29%	754	255	0.28%
	2020	1,141	167	0.41%	838	245	0.30%	795	271	0.29%
	2021	1,184	173	0.41%	901	246	0.31%	855	265	0.29%
Materials Science	Year	National Taiwan University			National Cheng Kung University			National Tsing Hua University (Taiwan)		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	2,055	36	0.41%	2,593	25	0.51%	1,896	45	0.38%
	2013	2,172	35	0.42%	2,619	27	0.51%	1,885	49	0.37%
	2014	2,636	46	0.44%	2,957	38	0.50%	2,170	67	0.36%
	2015	2,863	47	0.45%	3,035	40	0.47%	2,235	70	0.35%
	2016	3,028	49	0.44%	3,043	48	0.44%	2,310	77	0.34%
	2017	3,201	51	0.44%	3,080	58	0.42%	2,362	87	0.32%
	2018	3,400	60	0.42%	3,105	70	0.39%	2,453	101	0.31%
	2019	3,715	68	0.42%	3,103	90	0.35%	2,687	121	0.30%
	2020	3,824	76	0.39%	3,024	118	0.31%	2,724	138	0.28%
	2021	3,984	87	0.37%	2,944	145	0.28%	2,870	151	0.27%
Mathematics	Year	National Sun-Yat Sen University			China Medical University			-		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	447	194	0.16%	-	-	-	-	-	-
	2013	467	196	0.16%	-	-	-	-	-	-
	2014	556	222	0.16%	-	-	-	-	-	-
	2015	578	215	0.16%	-	-	-	-	-	-
	2016	589	227	0.15%	-	-	-	-	-	-
	2017	597	234	0.15%	-	-	-	-	-	-
	2018	576	242	0.13%	-	-	-	-	-	-
	2019	553	250	0.12%	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-	-	-
	2021	-	-	-	1190	160	0.24%	-	-	-
Microbiology	Year	National Taiwan University			Academia Sinica			-		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	530	95	0.29%	232	296	0.13%	-	-	-
	2013	552	92	0.30%	241	292	0.13%	-	-	-
	2014	432	181	0.26%	-	-	-	-	-	-
	2015	490	178	0.27%	282	313	0.16%	-	-	-
	2016	509	181	0.27%	302	319	0.16%	-	-	-

	2017	516	198	0.26%	320	331	0.16%	-	-	-
	2018	529	210	0.26%	342	338	0.17%	-	-	-
	2019	536	225	0.25%	362	355	0.17%	-	-	-
	2020	536	240	0.24%	375	373	0.17%	-	-	-
	2021	575	253	0.24%	386	402	0.16%	-	-	-
Molecular Biology and Genetics	Year	National Taiwan University			Academia Sinica			National Yang Ming Chiao Tung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	757	172	0.25%	695	194	0.23%	501	280	0.17%
	2013	800	318	0.26%	728	305	0.24%	530	427	0.17%
	2014	1,039	210	0.29%	954	235	0.26%	737	305	0.20%
	2015	1,230	190	0.31%	1,133	214	0.29%	847	300	0.22%
	2016	1,401	186	0.33%	1,279	205	0.30%	924	305	0.22%
	2017	1,554	182	0.35%	1,450	195	0.33%	1,041	292	0.23%
	2018	1,700	177	0.36%	1,565	195	0.33%	1,131	290	0.24%
	2019	1,736	182	0.36%	1,617	199	0.33%	1,179	297	0.24%
	2020	1,779	194	0.35%	1,653	218	0.33%	1,210	314	0.24%
	2021	1,812	203	0.34%	1,685	228	0.32%	1,405	288	0.26%
Neuroscience and Behavior	Year	National Yang Ming Chiao Tung University			National Taiwan University			Chang Gung Memorial Hospital		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	645	223	0.20%	542	261	0.17%	-	-	-
	2013	651	222	0.20%	562	257	0.18%	-	-	-
	2014	981	261	0.22%	917	271	0.21%	889	276	0.20%
	2015	1,095	249	0.23%	1,041	264	0.22%	1,019	268	0.22%
	2016	1,165	246	0.24%	1,109	260	0.23%	1,056	272	0.22%
	2017	1,240	251	0.25%	1,172	262	0.23%	1,113	285	0.22%
	2018	1,298	257	0.25%	1,231	272	0.24%	1,157	300	0.22%
	2019	1,370	261	0.26%	1,276	285	0.24%	1,202	308	0.22%
	2020	1,410	281	0.26%	1,316	305	0.24%	1,296	311	0.23%
	2021	1,616	259	0.28%	1,380	305	0.24%	1,372	308	0.24%
Pharmacology and Toxicology	Year	China Medical University			National Taiwan University			Taipei Medical University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	508	108	0.25%	745	37	0.37%	521	101	0.26%
	2013	563	87	0.27%	768	35	0.37%	540	100	0.26%
	2014	864	130	0.27%	1,183	66	0.37%	725	178	0.23%
	2015	1,017	104	0.30%	1,248	63	0.37%	767	177	0.23%
	2016	1,287	66	0.36%	1,129	89	0.32%	812	174	0.23%
	2017	1,205	92	0.32%	1,304	78	0.35%	852	180	0.23%
	2018	1,398	77	0.35%	1,361	81	0.34%	902	185	0.23%
	2019	1,498	72	0.36%	1,383	84	0.33%	944	195	0.23%
	2020	1,586	75	0.36%	1,400	102	0.32%	981	205	0.22%
	2021	1,666	87	0.36%	1,457	110	0.31%	1037	208	0.22%

	Year	National Taiwan University			Academia Sinica			National Tsing Hua University (Taiwan)		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Physics	2012	4,530	61	0.45%	2986	126	0.30%	2898	132	0.29%
	2013	4,586	59	0.46%	3087	119	0.31%	2905	135	0.29%
	2014	5,265	88	0.48%	3891	145	0.35%	3395	189	0.31%
	2015	5,527	85	0.48%	4021	147	0.35%	3546	189	0.31%
	2016	5,737	84	0.49%	4184	146	0.36%	3689	187	0.32%
	2017	5,492	89	0.49%	3893	170	0.35%	3609	193	0.32%
	2018	5,576	93	0.49%	3971	180	0.35%	3713	205	0.32%
	2019	5,512	98	0.48%	3900	196	0.34%	3624	219	0.32%
	2020	5,478	110	0.47%	3920	205	0.34%	3616	234	0.31%
	2021	5,419	121	0.46%	3866	219	0.33%	3593	245	0.31%

	Year	National Taiwan University			Academia Sinica			National Chung Hsing University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Plant and Animal Science	2012	1,524	100	0.26%	1,059	160	0.18%	261	671	0.04%
	2013	1,528	100	0.26%	1,055	159	0.18%	893	204	0.15%
	2014	1,554	151	0.25%	1,195	204	0.19%	953	281	0.15%
	2015	1,626	149	0.25%	1,264	203	0.19%	1,031	269	0.16%
	2016	1,692	159	0.25%	1,298	208	0.19%	1,083	272	0.16%
	2017	1,760	165	0.25%	1,327	227	0.19%	1,168	268	0.16%
	2018	1,836	171	0.25%	1,392	241	0.19%	1,224	284	0.16%
	2019	1,901	165	0.25%	1,418	253	0.19%	1,270	292	0.17%
	2020	1,961	174	0.25%	1,432	268	0.18%	1,349	288	0.17%
	2021	2,046	182	0.25%	1,459	284	0.18%	1,452	285	0.17%

	Year	National Taiwan University			National Yang Ming Chiao Tung University			National Cheng Kung University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Psychiatry Psychology	2012	327	317	0.12%	-	-	-	-	-	-
	2013	357	308	0.13%	-	-	-	-	-	-
	2014	489	333	0.16%	-	-	-	-	-	-
	2015	569	314	0.17%	-	-	-	-	-	-
	2016	651	299	0.18%	-	-	-	-	-	-
	2017	724	300	0.19%	393	480	0.10%	-	-	-
	2018	801	298	0.20%	430	493	0.11%	-	-	-
	2019	854	302	0.20%	463	508	0.11%	460	512	0.11%
	2020	925	312	0.20%	502	525	0.11%	490	534	0.11%
	2021	965	323	0.20%	757	415	0.16%	521	558	0.11%

	Year	National Taiwan University			National Cheng Kung University			National Taiwan Normal University		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
Social Sciences, General	2012	731	199	0.15%	386	347	0.08%	273	451	0.05%
	2013	814	186	0.16%	443	334	0.08%	321	423	0.06%
	2014	1,192	226	0.17%	664	395	0.10%	461	513	0.07%

	2015	1,280	231	0.17%	729	393	0.10%	537	493	0.07%
	2016	1,370	231	0.17%	777	402	0.10%	609	485	0.08%
	2017	1,446	240	0.17%	855	404	0.10%	692	480	0.08%
	2018	1,487	260	0.17%	917	412	0.10%	785	476	0.09%
	2019	1,537	275	0.16%	946	437	0.10%	491	725	0.05%
	2020	1,605	304	0.16%	992	470	0.10%	974	475	0.09%
	2021	1,682	315	0.15%	1,042	490	0.09%	1105	464	0.10%
Space Science	Year	Academia Sinica			-			-		
		Papers	Ranking	Ratio	Papers	Ranking	Ratio	Papers	Ranking	Ratio
	2012	-	-	-	-	-	-	-	-	-
	2013	-	-	-	-	-	-	-	-	-
	2014	-	-	-	-	-	-	-	-	-
	2015	-	-	-	-	-	-	-	-	-
	2016	1,274	112	0.89%	-	-	-	-	-	-
	2017	1,416	111	0.97%	-	-	-	-	-	-
	2018	1,603	111	1.06%	-	-	-	-	-	-
	2019	1,759	105	1.13%	-	-	-	-	-	-
	2020	2,008	101	1.27%	-	-	-	-	-	-
	2021	2,183	91	1.34%	-	-	-	-	-	-

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. Listed according to the 2021 data.
3. Only the top 3 ranked institutions in each field; no Taiwanese research institutions in other fields.
4. National Yang Ming University and National Chiao Tung University merged in 2021.

Source: ESI database (Table created by the authors)

3.6.2 Top Research Universities and Institutes

This section provides an analysis of the fields of academic excellence and the characteristics of five leading research institutions and universities: National Taiwan University, National Tsing Hua University (Taiwan), National Yang Ming Chiao Tung University, National Cheng Kung University, and Academia Sinica.

(1) National Taiwan University

National Taiwan University is one of the top general universities in Taiwan. An analysis of the data on the number of papers, rankings, average number of citations, and number of highly cited papers shows that the three most outstanding fields in the last 10 years at National Taiwan University are chemistry, materials science, and engineering. In terms of the number of papers, the number of papers in all three fields has increased steadily every year. As for ranking, although the university's ranking has been declining year by year overall, in three fields National Taiwan University still maintains its standing among the world's top 100 universities and research institutes, and is competitive with prominent universities and research institutes in other countries and regions around the world. And while the number of papers in materials science is lower than in chemistry and engineering, National Taiwan University has the best global ranking and the highest average number of citations among the three fields.

Table 3-11 National Taiwan University 2012-2021 Academic Papers Research Results

Year	Chemistry				Materials Science				Engineering			
	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers
2012	4,403	40	11.32	-	2,055	36	8.8	-	4,517	18	5.4	-
2013	4,467	40	11.72	-	2,172	35	9.65	-	4,622	18	5.69	-
2014	4,779	56	12.83	-	2,636	46	11.61	-	5,008	30	5.91	-
2015	4,971	58	14.39	-	2,863	47	13.22	-	5,220	28	6.64	-
2016	5,144	60	15.64	63	3,028	49	14.6	39	5,365	35	7.29	32
2017	5,563	64	16.6	66	3,201	51	15.86	40	5,425	42	7.95	26
2018	5,635	71	17.73	66	3,400	60	17.52	40	5,320	48	8.15	22
2019	5,599	79	18.37	67	3,715	68	20.11	47	5,248	60	8.68	22
2020	5,699	84	19.18	71	3,824	76	22.33	54	5,189	78	9.62	18
2021	5,769	92	20.48	74	3,984	87	23.47	58	5,127	93	10.36	22

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. Top 3 fields ranked by number of papers based on 2021 data.
3. The number of highly cited papers is based on data from 2016 onward, as statistical data for each field for 2012-2015 is not available.

Source: ESI database (Table created by the authors)

(2) National Yang Ming Chiao Tung University

In 2021, National Chiao Tung University, a top four university in Taiwan's academic rankings, merged with National Yang-Ming University to add a college of medicine, becoming National Yang Ming Chiao Tung University. According to the table below, the top three fields in terms of the highest number of papers, ranking, average number of papers cited, and number of highly cited papers in each field worldwide from 2012 to 2021 are computer science, engineering, and clinical medicine. Of these, National Yang Ming Chiao Tung University is continuing to maintain its position among the world's top 100 schools in the field of computer science, with the number of papers, ranking, and average number of citations all being outstanding. Engineering is next, and although the ranking has slid, the field continues to produce excellent results. The field of clinical medicine is also stable, with a rapid increase in the number of publications and highly cited papers in recent years, and is overall quite competitive worldwide.

Table 3-12 National Yang Ming Chiao Tung University 2012-2021 Academic Papers Research Results

Year	Computer Science				Engineering				Clinical Medicine			
	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers
2012	1,445	21	3.25	-	3,908	27	4.65	-	5,473	145	8.77	-
2013	1,447	22	3.43	-	3,973	27	4.95	-	5,788	133	8.68	-

2014	1,653	43	3.79	-	4,313	41	5.5	-	6,577	165	8.59	-
2015	1,706	43	4.12	-	4,436	44	6.04	-	6,955	162	9.34	-
2016	1,731	44	4.51	1	4,480	47	6.49	21	7,471	165	9.51	54
2017	1,750	44	5	2	4,421	54	6.89	18	8,002	169	10.1	77
2018	1,717	45	5.62	1	4,353	65	7.45	26	8,545	170	10.68	63
2019	1,721	48	6.17	2	4,260	85	7.84	20	8,955	173	11.65	85
2020	1,702	61	6.88	2	4,243	104	8.68	19	9,348	189	12.79	54
2021	1,761	69	7.56	1	4,329	118	9.25	23	10,523	181	13.87	108

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals
2. Top 3 fields ranked by number of papers based on 2021 data.
3. The number of highly cited papers is based on data from 2016 onward, as statistical data for each field for 2012-2015 is not available.

Source: ESI database (Table created by the authors)

(3) National Tsing Hua University (Taiwan)

National Tsing Hua University (Taiwan) is one of the top universities in Taiwan's academic rankings, and the number of papers, ranking, average number of papers cited, and number of highly cited papers in each field shown in the figure below reveal that the three most outstanding fields at the university are materials science, engineering, and computer science. Of these, engineering and computer science dropped significantly in 2021, going from the top 100 to the bottom 200. Materials science also fell below 150th place in 2021. Overall, National Tsing Hua University (Taiwan) has competitive advantages in science and engineering, but is in the upper middle range of the overall global rankings.

Table 3-13 National Tsing Hua University (Taiwan) 2012-2021 Academic Papers Research Results

Year	Materials Science				Engineering				Computer Science			
	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers
2012	1,896	45	9.84	-	2,551	69	4.58	-	796	87	3	-
2013	1,885	49	10.52	-	2,603	68	4.71	-	817	88	3.28	-
2014	2,170	67	12.28	-	2,651	100	5.48	-	986	114	3.93	-
2015	2,235	70	13.76	-	2,797	100	6.15	-	1,017	121	4.48	-
2016	2,310	77	15.36	43	2,911	107	6.83	23	1,020	121	5.12	0
2017	2,362	87	16.75	44	3,017	117	7.67	20	1,051	118	5.71	0
2018	2,453	101	19.03	39	2,932	133	7.78	13	1,027	129	6.26	2
2019	2,687	121	23.93	51	2,917	166	8.54	13	1,006	150	6.9	2
2020	2,724	138	27.24	56	2,918	189	9.38	12	967	180	7.5	1
2021	2,870	151	28.95	54	2,921	214	10.14	13	929	217	8.26	1

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. Top 3 fields ranked by number of papers based on 2021 data.
3. The number of highly cited papers is based on data from 2016 onward, as statistical data for each field for 2012-2015 is not available.

Source: ESI database (Table created by the authors)

(4) National Cheng Kung University

National Cheng Kung University is another top university in Taiwan's academic rankings, with strengths in the fields of science and engineering. According to the figure below, the top three fields at National Cheng Kung University in terms of the number of papers, ranking, average number of papers cited, and number of highly cited papers in each field worldwide are engineering, materials science, and computer science. Among these results, the number of papers published has been increasing steadily and only decreased slightly in 2021. In terms of ranking, materials science and computer science have fallen out of the top 100 in the last decade, but engineering has continued to excel, ranking in the top 100.

Table 3-14 National Cheng Kung University 2012-2021 Academic Papers Research Results

Year	Engineering				Materials Science				Computer Science			
	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers
2012	5,084	11	4.97	-	2,593	25	6.76	-	1,123	42	2.73	-
2013	5,216	10	5.21	-	2,619	27	7.17	-	1,177	40	3.05	-
2014	5,680	21	5.59	-	2,957	38	7.54	-	1,423	58	3.89	-
2015	5,956	22	6.28	-	3,035	40	8.49	-	1,522	53	4.65	-
2016	6,136	24	7.01	50	3,043	48	9.21	12	1,581	51	5.26	5
2017	6,248	26	7.7	44	3,080	58	9.88	15	1,628	52	6	8
2018	6,128	34	8.34	55	3,105	70	11.01	14	1,623	52	6.88	10
2019	6,015	43	9.03	49	3,103	90	12.18	13	1,578	64	7.88	8
2020	5,824	61	9.91	48	3,023	118	13.25	12	1,506	76	8.31	6
2021	5,678	80	10.59	48	2,944	145	14	11	1,423	109	9.05	5

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. Top 3 fields ranked by number of papers based on 2021 data.
3. The number of highly cited papers is based on data from 2016 onward, as statistical data for each field for 2012-2015 is not available.

Source: ESI database (Table created by the authors)

(5) Academia Sinica (National Academy of the Republic of China)

Academia Sinica is Taiwan's leading research institute and the top academic institution affiliated with the Office of the President. The figure below reveals that Academia Sinica's strengths lie mainly in the sciences, with the top three fields where it excels being physics, molecular biology and genetics, and chemistry. In terms of the number of papers and the average number of citations of papers, physics increased steadily from 2012 to 2016, but has been declining every year since then. On the other hand, the number of academic papers in the fields of molecular biology and genetics and chemistry has been increasing steadily year by year, moving up and down in the ranking. Although Academia Sinica does not publish a high volume of academic papers, its performance in terms of average citations and number of highly cited papers is very good, indicating that it has a certain influence and competitiveness in these aspects of academic research quality.

Table 3-15 Academia Sinica 2012-2021 Academic Papers Research Results

Year	Physics				Molecular Biology and Genetics				Chemistry			
	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers	Papers	Ranking	Average Citations	Number of highly cited papers
2012	2,986	126	11.44	-	695	194	17.22	-	2,442	127	11.74	-
2013	3,087	119	11.37	-	728	305	17.49	-	2,486	122	11.92	-
2014	3,891	145	13	-	954	235	21.96	-	2,371	210	13.07	-
2015	4,021	147	14.05	-	1,133	214	20.11	-	2,510	207	14.16	-
2016	4,184	146	15.43	102	1,279	205	21.54	10	2,642	203	15.47	32
2017	3,893	170	16.68	111	1,450	195	21.07	15	3,095	192	16.16	31
2018	3,971	180	18.53	112	1,565	195	23.04	12	3,138	202	17.4	33
2019	3,900	196	19.81	140	1,617	199	24.21	14	3,141	219	17.41	20
2020	3,920	205	22.51	149	1,653	218	25.84	18	3,201	229	17.98	23
2021	3,866	219	24.27	127	1,685	228	28.3	20	3,263	237	18.82	24

Notes: 1. The numbers of papers in the ESI database are statistics for all 11 years. Therefore, all successive data is statistics for the number of papers at 11-year intervals.
2. Top 3 fields ranked by number of papers based on 2021 data.
3. The number of highly cited papers is based on data from 2016 onward, as statistical data for each field for 2012-2015 is not available.

Source: ESI database (Table created by the authors)

3.7 Notable Researchers

The “World’s Top 2% Scientists 2020,” published in 2021 by Stanford University in the U.S. using an analysis of the Scopus thesis database, selects the world's top 2% scientists from a pool of approximately 8 million scientists, taking the five major categories of applied sciences, health sciences, natural sciences, economic and social sciences, and arts and humanities and dividing them into 20 major fields and 176 subfields to be ranked.

The following six key indicators are used to rate the scientists: (1) total citations, (2) Hirsch h-index, (3) Schreiber Hm-index modified to account for multiple authors, (4) sole author, (5) sole or first author, and (6) number of citations by sole, first or last author.

Among the 20 major fields, a total of 17 corresponding faculties at Taiwanese institutions were represented, and a total of 1,479 researchers were ranked in the top 2% of most influential researchers. The fields with the largest number of scientists in the ranking were engineering, information and communication technology, clinical medicine, materials science, space science, and chemistry, with a total of 1,080 researchers, accounting for 73% of the total number of researchers from Taiwan. In this section, the top researchers within the top 1% of the ranking in each subfield (details in the attached document) are selected from this list to serve as candidates for future Taiwan-Japan collaboration.

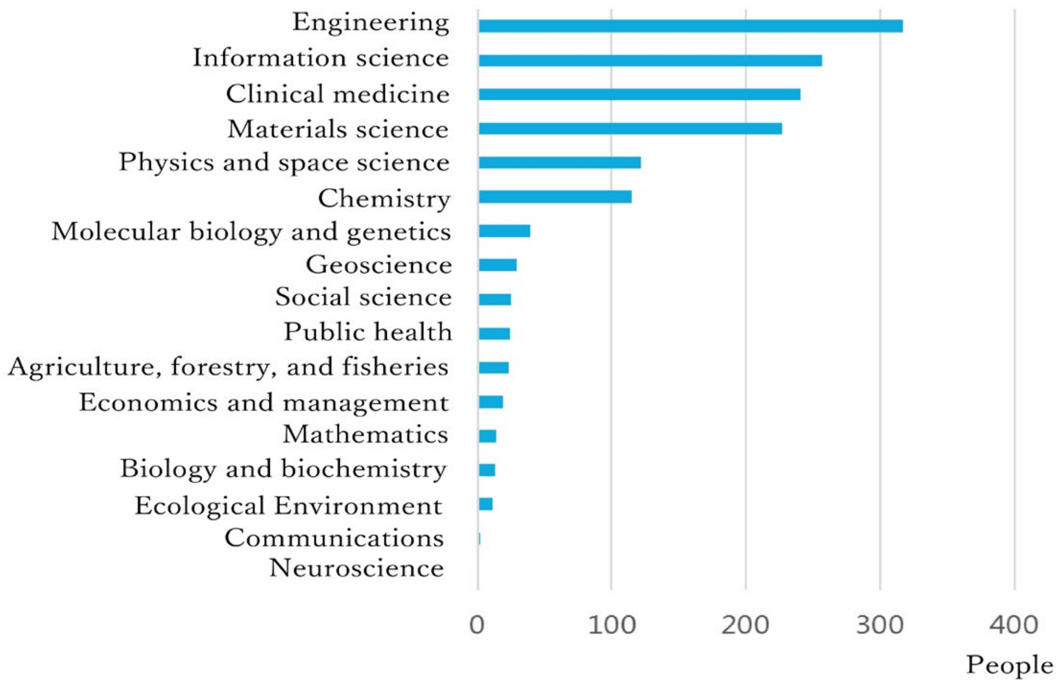


Fig. 3-18 Taiwanese Scientists in the World's Top 2% in 2020

Source: Scopus database (Figure created by the authors)

The "Highly Cited Researchers" list published by Clarivate is a commonly used indicator of outstanding researchers in the academia. The researchers selected have published a large number of highly cited papers in the past 10 years, and these papers are in the top 1% of papers cited in the same faculty and year of publication in the Web of Science database, indicating that they have an important academic influence on their respective fields.

6,600 researchers from around the world were selected for the list, including 16 from Taiwan in 2021. Five of them are in the biomedical field, the most in history. This shows Taiwan's potential from basic medical research to clinical trials. Taiwan's biomedical industry has grown significantly in recent years, and besides Professor James Chih-Hsin Yang and Professor Ann-Lii Cheng of National Taiwan University participating in clinical cancer treatment trials at an international center targeting PD-1/PD-L1, a well-known immunotherapy, or EGFR mutation, Professor Xue Bo-Jen of National Taiwan University and Professor Wen-Chien Ko of National Cheng Kung University jointly published a COVID-19 paper which attracted a great deal of attention among the worldwide outbreak of the virus. In basic science research, Professor Mien-Chie Hung of China Medical University received international recognition for his paper on the mechanisms involved in drug intervention and related biological markers.

There are also a number of scholars who have been highly cited for several years, and among them the most frequently selected is Professor Jen-Chih Yao of China Medical University, with a total of seven citations in the field of applied mathematics, specializing in nonlinear analysis and optimization control. Professor Wei-Hsin Chen of the Department of Aeronautics and Astronautics at National Cheng Kung University, who has appeared on the list six times, specializes in hydrogen energy, bioenergy, clean energy, energy systems, heat flow, and environmental engineering. Professor Ru-Shi Liu of the Department of Chemistry at National Taiwan University, who has been selected four times, focuses on light-to-light, light-to-electricity, and light-to-heat conversion materials used in cell phone monitors, fuel cells, and biomedical thermotherapy.

In the field of physics, Professor Tay-Rong Chang of the Department of Physics at National Cheng Kung University, Assistant Professor Shin-Ming Huang of the Department of Physics at National Sun Yat-sen University, Professor Horng-Tay Jeng of the Department of Physics at National Tsinghua University (Taiwan), and Associate Research Fellow Hsin Lin of the Institute of Physics, Academia Sinica, were highly regarded in 2021.

Professor Chu Ying-Hao of the Department of Electrophysics and the Department of Materials Science and Engineering at National Yang Ming Chiao Tung University, Professor Chung Sun-Lin of the Department of Geosciences at National Taiwan University and Member of the Institute of Earth Sciences, Academia Sinica, and Professor Chi-Jen Lin of the Department of Computer Science and Information Engineering at National Taiwan University were not on the list of highly cited researchers in 2021, but because they appeared on the list at least three times between 2012 and 2021, they can be said to be some of Taiwan's most outstanding researchers.

To examine the potential for these highly cited researchers to expand their collaborative research with Japan, we looked into their experience in co-authoring papers with Japanese scholars within the last five years, and found that most of them had close collaborative relationships with the Japanese academic community. Most of the papers published by the researchers in the figure below were the result of collaboration with other countries and regions, and only Professor Yi-Hsien Lee of National Tsing Hua University (Taiwan) and Professor Chi-Jen Lin of National Taiwan University had no collaborative research experience with Japan, with all of the collaborators on their papers being Taiwanese researchers. The analysis shows that most of the researchers are open and active in international cooperation, and are potential participants in future Japan-Taiwan joint research.

Table 3-16 Taiwanese Scholars Included in the Highly Cited Researchers List in 2021

English Name	Chinese Name	Field	Institution	Number of times on the highly-cited scholars list during 2012-2021 (3 times or more)	Number of joint Japan-Taiwan publications (within 5 years)
Jo-Shu, Chang	張嘉修	Biology and biochemistry	National Cheng Kung University /Tunghai University	3	14
James Chih-Hsin, Yang	楊志新	Clinical Medicine	National Taiwan University	3	21
Ann-Lii, Cheng	鄭安理	Multidisciplinary	National Taiwan University	-	31
Mien-Chie, Hung	洪明奇	Multidisciplinary	China Medical University	-	3
Duu-Jong, Lee	李篤中	Multidisciplinary	National Taiwan University	-	22
Yi-Hsien, Lee	李奕賢	Multidisciplinary	National Tsing Hua University (Taiwan)	3	-
Ru-Shi, Liu	劉如熹	Multidisciplinary	National Taiwan University	4	5
Kevin C. W., Wu	吳嘉文	Multidisciplinary	National Taiwan University	-	14
Wei-Hsin, Chen	陳維新	Engineering	National Cheng Kung University /Tunghai University	6	1

Jen-Chih, Yao	姚任之	Mathematics	China Medical University/ National Sun Yat-sen University	7	5
Po-Ren, Hsueh	薛博仁	Pharmacology and toxicology	National Taiwan University		7
Wen-Chien, Ko	柯文謙	Pharmacology and toxicology	National Cheng Kung University		1
Tay-Rong, Chang	張泰榕	Physics	National Cheng Kung University	3	9
Shin-Ming, Huang	黃信銘	Physics	National Sun Yat-sen University	-	2
Horng-Tay, Jeng	鄭弘泰	Physics	National Tsing Hua University (Taiwan)/ Academia Sinica	3	6
Hsin, Lin	林新	Physics	Academia Sinica	4	7

Source: ISI official website, list of researchers and authors (Table created by the authors)

Table 3-17 Other Taiwanese Scholars Who Have Appeared on the Highly Cited Researchers List Three Times or More Between 2012 and 2021

English Name	Chinese Name	Field	Institution	Number of times on the highly-cited scholars list during 2012-2021 (3 times or more)	Number of joint Japan-Taiwan publications (within 5 years)
Chung, Sun-Lin	鍾孫霖	Geoscience	National Taiwan University /Academia Sinica	4	8
Chu, Ying-Hao	朱英豪	Multidisciplinary	National Yang Ming Chiao Tung University	4	12
Chih-Jen, Lin	林智仁	Computer Science	National Taiwan University	3	-

Source: ISI official website, list of researchers and authors (Table created by the authors)

Appendix

[Top 1% of Most Influential Researchers in Taiwan]

Field	Sub-field	Sub-field rank	Rank percentile	Name	Name of Organization
Agriculture, Fisheries & Forestry	Fisheries	111	0.34%	Shiau, Shi Yen	Fu Jen Catholic University
		168	0.52%	Chen, Jiann Chu	National Taiwan Ocean University
		263	0.81%	Lin, Yu Hung	National Pingtung University of Science and Technology
		272	0.84%	Liu, Chun Hung	National Pingtung University of Science and Technology
	Food Science	28	0.05%	Chen, Mei Fang	Tatung University
		47	0.08%	Yen, Gow Chin	National Chung Hsing University
		193	0.33%	Mau, Jeng Leun	National Chung Hsing University
		252	0.43%	Pan, Min Hsiung	National Taiwan University
		426	0.73%	Yin, Mei Chin	China Medical University Hospital Taichung
		454	0.78%	Duh, Pin Der	Chia-Nan University of Pharmacy and Science Taiwan
		461	0.79%	Chen, Bing Huei	Fu Jen Catholic University
	Forestry	112	0.40%	Chang, Shang Tzen	National Taiwan University
Biology	Ecology	66	0.12%	Chao, Anne	National Tsing Hua University
	Plant Biology & Botany	463	0.34%	Schmidt, Wolfgang	National Chung Hsing University
		570	0.42%	Verslues, Paul E.	Academia Sinica, Institute of Plant and Microbial Biology
		1,083	0.80%	Chiou, Tzyy Jen	Academia Sinica, Agricultural Biotechnology Research Center
		1,190	0.88%	Tsay, Yi Fang	Academia Sinica, Institute of Molecular Biology
Biomedical Research	Biochemistry & Molecular Biology	658	0.35%	Liu, Leroy F.	Taipei Medical University
		1,377	0.73%	Angata, Takashi	Academia Sinica, Institute of Biological Chemistry
		1,407	0.74%	Liang, Po Huang	Academia Sinica, Institute of Biological Chemistry
		1,824	0.96%	Huang, Chih Yang	China Medical University
		1,837	0.97%	Wang, Andrew H.J.	Academia Sinica, Institute of Biological Chemistry
	Microbiology	107	0.06%	Hsueh, Po Ren	National Taiwan University Hospital
		568	0.34%	Lai, Chih Cheng	Veterans General Hospital-Kaohsiung Taiwan

		995	0.60%	Chang, Shan Chwen	National Taiwan University Hospital
		1,415	0.86%	Ko, Wen Chien	National Cheng Kung University Hospital
	Nutrition & Dietetics	298	0.70%	Hu, Miao Lin	National Chung Hsing University
		318	0.75%	Wahlqvist, Mark L.	National Health Research Institutes Taiwan
	Oncology & Carcinogenesis	2,602	0.96%	Wu, Kou Juey	Chang Gung Memorial Hospital
	Physiology	130	0.53%	Hwang, Pung Pung	Academia Sinica, Institute of Cellular and Organismic Biology
	Toxicology	225	0.42%	Yang, Chun Yuh	National Health Research Institutes Taiwan
	Virology	86	0.13%	Lai, Michael M.C.	China Medical University
Built Environment & Design	Building & Construction	39	0.13%	Chou, Jui Sheng	National Taiwan University of Science and Technology
		290	0.96%	Cheng, Min Yuan	National Taiwan University of Science and Technology
	Design Practice & Management	85	0.85%	Hsieh, Chiu Fan	National Formosa University Taiwan
Chemistry	Analytical Chemistry	237	0.23%	Tsai, Tung Hu	Kaohsiung Medical University
		387	0.38%	Huang, Chih Ching	National Taiwan Ocean University
		462	0.45%	Urban, Pawel L.	National Tsing Hua University
		639	0.62%	Palanisamy, Selvakumar	National Taipei University of Technology
		822	0.80%	Tsao, Chia Wen	National Central University
		970	0.94%	Chang, Huan Tsung	National Taiwan University
	Chemical Engineering	334	0.50%	Chen, Chiing Chang	National Taichung University of Education
	Chemical Physics	317	0.34%	Chou, Pi Tai	National Taiwan University
		537	0.58%	Wei-Guang Diau, Eric	National Chiao Tung University
	Environmental Sciences	664	0.86%	Doong, Ruey An	National Tsing Hua University
	General Chemistry	231	0.45%	Kuo, Yueh Hsiung	China Medical University
	Medicinal & Biomolecular Chemistry	188	0.21%	Wu, Yang Chang	China Medical University Hospital Taichung
		195	0.22%	Wu, Tian Shung	National Cheng Kung University College of Medicine
		393	0.44%	Chang, Fang Rong	Kaohsiung Medical University
		427	0.48%	Chen, Chung Yi	Fooyin University Taiwan
		488	0.55%	Wang, Hui Min David	China Medical University
		647	0.73%	Hwang, Tsong Long	Chang Gung University of Science and Technology
		758	0.85%	Wang, Sheng Yang	National Chung Hsing University

		800	0.90%	Nepali, Kunal	Taipei Medical University
		859	0.97%	Lee, Ching Kuo	Taipei Medical University
		887	1.00%	Chen, Ih Sheng	Kaohsiung Medical University
	Nanoscience & Nanotechnology	9	0.01%	Pumera, Martin	China Medical University Hospital Taichung
		452	0.51%	Huang, Michael H.	National Tsing Hua University
		773	0.87%	Chen, Hao Ming	National Taiwan University
	Organic Chemistry	450	0.31%	Wu, Kevin C.W.	National Taiwan University
	Physical Chemistry	175	0.49%	Wu, Jeffrey C.S.	National Taiwan University
	Polymers	109	0.11%	Liu, Ying Ling	National Tsing Hua University
		148	0.15%	Kuo, Shiao Wei	National Sun Yat-Sen University
		192	0.19%	Mi, Fwu Long	Taipei Medical University
		281	0.28%	Wu, Chin San	Kao Yuan University Taiwan
		553	0.55%	Liaw, Der Jang	National Taiwan University of Science and Technology
Clinical Medicine	Acoustics	225	0.70%	Liu, Hao Li	National Taiwan University
	Biochemistry & Molecular Biology	823	0.43%	Wei, Yau Huei	Changhua Christian Hospital Taiwan
	Cardiovascular System & Hematology	1,097	0.57%	Burnouf, Thierry	Taipei Medical University
		1,311	0.68%	Wu, Kenneth K.	National Health Research Institutes Taiwan
		1,834	0.96%	Chen, Shih Ann	Veterans General Hospital-Taipei
	Complementary & Alternative Medicine	37	0.32%	Lin, Jaung Geng	China Medical University
		39	0.33%	Lin, Chun Ching	Kaohsiung Medical University
		46	0.39%	Hsieh, Ching Liang	China Medical University Hospital Taichung
		47	0.40%	Lin, Chun Ching	Kaohsiung Medical University
		57	0.49%	Ho, Tin Yun	China Medical University
		68	0.58%	Li, Tsai Chung	China Medical University
		79	0.68%	Yang, Wen Chin	Academia Sinica, Agricultural Biotechnology Research Center
		114	0.98%	Yen, Hung Rong	China Medical University Hospital Taichung
	Dentistry	123	0.17%	Tu, Yu Kang	National Taiwan University
		511	0.71%	Liou, Eric J.W.	Chang Gung Memorial Hospital
	Dermatology & Venereal Diseases	330	0.66%	Chung, Wen Hung	Chang Gung Memorial Hospital
		387	0.78%	Chu, Chia Yu	National Taiwan University College of Medicine
		442	0.89%	Tsai, Tsen Fang	National Taiwan University Hospital
		481	0.97%	Chi, Ching Chi	Chang Gung Memorial Hospital
	Emergency & Critical Care Medicine	317	1.00%	Guo, How Ran	National Cheng Kung University Hospital

Endocrinology & Metabolism	220	0.27%	Tseng, Chin Hsiao	National Taiwan University Hospital
Gastroenterology & Hepatology	171	0.19%	Kao, Jia Horng	National Taiwan University Hospital
	268	0.29%	Chen, Ding Shinn	National Taiwan University Hospital
	464	0.51%	Liaw, Yun Fan	Chang Gung University College of Medicine
	542	0.59%	Liu, Chun Jen	National Taiwan University Hospital
	633	0.69%	Chen, Pei Jer	National Taiwan University Hospital
	853	0.93%	Liaw, Yun Fan	Chang Gung University College of Medicine
	893	0.98%	Wu, Chun Ying	National Yang-Ming University Taiwan
General & Internal Medicine	1,051	0.47%	Chou, Pesus	National Yang-Ming University Taiwan
	1,212	0.54%	Li, Chung Yi	National Cheng Kung University College of Medicine
	1,561	0.70%	Lin, Jen Der	Chang Gung Memorial Hospital
	1,653	0.74%	Lai, Shih Wei	China Medical University
	2,182	0.97%	Hwang, Shinn Jang	Veterans General Hospital-Taipei
Geriatrics	19	0.19%	Chen, Liang Kung	Veterans General Hospital-Taipei
Immunology	517	0.40%	Liu, Fu Tong	Academia Sinica, Institute of Biomedical Sciences
Industrial Engineering & Automation	472	0.49%	Lin, Feng Tse	Chinese Culture University Taiwan
Medicinal & Biomolecular Chemistry	696	0.78%	Chiang, Lien Chai	School of Medicine
Neurology & Neurosurgery	1,360	0.49%	Wang, Shuu Jiun	National Yang-Ming University Taiwan
Nuclear Medicine & Medical Imaging	163	0.16%	Kao, Chia Hung	China Medical University Hospital Taichung
	682	0.67%	Yen, Tzu Chen	Chang Gung Memorial Hospital
Nursing	373	0.41%	Tsai, Pei Shan	Taipei Medical University
	684	0.75%	Chen, Shu Ching	Chang Gung University of Science and Technology
Obstetrics & Reproductive Medicine	373	0.44%	Chen, Chih Ping	Mackay Memorial Hospital Taiwan
	504	0.59%	Tsai, Fuu Jen	China Medical University Hospital Taichung
Oncology & Carcinogenesis	261	0.10%	Chen, Chien Jen	Academia Sinica, Genomics Research Center
	376	0.14%	Yang, J. C.H.	National Taiwan University Hospital
	719	0.26%	Yang, Pan Chyr	National Taiwan University Hospital
	745	0.27%	Cheng, Ann Lii	National Taiwan University Hospital
	901	0.33%	Lin, Jen Kun	National Taiwan University College of Medicine

		1,192	0.44%	Hung, Mien Chie	China Medical University
		1,244	0.46%	Tang, Chih Hsin	China Medical University
		2,016	0.74%	Kuo, Po Lin	College of Medicine
		2,236	0.82%	Chung, Jing Gung	China Medical University
		2,409	0.89%	Yang, Muh Hwa	Veterans General Hospital-Taipei
	Orthopedics	97	0.14%	Wang, Ching Jen	Chang Gung University College of Medicine
		662	0.98%	Wang, Feng Sheng	Chang Gung University College of Medicine
	Otorhinolaryngology	298	0.69%	Chan, Roger W.	National Taipei University of Nursing and Health Sciences
		304	0.70%	Li, Hsueh Yu	Chang Gung Memorial Hospital
		350	0.81%	Young, Yi Ho	National Taiwan University Hospital
	Pediatrics	94	0.15%	Chang, Mei Hwei	National Taiwan University Hospital
		399	0.62%	Kuo, Ho Chang	Chang Gung University College of Medicine
		432	0.68%	Lin, Tzou Yien	Chang Gung Memorial Hospital
	Pharmacology & Pharmacy	186	0.14%	Fang, Jia You	Chang Gung University
		256	0.20%	Huang, Leaf	Chung Yuan Christian University
		693	0.53%	Lin, Shan Yang	Yuanpei University of Medical Technology
		843	0.64%	Sheu, Joen Rong	Taipei Medical University
		881	0.67%	Chou, Tz Chong	National Defense Medical Center Taiwan
		1,168	0.89%	Chen, Yunching	National Tsing Hua University
	Psychiatry	343	0.50%	Tsai, Shih Jen	Veterans General Hospital-Taipei
		428	0.62%	Ko, Chih Hung	Kaohsiung Medical University Chung-Ho Memorial Hospital
	Rehabilitation	148	0.61%	Hong, Chang Zern	Taiwan Myopain Society
	Sport Sciences	190	0.73%	Chang, Yu Kai	National Taiwan Normal University
	Surgery	491	0.43%	Wei, Fu Chan	Chang Gung Memorial Hospital
		596	0.53%	Chen, Miin Fu	Chang Gung Memorial Hospital
		706	0.62%	Cheng, Ming Huei	Chang Gung Memorial Hospital
		953	0.84%	Liang, Jin Tung	National Taiwan University Hospital
		978	0.86%	Lee, Wei Jei	Min-Sheng General Hospital
		1,058	0.94%	Chen, Chao Long	Chang Gung Memorial Hospital
	Toxicology	437	0.82%	Guo, Yue Leon	National Taiwan University
		449	0.84%	Liu, Shing Hwa	National Taiwan University College of Medicine
	Urology & Nephrology	260	0.34%	Kuo, Hann Chorng	Tzu Chi University

		518	0.68%	Yang, Chih Wei	Chang Gung University College of Medicine
Communication & Textual Studies	Communication & Media Studies	56	0.51%	LaRose, Robert	National Chiao Tung University
Earth & Environmental Sciences	Agronomy & Agriculture	516	0.80%	Hseu, Zeng Yei	National Taiwan University
	Building & Construction	99	0.33%	Lin, Tzu Ping	National Cheng Kung University
	Environmental Sciences	29	0.04%	Tseng, Ming Lang	Asia University
		499	0.65%	Liang, Chenju	National Chung Hsing University
		679	0.88%	Lu, Ming Chun	National Chung Hsing University
		706	0.91%	Chung, Ying Chien	China University of Science and Technology
		734	0.95%	Pan, Shu Yuan	National Taiwan University
	Geochemistry & Geophysics	14	0.02%	Jahn, Bor ming	National Taiwan University
		143	0.18%	Chung, Sun Lin	Academia Sinica, Institute of Earth Sciences
		538	0.66%	Shellnutt, J. Gregory	National Taiwan Normal University
	Meteorology & Atmospheric Sciences	44	0.07%	Huang, Norden E.	National Central University
	Oceanography	10	0.06%	Chen, Chen Tung Arthur	National Sun Yat-Sen University
		95	0.57%	Oey, Lie Yauw	National Central University
Economics & Business	Artificial Intelligence & Image Processing	2,110	0.83%	Hsu, Li Chang	Ling Tung University
	Business & Management	61	0.14%	Chen, Yu Shan	National Taipei University
		76	0.17%	Lin, Hsiu Fen	National Taiwan Ocean University
		253	0.56%	Lin, Chieh Peng	National Yang Ming Chiao Tung University
		338	0.75%	Chang, Ching Hsun	National Taiwan Normal University
	Energy	927	0.40%	Hu, Jin Li	National Chiao Tung University
	Information Systems	62	0.35%	Chang, Hsin Hsin	National Cheng Kung University
	Logistics & Transportation	16	0.07%	Sheu, Jiuh Biing	National Taiwan University
		154	0.65%	Yu, Ming Miin	National Taiwan Ocean University
		216	0.91%	Lu, Chung Cheng	National Chiao Tung University
	Sport, Leisure & Tourism	13	0.18%	Chen, Ching Fu	National Cheng Kung University
		40	0.57%	Lee, Tsung Hung	National Yunlin University of Science and Technology
Enabling & Strategic Technologies	Analytical Chemistry	719	0.70%	Lei, Kin Fong	Chang Gung University

	856	0.83%	Fu, Lung Ming	National Cheng Kung University
Applied Physics	2,366	0.88%	Young, Sheng Joue	National United University Taiwan
Bioinformatics	162	0.84%	Le, Nguyen Quoc Khanh	Taipei Medical University
Biotechnology	16	0.03%	Lee, Duu Jong	National Taiwan University
	31	0.06%	Chang, Jo Shu	Tunghai University
	85	0.16%	Chen, Jyh Ping	Chang Gung University
	190	0.36%	Chen, Chun Yen	National Cheng Kung University
	200	0.38%	Patel, Anil Kumar	National Kaohsiung University of Science and Technology
	225	0.43%	Singhania, Reeta Rani	National Kaohsiung University of Science and Technology
	323	0.62%	Hu, Yu Chen	National Tsing Hua University
	334	0.64%	Chang, Te Sheng	National University of Tainan Taiwan
	392	0.75%	Chen, Bor Yann	National Ilan University
Building & Construction	279	0.92%	Lin, Kae Long	National Ilan University
Chemical Engineering	378	0.57%	Liou, Tzong Horng	Ming Chi University of Technology
Energy	52	0.02%	Chen, Wei Hsin	National Cheng Kung University
	93	0.04%	Tsai, Wen Tien	National Pingtung University of Science and Technology
	224	0.10%	Chen, Shen Ming	National Taipei University of Technology
	459	0.20%	Hwang, Bing Joe	National Taiwan University of Science and Technology
	464	0.20%	Yang, Chun Chen	Ming Chi University of Technology
	692	0.30%	Hu, Chi Chang	National Tsing Hua University
	707	0.31%	Teng, Jen Hao	National Sun Yat-Sen University
	726	0.32%	Lin, Chiu Yue	Feng Chia University
	847	0.37%	Wu, Nae Lih	National Taiwan University
	982	0.43%	Wu, Mao Sung	National Kaohsiung University of Science and Technology
	1,080	0.47%	Hwang, Jenn Jiang	National University of Tainan Taiwan
	1,180	0.51%	Viswanathan, Karthickeyan	National Cheng Kung University
	1,398	0.61%	Gaing, Zwe Lee	Kao Yuan University Taiwan
	1,481	0.65%	Hsieh, Chien Te	Yuan Ze University
	1,648	0.72%	Chang, Tian Pau	Nankai University of Technology
	1,680	0.73%	Wang, Wei Cheng	National Cheng Kung University
	1,746	0.76%	Wang, Li	National Cheng Kung University

	1,995	0.87%	Lin, Cherng Yuan	National Taiwan Ocean University
	2,229	0.97%	Lin, Whei Min	National Sun Yat-Sen University
Materials	3	0.00%	Yeh, Jien Wei	National Tsing Hua University
	217	0.08%	Tsai, Ming Hung	National Chung Hsing University
	559	0.20%	Hocheng, Hong	National Tsing Hua University
	767	0.27%	Liu, Dean Mo	National Chiao Tung University
	811	0.28%	Hsueh, Chun Hway	National Taiwan University
	1,054	0.37%	Chi, Maochieh	National Taiwan Ocean University
	1,243	0.44%	Huang, H. H.	China Medical University Hospital Taichung
	1,318	0.46%	Ho, Wen Fu	National University of Kaohsiung
	1,634	0.57%	Chang, Shou Yi	National Tsing Hua University
	1,845	0.65%	Shun, Tao Tsung	Feng Chia University
	2,032	0.71%	Fu, Yen Pei	National Dong Hwa University
	2,099	0.74%	Chang, Yu Cheng	Feng Chia University
	2,123	0.74%	Lin, Chun Ming	National Taipei University of Technology
	2,145	0.75%	Tsao, Lung Chuan	National Pingtung University of Science and Technology
	2,378	0.83%	Chen, Swe Kai	National Tsing Hua University
	2,451	0.86%	Hong, H. Y.P.	National Taiwan University of Science and Technology
	2,461	0.86%	Ger, Ming Der	National Defense University Taiwan
	2,722	0.95%	Wang, Sea Fue	National Taipei University of Technology
Nanoscience & Nanotechnology	324	0.36%	Chu, Ying Hao	National Chiao Tung University
	565	0.63%	Ho, Kuo Chuan	National Taiwan University
	774	0.87%	Chung, Sheng Heng	National Cheng Kung University
	829	0.93%	Teng, Hsisheng	National Cheng Kung University
	878	0.98%	Hu, Che Ming Jack	Academia Sinica, Institute of Biomedical Sciences
Optics	523	0.81%	Wu, Pin Chieh	National Cheng Kung University
Optoelectronics & Photonics	240	0.22%	Lin, Gong Ru	National Taiwan University
	319	0.29%	Chow, Chi Wai	National Chiao Tung University
	421	0.39%	Yeh, Chien Hung	Feng Chia University
	564	0.52%	Lin, Jehnming	National Cheng Kung University
	690	0.64%	Lo, Yu Lung	National Cheng Kung University
	741	0.68%	Lin, Fan Yi	National Tsing Hua University
	852	0.79%	Chi, Yu Chieh	National Taiwan University
	981	0.91%	Lee, Chih Kung	National Taiwan University

Engineering	Aerospace & Aeronautics	306	0.60%	Juang, Jer Nan	National Cheng Kung University
	Artificial Intelligence & Image Processing	1,412	0.56%	Chang, Kuei Hu	Chinese Military Academy Taiwan
	Biomedical Engineering	155	0.24%	Lai, Jui Yang	Chang Gung University
		165	0.26%	Sung, Hsing Wen	National Tsing Hua University
		169	0.26%	Hsu, Shan hui	National Taiwan University
		532	0.83%	Lin, Feng Huei	National Health Research Institutes Taiwan
		628	0.97%	Chen, Po Yu	National Tsing Hua University
		641	0.99%	Chen, Mei Chin	National Cheng Kung University
	Chemical Engineering	50	0.08%	Juang, Ruey Shin	Chang Gung University
		118	0.18%	Lin, Kunyi Andrew	National Chung Hsing University
		163	0.25%	Tseng, Ru Ling	National United University Taiwan
		313	0.47%	Wu, Chung Hsin	National Kaohsiung University of Science and Technology
		322	0.49%	Wu, Feng Chin	National United University Taiwan
		398	0.60%	Lin, Yu Chuan	National Cheng Kung University
		424	0.64%	Lai, Juin Yih	National Taiwan University of Science and Technology
		635	0.96%	Chien, I. Lung	National Taiwan University
	Civil Engineering	150	0.31%	Yau, J. D.	Tamkang University
		346	0.73%	Loh, Chin Hsiung	National Taiwan University
		400	0.84%	Chou, Chung Che	National Taiwan University
		476	1.00%	Lin, Yu Cheng	National Taipei University of Technology
	Design Practice & Management	60	0.60%	Hsiao, Shih Wen	National Cheng Kung University
	Electrical & Electronic Engineering	63	0.06%	Wai, Rong Jong	National Taiwan University of Science and Technology
		116	0.11%	Lau, John H.	Unimicron Technology Corporation
		130	0.12%	Lin, Faa Jeng	National Central University
		223	0.21%	Wu, Yuan Kang	National Chung Cheng University
		245	0.23%	Wu, Tsai Fu	National Tsing Hua University
		258	0.25%	Yang, Lung Sheng	Far East University
		289	0.28%	Liang, Tsorng Juu Peter	National Cheng Kung University
		334	0.32%	Horng, Jiun Wei	Chung Yuan Christian University
		338	0.32%	Chen, Yaow Ming	National Taiwan University
		365	0.35%	Lai, Yen Shin	National Taipei University of Technology
		430	0.41%	Chen, Jiann Fuh	National Cheng Kung University

	460	0.44%	Su, Chun Lien	National Kaohsiung University of Science and Technology
	462	0.44%	Chen, Liang Rui	National Changhua University of Education
	494	0.47%	Chang, Meng Fan	National Tsing Hua University
	500	0.48%	Lin, Bor Ren	National Yunlin University of Science and Technology
	511	0.49%	Lee, Jin Shyan	National Taipei University of Technology
	525	0.50%	Lai, Ching Ming	National Chung Hsing University
	584	0.56%	Hwu, Kuo Ing	National Taipei University of Technology
	617	0.59%	Liu, Shen Iuan	National Taiwan University
	679	0.65%	Liu, Yi Hwa	National Taiwan University of Science and Technology
	698	0.66%	Lee, Jri	National Taiwan University
	731	0.70%	Yang, Shih Chin	National Taiwan University
	809	0.77%	Liaw, Chang Ming	National Tsing Hua University
	879	0.84%	Chao, Kuei Hsiang	National Chin-Yi University of Technology
	907	0.86%	Tseng, Kuo Ching	National Kaohsiung University of Science and Technology
	981	0.93%	Chu, Chia Chi	National Tsing Hua University
	989	0.94%	Shyu, Kuo Kai	National Central University
	994	0.95%	Hua, Chih Chiang	National Yunlin University of Science and Technology
	1,007	0.96%	Chen, Yie Tone	National Yunlin University of Science and Technology
	1,024	0.97%	Kim, Katherine A.	National Taiwan University
Energy	276	0.12%	Band, Shahab S.	National Yunlin University of Science and Technology
Environmental Engineering	200	0.39%	Weng, Chih Huang	I-Shou University
	288	0.56%	Shiau, Jenq Tzong	National Cheng Kung University
	394	0.77%	Chang, Fi John	National Taiwan University
	494	0.97%	Lin, Sheng H.	Yuan Ze University
	767	0.99%	Lo, Shang Lien	National Taiwan University
Geological & Geomatics Engineering	35	0.07%	Chang, Chein I.	Providence University Taiwan
	186	0.35%	Juang, C. Hsein	National Central University
	328	0.63%	Wu, Jian Hong	National Cheng Kung University
	367	0.70%	Ching, Jianye	National Taiwan University
Industrial Engineering & Automation	61	0.06%	Mobayen, Saleh	National Yunlin University of Science and Technology
	410	0.43%	Kuo, Tsai Chi	National Taiwan University of Science and Technology

		674	0.70%	Luo, Ren C.	National Taiwan University
		866	0.90%	Chen, Chih Chiang	National Cheng Kung University
	Materials	31	0.01%	Civalek, O.	China Medical University
		386	0.14%	Tsao, Chung Chen	LungHwa University of Science and Technology
	Mechanical Engineering & Transports	113	0.10%	Wang, Chi Chuan	National Chiao Tung University
		130	0.12%	Yan, Wei Mon	National Taipei University of Technology
		139	0.13%	Hsiao, Kai Long	Taiwan Shoufu University
		537	0.49%	Ho, C. J.	National Cheng Kung University
		570	0.52%	Wu, Horng Wen	National Cheng Kung University
		646	0.59%	Chen, Chien Hsin	National Formosa University Taiwan
		736	0.67%	Ju, Shen Haw	National Cheng Kung University
		742	0.68%	Jeng, Yeau Ren	National Cheng Kung University
		888	0.81%	Liu, Kuo Chi	Far East University
		935	0.85%	Chen, Chao Kuang	National Cheng Kung University
		947	0.86%	Cho, Ching Chang	National Formosa University Taiwan
		1,019	0.93%	Lin, J. R.	Nanya Institute of Technology Taiwan
		1,058	0.96%	Pao, Yih Hsing	Institute of Applied Mechanics, National Taiwan University
	Operations Research	12	0.05%	Kao, Chiang	National Cheng Kung University
		106	0.41%	Wee, Hui Ming	Chung Yuan Christian University
		126	0.48%	Tsao, Yu Chung	National Taiwan University of Science and Technology
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		197	0.76%	Chen, Mu Chen	National Chiao Tung University
		210	0.81%	Liu, Shiang Tai	Vanung University Taiwan
		236	0.91%	Lee, Amy H.I.	Chung Hua University
	Science Studies	2	0.05%	Ho, Yuh Shan	Asia University
Historical Studies	Archaeology	90	0.71%	Turner-Walker, Gordon	National Yunlin University of Science and Technology
Information & Communication Technologies	Acoustics	307	0.95%	Kuo, Sen M.	Chung Yuan Christian University
	Artificial Intelligence & Image Processing	33	0.01%	Chen, Shyi Ming	National Taiwan University of Science and Technology
		96	0.04%	Lin, Chih Jen	National Taiwan University
		152	0.06%	Jang, Jyh Shing Roger	National Taiwan University
		169	0.07%	Hong, Wei Chiang	Oriental Institute of Technology Taiwan
		233	0.09%	Chen, Ting Yu	Chang Gung University

238	0.09%	Tsai, Chih Fong	National Central University
245	0.10%	Tzeng, Gwo Hshiung	National Taipei University
352	0.14%	Cheng, Ching Hsue	National Yunlin University of Science and Technology
393	0.16%	Liao, Shu Hsien	Tamkang University
526	0.21%	Yeh, I. Cheng	Tamkang University
550	0.22%	Yeh, Wei Chang	National Tsing Hua University
562	0.22%	Yang, Miin Shen	Chung Yuan Christian University
612	0.24%	Chen, Chih Ming	National Chengchi University
655	0.26%	Wu, Wei Wen	Ta Hwa University of Science and Technology
664	0.26%	Pao, Hsiao Tien	National Chiao Tung University
669	0.26%	Kuo, R. J.	National Taiwan University of Science and Technology
685	0.27%	Chen, Chen Tung	National United University Taiwan
691	0.27%	Chang, Chin Chen	Feng Chia University
783	0.31%	Liou, James J.H.	National Taipei University of Technology
851	0.34%	Chen, Mu Yen	National Cheng Kung University
867	0.34%	Yang, Ching Nung	National Dong Hwa University
877	0.35%	Wu, Hsien Chung	National Kaohsiung Normal University
1,091	0.43%	Hong, Wien	National Taichung University of Science and Technology
1,092	0.43%	Raja, Muhammad Asif Zahoor	National Yunlin University of Science and Technology
1,148	0.45%	Huang, Shih Chia	National Taipei University of Technology
1,221	0.48%	Tsai, Du Ming	Yuan Ze University
1,377	0.54%	Lee, Cheng Chi	Asia University
1,484	0.59%	Wong, Tzu Tsung	College of Management
1,495	0.59%	Tsai, Chun Wei	National Sun Yat-Sen University
1,637	0.65%	Pai, Ping Feng	National Chi Nan University
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1,692	0.67%	Tseng, Vincent S.	National Chiao Tung University
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	2,484	0.98%	Singh, Pritpal	National Taipei University of Technology
Computation Theory & Mathematics	104	0.58%	Lee, D. T.	Academia Sinica, Institute of Information Science
Computer Hardware & Architecture	174	0.96%	Ho, Tsung Yi	National Tsing Hua University
Education	327	0.47%	Huang, Yueh Min	National Cheng Kung University
Electrical & Electronic Engineering	626	0.60%	Chang, Hsueh Hsien	Jinwen University of Science and Technology
Information Systems	29	0.16%	Wang, Yi Shun	National Changhua University of Education
	69	0.38%	Chiu, Chao Min	National Sun Yat-Sen University
	90	0.50%	Liang, Ting Peng	National Sun Yat-Sen University
	94	0.52%	Wu, Ing Long	National Chung Cheng University
	121	0.67%	Teng, Ching I.	Chang Gung University
	132	0.73%	Fang, Yu Hui	Tamkang University
	154	0.86%	Wang, Eric T.G.	National Central University
	163	0.91%	Lu, Hsi Peng	National Taiwan University of Science and Technology
Networking & Telecommunications	154	0.08%	Navimipour, Nima Jafari	National Yunlin University of Science and Technology
	237	0.13%	Chen, Hsiao Hwa	National Cheng Kung University
	328	0.18%	Lee, Ming Chi	National Pingtung University
	374	0.20%	Wong, Kin Lu	National Sun Yat-Sen University
	446	0.24%	Pei, Soo Chang	National Taiwan University

		570	0.31%	Yeh, Kuo Hui	National Dong Hwa University
		735	0.40%	Tseng, Chien Cheng	National Kaohsiung University of Science and Technology
		778	0.42%	Wen, Chao Kai	National Sun Yat-Sen University
		806	0.44%	Chen, Jung Chieh	National Kaohsiung Normal University
		863	0.47%	Tsai, Jia Lun	National Chung Hsing University
		875	0.48%	Row, Jeen Sheen	National Changhua University of Education
		925	0.50%	Lin, Chun Cheng	National Chiao Tung University
		1,097	0.60%	Chao, Han Chieh	National Dong Hwa University
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		1,352	0.74%	Lin, Ying Dar	National Chiao Tung University
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		1,703	0.93%	Liu, Chun Lin	National Taiwan University
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		1,753	0.95%	Chen, Chi Feng	Tunghai University
		1,776	0.97%	Jiang, Jehn Ruey	National Central University
		1,778	0.97%	Su, Ming Yang	Ming Chuan University
		1,785	0.97%	Wang, Li Chun	National Chiao Tung University
		1,821	0.99%	Chen, Horng Dean	National Kaohsiung Normal University
		1,823	0.99%	Wang, You Chiun	National Sun Yat-Sen University
		1,827	0.99%	Fang, Shih Hau	Yuan Ze University
Mathematics & Statistics	Applied Mathematics	137	0.77%	Hsu, Sze Bi	National Tsing Hua University
	General Mathematics	124	0.21%	Yao, J. C.	China Medical University
		137	0.23%	Mursaleen, M.	China Medical University Hospital Taichung
		201	0.34%	Lin, Chang Shou	National Taiwan University
		338	0.57%	Chang, Shih sen	China Medical University
	Numerical & Computational Mathematics	41	0.28%	Stević, Stevo	China Medical University Hospital Taichung
		47	0.32%	Lin, Yi Chi	Chang Gung University College of Medicine
	Statistics & Probability	80	0.41%	Shmueli, Galit	National Tsing Hua University

Physics & Astronomy	Applied Physics	159	0.06%	Liu, Ru Shi	National Taiwan University
		843	0.31%	Chen, Lih Juann	National Tsing Hua University
		1,002	0.37%	Ho, Ching Hwa	National Taiwan University of Science and Technology
		1,060	0.39%	Guo, Guang Yu	National Taiwan University
		1,216	0.45%	Sze, Simon M.	National Chiao Tung University
		1,378	0.51%	Chiu, Fu Chien	Ming Chuan University
		1,385	0.51%	Galagan, Yulia	National Taiwan University
		1,413	0.52%	Lin, Hsin	Academia Sinica, Institute Of Physics
		1,421	0.53%	Chen, Fang Chung	National Chiao Tung University
		1,667	0.62%	Pai, Chi Feng	National Taiwan University
		1,678	0.62%	Chin, Tsung Shune	Feng Chia University
		1,704	0.63%	Chen, Chin Ti	Academia Sinica, Institute of Chemistry
		1,770	0.66%	Chen, Li Chyong	National Taiwan University
		1,970	0.73%	Chen, Chien Te	National Synchrotron Radiation Research Center Taiwan
		2,244	0.83%	Chang, Chi Jung	Feng Chia University
		2,353	0.87%	Wu, Chung Chih	National Taiwan University
		2,367	0.88%	Chang, Shoou Jinn	National Cheng Kung University
		2,369	0.88%	Lin, Yu Ming	Taiwan Semiconductor Manufacturing Company
		2,426	0.90%	Lee, Ching Ting	National Cheng Kung University
		2,560	0.95%	Chang, Tay Rong	National Cheng Kung University
		2,606	0.97%	Khandy, Shakeel Ahmad	National Taiwan University
	Chemical Physics	211	0.23%	Chai, Jeng Da	National Taiwan University
	General Physics	60	0.08%	Inc, Mustafa	China Medical University Hospital Taichung
		427	0.60%	Ho, Yew Kam	Academia Sinica, Institute of Atomic and Molecular Sciences
		607	0.85%	Chu, Shih I.	National Taiwan University
	Nuclear & Particle Physics	162	0.12%	Cheng, Hai Yang	Academia Sinica, Institute Of Physics
		367	0.27%	Sasaki, Misao	National Taiwan University
		499	0.37%	Cheung, K.	National Tsing Hua University
		518	0.38%	Hou, Wei Shu	National Taiwan University
		635	0.47%	He, Xiao Gang	National Taiwan University
		892	0.66%	Chen, P.	National Taiwan University
		899	0.66%	Ohta, Nobuyoshi	National Central University
		1,340	0.99%	Li, Hsiang nan	Academia Sinica, Institute Of Physics

	Optics	221	0.34%	Chen, Y. F.	National Chiao Tung University
		342	0.53%	Yeh, Pochi	National Chiao Tung University
	Optoelectronics & Photonics	364	0.34%	Kuo, Hao Chung	National Chiao Tung University
		646	0.60%	Lu, Tien Chang	National Chiao Tung University
		694	0.64%	Sun, Chi Kuang	National Taiwan University
Public Health & Health Services	Nursing	221	0.24%	Hsieh, Hsiu Fang	Fooyin University Taiwan
		224	0.25%	Chou, Kuei Ru	Taipei Medical University Shuang-Ho Hospital
		395	0.44%	Tsay, Shiow Luan	Da-Yeh University
		473	0.52%	Tsai, Yun Fang	Chang Gung Memorial Hospital
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		548	0.60%	Shyu, Yea Ing L.	Chang Gung Memorial Hospital
		612	0.68%	Yeh, Mei Ling	National Taipei University of Nursing and Health Sciences
		625	0.69%	Chen, Yu Chih	Veterans General Hospital-Taipei
		702	0.77%	Hsiao, Chiu Yueh	Chang Gung Memorial Hospital
		710	0.78%	Hsu, Li Ling	Ching Kuo Institute of Management & Health
		746	0.82%	Chang, Shu Fang	National Taipei University of Nursing and Health Sciences
		772	0.85%	Wang, Jing Jy	National Cheng Kung University College of Medicine
		877	0.97%	Lai, Hui Ling	Tzu Chi University
		884	0.98%	Huang, Tzu Ting	Chang Gung University College of Medicine
	Rehabilitation	54	0.22%	Pan, Chien Yu	National Kaohsiung Normal University
Social Sciences	Education	18	0.03%	Hwang, Gwo Jen	National Taiwan University of Science and Technology
		24	0.03%	Tsai, Chin Chung	National Taiwan Normal University
		155	0.22%	Huang, Chiungjung	National Changhua University of Education
		286	0.41%	Liaw, Shu Sheng	China Medical University
		432	0.62%	Hung, Hsiu Ting	National Kaohsiung University of Science and Technology
		462	0.66%	Yang, Ya Ting Carolyn	National Cheng Kung University
		463	0.66%	Hsu, Ting Chia	National Taiwan Normal University
		492	0.70%	Hou, Huei Tse	National Taiwan University of Science and Technology
		684	0.98%	Wu, Hsin Kai	National Taiwan Normal University
	Information & Library Sciences	34	0.28%	Hsiao, Kuo Lun	National Taichung University of Science and Technology

	50	0.41%	Huang, Mu Hsuan	National Taiwan University
	111	0.91%	Chang, Chiao Chen	Taipei Medical University

Source: Scopus database

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Shigeru Kitaba	(JST Asia and Pacific Research Center, Director)
Masabumi Kawasaki	(JST Asia and Pacific Research Center, Chief)

This report summarizes the results of “Research on science and technology innovation policy trends and research and development trends in Taiwan” commissioned by the Asia and Pacific Research Center, Japan Science and Technology Agency to Nomura Research Institute Taiwan Co., Ltd. in the April 2021-March 2022 fiscal year. We would like to take this opportunity to thank the many people who cooperated with us in carrying out our work.

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