Part 1

For Further Reinforcing the Fundamental Capability for STI

Chapter 1 Reality of and Challenges to Fundamental Capability for STI

Section 1: Why is the reinforcement of fundamental capability necessary?

1 Role of fundamental capability in creating science, technology and innovation

Science and technology have been contributing to the development of entire human society. There are extremely strong expectations for science and technology now that human beings as a whole will have to address global warming, energy and other problems. In particular, Japan, short on natural resources, has been working to become “the Advanced Science and Technology-oriented Nation” that opens up its future with science and technology. Science and technology have greatly contributed to the sustainable development of Japan’s economy and society and improvement of its social welfare. To become “the world’s most innovation-friendly country,” science and technology will become more important for sustainable growth, self-sustaining development of local communities, the safety and security of the nation and citizens, affluent and high-quality daily life, responses to global problems and contribution to world development, and sustainable creation of knowledge as assets.

With the start of the 21st century, rapid advances in information and communication technology as well as the development of IoT, robotics, AI and other technologies have greatly changed the lifestyle of people and the industrial structure. In addition, social and economic structures are greatly changing as various social activities are underway beyond national boundaries amid further globalization. While these movements are mutually linked and accelerating, they are greatly affecting the creation of science, technology and innovation.

Amid these developments, there are signs of a decline in Japan’s position in terms of research capacity such as the dwindling number of research papers and a fall in its international share in the number of adjusted top 10% papers, which is an indicator of the quality of papers. Regarding Japan’s international share in the number of scientific papers, the Nature Index of March 2017 noted a fall in Japan’s share of high-quality scientific papers. These signs show that Japan’s scientific studies have been stalling in recent years.

In the meantime, Japan needs a fundamental capability that makes it possibly to flexibly and accurately deal with various situational changes for successive creation of science, technology and innovation. The 5th Science and Technology Basic Plan (adopted at a Cabinet meeting on January 22, 2016, and hereinafter referred to as the “basic science and technology plan) calls for reinforcement of this fundamental capability by strengthening human resources, the foundations of knowledge and financial reforms.

Since the start of the 21st century, Japan has trailed only the U.S. in the number of Nobel laureates in fields related to natural science. Innovative and bold studies tenaciously continued by excellent researchers have resulted in achievements highly esteemed globally. In addition to such achievements that have led to Nobel prizes, Japan has produced excellent study results in wide-ranging areas, supported by none other than “people.” Human resources that create new knowledge and value and achieve innovation are the core of fundamental capability.

With regard to the foundations of knowledge, furthermore, Japan has generated a variety of excellent knowledge as the source of innovation through steady advances in academic researches and basis studies. In addition, Japan has supported excellent research activities by establishing cutting-edge research facilities and equipment and information infrastructure, etc., while encouraging their joint use and establishing institutions and mechanisms for science, technology and innovation.

As for research funds, research and development investment has been secured from both public and private sectors. According to a research report on scientific and technological studies compiled by the Ministry of Internal Affairs and Communications, a total of 19 trillion yen was invested in R&D programs in fiscal 2016. In particular, governmental expenses consist of foundational expenses, such as subsidies for the management of universities, to support research and education on a stable and continuous basis and public subscription-type funds aimed at financing excellent studies or those with specific purposes. The combined expenses have supported the base of science, technology and innovation activities.

Fundamental capability such as "human resources," "foundations of knowledge" and "research funds," have thus been playing important roles to create science, technology and innovation.

2　Diversification of process of and acceleration of speed of innovation

The transitional process of knowledge toward the social implementation of study results has diversified and speed of the transition has accelerated in recent years.

Venture businesses, for example, are generally said to have a faster sense of speed for management. They can make prompt decisions and implement risk-taking management under flexible organizations. While taking advantage of such strength, they can quickly bring new technologies to the market by utilizing excellent studies and bold ideas. Venture businesses include those that have destroyed existing business models and been growing noticeably while developing new markets.

In recent years in particular, the widespread availability of information and communication infrastructure has made it easier through the Internet not only to gain access to global markets and expand sales routes but also to promptly raise funds and secure human resources. As the cost of launching businesses therefore has dropped sharply, venture businesses have become highly active throughout the world.

These activities have been especially noticeable since the 2000s at IT companies and mega-venture businesses such as Google Inc., Apple Inc. and Facebook Inc., many of which are based in Silicon Valley in the United States. The companies, as a common feature, are based on IT and have captured core positions in platforms in their business models and have grown rapidly since they were founded. They also rank high in global rankings by market capitalization.

As a recent trend, the companies are aggressively investing not only in IT but also in technologies across the board and accelerating investment in and acquisition of venture businesses having advanced technologies and human resources. Recent deals that drew significant attention include Google's 2014 acquisition of DeepMind Technologies, a British AI-related venture business that developed AlphaGo, an AI program that beat a professional human player of the board game Go for the first time.

There are cases in which acquisitions lead to the social implementation of study results in a short period of time because acquired venture businesses can rely on big companies during the phase of development that requires huge funds. Open innovation, such as investment in venture businesses by big companies or mergers and acquisitions by them, are not limited to Silicon Valley as competition to acquire excellent personnel and study results is accelerating all over the world, including Japan, amid advances in globalization.

The process from study results to their social implementation was occasionally explained as a classical linear model stating that results of basic studies eventually culminate in sales of products through application and development researches aimed at achieving practical use of them. As mentioned above, however, there are cases in which results of basic studies are directly led to social implementation amid trends of venture businesses and open innovation.

The process of innovation that connects new knowledge to economic, social and public values is changing greatly, as just mentioned. The change is accelerating day-to-day and growing more diversified, coupled with remarkable advances in science and technology and rapid globalization.

3 Need and importance of further reinforcing fundamental capability

"Society 5.0" that Japan aspires to is a society that will highly integrate cyberspace and physical space by means of IoT, big data, AI, robotics and other technologies and will be able to provide goods and services to people in need when necessary and in the necessary amounts. Responding to various social needs, the society will ensure high-quality services for all people. As "Society 5.0" will realize affluent and high-quality daily life for citizens and help improve productivity, Japan needs to become the first country in the world to achieve it.

On the other hand, challenges in Japan and abroad, such as energy constraints, a falling birth rate and aging population, escalation of global problems and changes in security environments, are increasing and growing complex. Science and technology are now expected to contribute more than ever before to settling them. In addition, the situation concerning science, technology and innovation is going through great changes, including the diversifying and accelerating process of innovation, as mentioned above. Japan, in particular, is faced with a fall in research capacity, caused by a delay in participation of international brain environment circulation and a slowdown in the number of young researchers, and thus needs to settle the problems and continuously create excellent knowledge.

Under the circumstances, Japan should not be bound by existing paradigms but push ahead with bold and brave programs for the creation of innovation in order to become "the world's most innovation-friendly country" and continue growing in the future. To create knowledge that will serve as the source of innovation, the further reinforcement of fundamental capabilities -- "human resources," "foundations of knowledge" and "research funds" -- is becoming increasingly necessary and important.

Section 2 Current state of and challenges to fundamental capability

1 International fundamental capability comparison

Japan has been promoting innovation policy in an integrated manner as a nation. Scientific and technological achievements generated by the policy have brought great changes to people's life and the economy and continued to contribute to the development of not only Japan but also the rest of the world through such means as settling global problems. Since the start of the 21st century, Japan has attained the world's No. 2 position in the number of Nobel laureates in the field of natural science, testifying to the great presence of its scientific and technological power in the world.

In contrast with such great achievements, however, there also are various problems. As mentioned in Section 1, the creation of science, technology and innovation requires a strong fundamental capability as an indispensable factor. But Japan's fundamental capability is said to have been weakening rapidly in recent years.

This section will analyze movements concerning science, technology and innovation in other countries and the reality of Japan's position in the world, based on various indicators. The current state of Japan will be summarized through an international comparison of innovation policy trends of the top 7 countries in the fiscal 2016 ranking of R&D expenses -- Japan, the U.S., the United Kingdom, Germany, France, China and Republic of Korea which will be hereinafter referred to as "major countries" -- and main indexes.

(1) Science, technology and innovation policy trends of major countries

To make an international comparison to analyze Japan's fundamental STI capability, it is important to take the social situation of each country or region into consideration. Backgrounds of the major countries' fundamental capabilities, such as the trends of science, technology and innovation policies and science and technology-related budgets, will be analyzed for clarification here.

A. Science, technology and innovation policy

Countries have adopted policies focused on science and technology, especially innovation, and those for the creation of innovation designed for social implementation. Brief explanations of the major countries' science, technology and innovation policies follow here in connection with the reinforcement of the fundamental capability for innovation which will be analyzed in the section below (Table 1-1-1).

Human resources policies highly conscious of nurturing young researchers and developers and of international mobility have been introduced. For the cultivation of young researchers and developers, the U.S. government, for example, invests in the education of science, technology, engineering and mathematics to nurture bearers of innovation. From the viewpoint of international mobility, China has adopted an original policy of both encouraging students abroad to return to the country and actively sending competent students in China to topnotch institutions overseas.

Countries have also implemented original measures to reinforce research facilities and other foundations of knowledge. China, for example, designated national priority laboratories which were eligible for preferential budget appropriations and stably received some 8 million to 10 million yuan per year. Based on a decision to set up national laboratories above them, China had established 6 national laboratories by 2017 after starting in the 1990s. China then decided to create large-scale national laboratories, starting in 2000, and 15 large-scale national laboratories are awaiting authorization. Among other countries, the Republic of Korea is promoting projects such as construction of the International Science Business Belt having a particle accelerator and international basic study facilities. The ISBB project may be positioned as a large-scale regional cluster scheme.

In business-academia collaboration that contributes to an increase in research funds, there are moves to adopt measures focused on the establishment of bases or networks to put study results into practical use and create innovation. The UK, for example, is carrying out the "Catapult Programme" to create world-leading centers for science, technology and innovation in specific areas in which engineers and scientists engage in joint R&D work. France started the "Carnot Program" in 2006 that grants certain licenses and provides special support for public research institutes and higher educational institutes engaging in joint R&D work with enterprises. While public institutes have been hesitant to conduct joint work with enterprises, the value of direct contracts with enterprises for the entirety of Instituts Carnot more than doubled in 10 years thanks to the program.

Although simple comparison is difficult because countries have different structures, budget scales, social issues and geographical conditions, they lay weight on strengthening the fundamental capability for innovation and are making effective efforts as mentioned above.

Table 1-1-1 Science, technology and innovation policies of major countries

U.S.

<Basis policy>
The joint memorandum announced on August 17, 2017, by the Office of Management and Budget and the Office of Science and Technology Policy for compilation of the fiscal 2019 budget under the Trump administration, formed in 2017, gives top priority to national security and military technology, laying weight on the U.S. economic growth and efficient government operations. Unlike the Obama administration, the Trump administration has proposed the promotion of innovative basic studies, infrastructures and cultivation of human resources.
<Human resources policy>
The U.S. is promoting policies to meet 2 targets of maintaining an inflow of human resources from abroad and improving science and mathematics education for American people. Laying weight on STEM education to nurture bearers of innovation, the U.S. annually invests some $3 billion to implement necessary measures.
<Business-academia collaboration and regional promotion>
Various types of collaboration exist, ranging from spontaneous industrial clusters to state government-led industrial clusters. Government involvement varies depending on areas. There also are cases in which clusters have been formed through original networks established mainly by universities and enterprises and supported indirectly by state governments.
<Establishment of research facilities>
The U.S. has various R&D facilities and large ones are devoted to basic studies. Many large-scale R&D facilities belong to national laboratories under the wing of the Department of Energy. The National Science Foundation provides funds to fields such as gravitational-wave observation and to other fields with large-scale research equipment and facilities.

UK

<Basic policy>
"Our Plan for Growth: Science and Innovation," announced by the UK government in December 2014, shows 6 pillars, such as cultivation of competent human resources and investment in infrastructures of science, to make the UK the best place in the world for science and business. The UK government recently decided to extensively invest in R&D and innovation in a bid to wipe out concern about a cut in its budget for science and technology, with an eye toward coming negotiations for the UK's withdrawal from the European Union. The UK's Industrial Strategy, announced in November 2017, has a target of raising the ratio of R&D investment to 2.4% of its GDP by 2027 (1.6% in 2016).
<Human resources policy>
The UK has implemented measures for the development of research careers, such as new government investment and the establishment of a scholarship program and an entity to support the career of researchers.
<Business-academia collaboration>
The UK is working to reinforce business-academia collaboration for creation of innovation as it has been struggling in recent years to lead achievements of scientific studies to their practical use. Specifically, it is carrying out the "Catapult Programme" to establish world-leading centers for science, technology and innovation in specific areas in which engineers and scientists engage in joint R&D work and has established "University Enterprise Zones" where collaboration between startup companies and universities are encouraged to prompt entrepreneurship and innovation.

Germany

<Basic policy>
Germany announced the new High-Tech Strategy, more oriented toward innovation than before, in 2014 in the form of succeeding the high-tech strategy of the previous 8 years against the backdrop of a steady increase in R&D investment and favorable business sentiment. The new strategy sets forth that studies be preferentially implemented in fields where innovation is already exerting big driving power.
<Human resources policy>
Germany actively provides support for young human resources in the face of its aging population as in the case of Japan. The federal government launched the Tenure-Track-Professor program in 2017 to offers subsidies for 1,000 tenure-track posts and plans to continue it through 2032
<Business-academia collaboration>
In Germany, adopting a federal system, each state has its industrial policy and authority over education. Many business-academia clusters are formed on the basis of state governments' policies while the federal government provides significant subsidies for a limited time.
<Policy of reinforcing studies on cutting-edge manufacturing technology>
Germany has adopted "Industry 4.0," which stands for the Fourth Industrial Revolution, to promote R&D programs to digitize manufacturing technology. Multiple industry-academic-government collaboration projects are being implemented under the policy.

France

<Basic Policy>
The national research strategy "France Europe 2020," released in March 2015, upholds priority issues until 2020 and sets directions of research for 10 social challenges and 5 plans divided by theme. Specifically, "reasoned resource management and adaptation to climate change" and "clean, secure and efficient energy" are among them
<Human resources policy>
France has introduced a support program for young researches and policies aimed at empowerment of young people such as provision of subsidies to enterprises concluding three-year employment contracts with doctoral students.
<Business-academia collaboration>
The "Carnot Program" has been underway since 2006 to grant certain licenses and provide special support for public research institutes and higher educational institutes promoting joint R&D work with enterprises.
<Development of research foundation)
Funds are allocated under the "EQUIPEX" program to research facilities needed to promote advanced studies.

China

<Basic policy>
The 13th Five-Year Scientific and Technological Innovation Plan announced by China in August 2016 lays weight on innovation more clearly than past five-year science and technology plans. While the following policies set in the "Medium- to Long-Term Plan for the Development of Science and Technology" to make China into an innovation-oriented country with world-leading levels of science and technology by 2020 and the "National Innovation-Driven Development Strategy Outline" setting phased national goals 2050, the plan specifically presents matters to be implemented by 2020, including 10 priority areas for establishment of scientific and technological competitiveness.
<Human resources policy>
China has been making efforts to call back students studying abroad since the 1990s. In 2008, it introduced the "Thousand Talents Plan" in the form of reinforcing and integrating the call-back efforts. It launched the "Young Scholar 1000 Talents Plan" in 2011 to invite competent young researchers with foreign experience and the "National Plan for the Special Support of High-Level Talents" (commonly called the "Ten Thousand Talents Program") in 2012 to support competent researchers in China.
<Development of research foundation>
China designated national priority laboratories (designation of 75 laboratories belonging to enterprises in October 2015) which were eligible for preferential budget appropriations and stably received some 8 million to 10 million yuan per year. Based on a decision to set up national laboratories above them, China had established 6 national laboratories by 2017 after starting in the 1990s. China then decided to create large-scale national laboratories, starting in 2000, and 15 large-scale national laboratories are awaiting authorization.

Republic of Korea

<Basic policy>
"The fourth industrial revolution led by science and technology" is adopted as one of 5 strategies under "living prosperously together," which is the second of 5 main national goals, along with 3 challenges to national policy -- (1) fourth industrial revolution, (2) creation of environments for science, technology and innovation and (3) support for young scientists and basic studies.
<Human resources policy>
The policy is aimed at nurturing human resources in step with the times through such measures as expanding the integrated education of software to lead the fourth industrial revolution and establishing the foundation of lifelong education.
<Business-academia collaboration>
Adopting a policy of changing the purpose of business-academia collaboration to the launch of new businesses or creation of new industries, the Republic of Korea not only supports technological innovation by small and midsize enterprises and venture businesses but also targets a "total solution-type policy" such as promoting R&D plans with an eye toward intellectual property and abolishing regulations.
<Reinforcement of basic research foundation>
The Republic of Korea is promoting projects such as construction of the International Science Business Belt having a particle accelerator and international basic study facilities. The ISBB project may be positioned as a large-scale regional cluster scheme.

(Reference) EU

<Basic policy>
The Framework Program 8 or "Horizon 2020" sets 3 priorities -- (1) excellence in science, (2) industrial leadership and (3) tackling social challenges -- and other programs and subscription-type funds are allocated in compliance with them. Studies have already gotten underway to work out the Framework Program 9 (plan period from 2021 to 2027) to succeed the Horizon 2020 due to end in 2020. For the successor program, which the European Commission has proposed calling the "Horizon Europe," appropriate a total budget of 10 million euros and set 3 new priorities -- (1) open science, (2) global challenge and industrial competitiveness and (3) open innovation. All proposals by the EC are still informal and the name, budget and contents are expected to be finalized by the end of fiscal 2019 after approval by the European Council and the European Parliament.

Source: Prepared by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) based on the "Overview Report on Research and Development: R&D Strategies by Major Countries (2018)" (March 2018) by the Center for Research and Development Strategy of the Japan Science and Technology Agency

B. Population transitions, etc.

Table 1-1-2 summarizes changes in the major countries' population and workforce every five years. It shows that the populations Japan and Germany partially contracted while other major countries generally displayed marked population increases. In 2015, the U.S. had a population 1.40 times larger than in 1981, logging the largest population growth among the major countries. Similar trends are seen in the major countries as far as their labor populations are concerned. In particular, the workforces of the U.S., Germany and Republic of Korea showed increases more than those of other countries, registering gains of about 1.43, 1.49 and 1.83 times, respectively.

It should be noted that population and other social situations affect each country's key policy issues and fiscal structures. In international comparisons and analyses of researcher numbers, aging and other changes in working population down the road, in addition to simple population comparisons, need to be taken into account. According to the 2017 Annual Report on the Aging Society, the population aging rate of Japan has been much higher than those of other countries. While the graying of Japan's population is forecast to rapidly advance toward 2020, its workforce is also expected to keep declining. With the aging of population expected to progress in other major countries as well, the pace of graying in China and Republic of Korea is forecast to be faster than in Japan.

As a general rule, a setback in the supply of labor may act as a drag on growth when the aging of population is underway. Efforts to make efficient use of labor are necessary in addition to the supply of potential labor. As science, technology and innovation plays a key role in such efforts, the importance of science, technology and innovation and the fundamental capability to support them is expected to further increase in Japan and other major countries.

Table 1-1-2 Changes in population and workforce (in thousands) in major countries

Year	Japan		U.S.		UK		Germany		France		China		Republic of Korea	
	Population	Workforce	Population	Workforce	Population	Workforce	Population	Workforce	Population	Workforce	Population	Workforce	Population	Workforce
1981	117,902	57,070	230,008	110,812	56,358	26,740	61,682	28,305	55,462	24,575	1,000,720	-	38,723	14,683
1985	121,049	59,630	238,506	117,695	56,554	27,486	61,024	28,434	56,649	25,020	1,058,510	-	40,806	15,592
1990	123,611	63,840	250,181	128,007	57,238	28,909	63,254	30,771	58,227	25,416	1,143,330	653,230	42,869	18,539
1995	125,436	66,660	266,588	133,924	58,025	28,024	81,308	39,376	59,501	25,771	1,211,210	688,550	45,093	20,845
2000	126,831	67,660	282,398	144,016	58,886	28,740	81,457	39,533	60,872	27,062	1,267,430	739,920	47,008	22,134
2005	127,755	66,510	295,993	150,711	60,413	30,133	81,337	40,928	63,133	28,102	1,307,560	761,200	48,185	23,743
2010	128,043	66,320	309,801	155,323	62,759	31,560	80,284	41,684	64,974	28,754	1,340,910	783,880	49,554	24,748
2015	126,981	65,980	321,173	158,520	65,110	32,921	81,687	42,097	66,590	29,496	1,374,620	800,910	51,015	26,913

[Population]

Note: The populations of the U.S., the UK, France and China increased in almost all years under review, while Germany witnessed its population consistently decrease from 2002 till 2011 but turn upward after 2011.

<U.S.> Data for the period from 2000 till 2012 are based on findings by the 2010 national census and exclude military personnel stationed overseas.

<German> The population of Germany till 1990 is that of old West Germany and of unified Germany after 1991.

Source: Prepared by MEXT based on the Organization for Economic Cooperation and Development's "Economic Indicators for MSTI" (February 2017)

[Workforce]

Note: Unlike population transitions, the workforces of major countries, in addition to Japan and Germany, also marked small ups and downs. Japan and Germany showed decreases from 1998 till 2004 and 2008 till 2012, respectively, but upward trends from 2004 till 2008 and after 2012. Germany maintains an increasing tendency on a long-term basis but repeated ups and downs on an annual basis. According to the Economic Bulletin (of September 2017) released by the European Central Bank, the increase in Germany's workforce since 2013 is considered greatly attributable to immigrants.

<Japan> Starting with results in January 2012, the basis of calculation has been changed to the estimated population (new standard) based on the fixed population of the 2010 national consensus. Taking fluctuations resulting from the change into account, data from 2005 till 2010 are posted after conversion to figures for the time-series continuation (adjusted based on the fixed population of the 2010 national consensus).

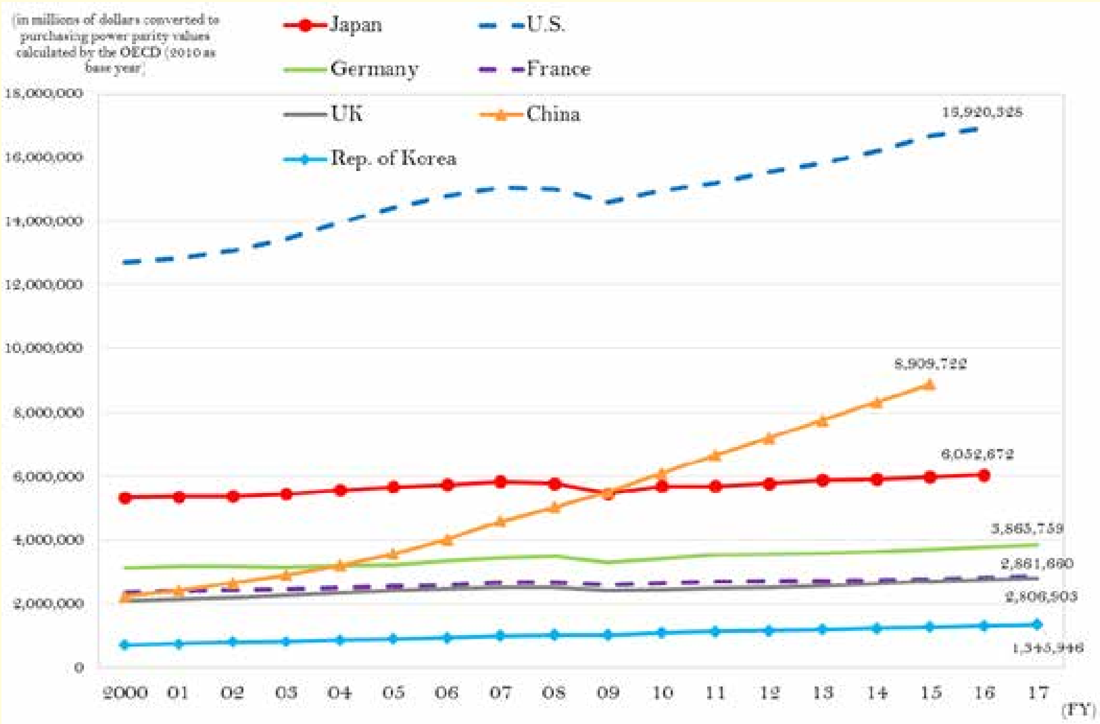
Source: Prepared by MEXT, based the Organization for Economic Cooperation and Development's "Economic Indicators for MSTI" (February 2017)

C. Gross Domestic Product (GDP)

Figure 1-1-3 shows changes in the major countries' GDP in real terms. Japan's real GDP has maintained solid growth as it expanded by 37 trillion yen in the five years from 2012 to an all-time high, though the rate of growth was slower than the rates of the U.S. and China.

The U.S. and China marked especially high GDP growth rates. The U.S. economy has maintained long-term growth for more than 8 years[1] since the global financial crisis thanks to such developments as an increase in consumer spending, a recovery in the corporate sector and a rise in employment in the labor market. In China, Shenzhen, which is called "Asia's Silicon Valley," has been drawing keen attention recently. The No. 1 city in China for many years in terms of GDP per capita is strengthening its presence as hub for the creation of innovation[2]. Active creation of innovation is considered to contribute to China's growth of GDP.

Figure 1-1-3 Changes in GDP of major countries



Source: Prepared by MEXT based on the OECD's "Main Science and Technology Indicators" (February 2017)

D. Changes in science and technology-related budgets

Figure 1-1-4 shows changes in science and technology-related budgets of the major countries. Japan's science and technology budgets are displaying a gradual increase over the long term. But in terms of growth rates from fiscal 2000 as the base year, the budgets of China and Republic of Korea have increased much more sharply, as seen in Figure 1-1-5, and the growth of Japan's budget has remained almost unchanged and slower in comparison with other major countries.

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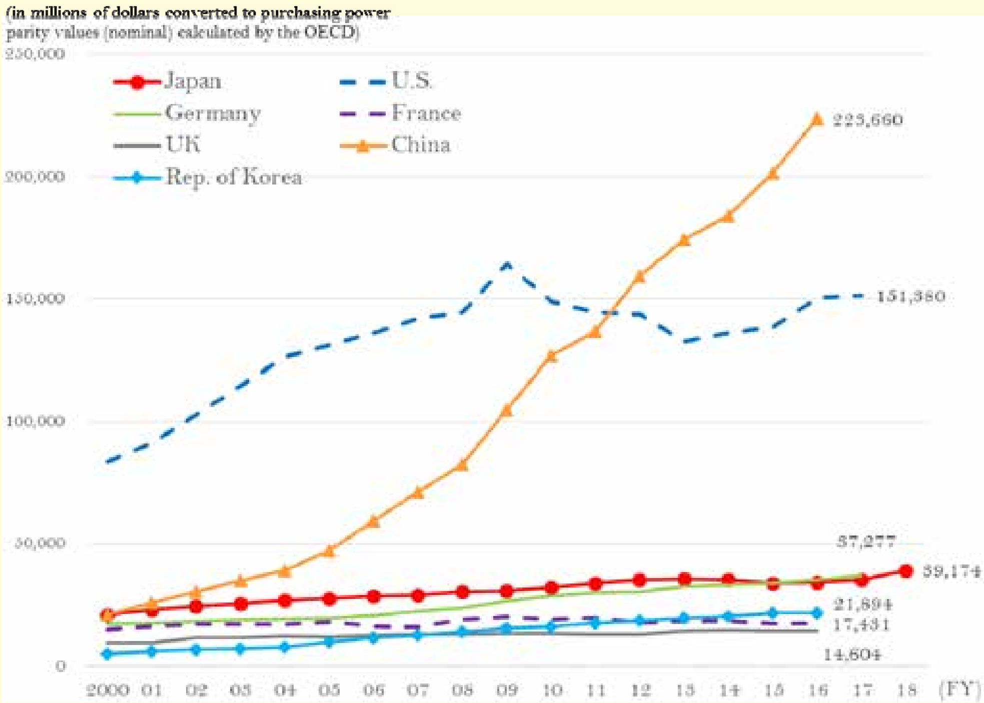
1 Based on cycle dating procedures of the U.S. National Bureau of Economic Research (NBER).

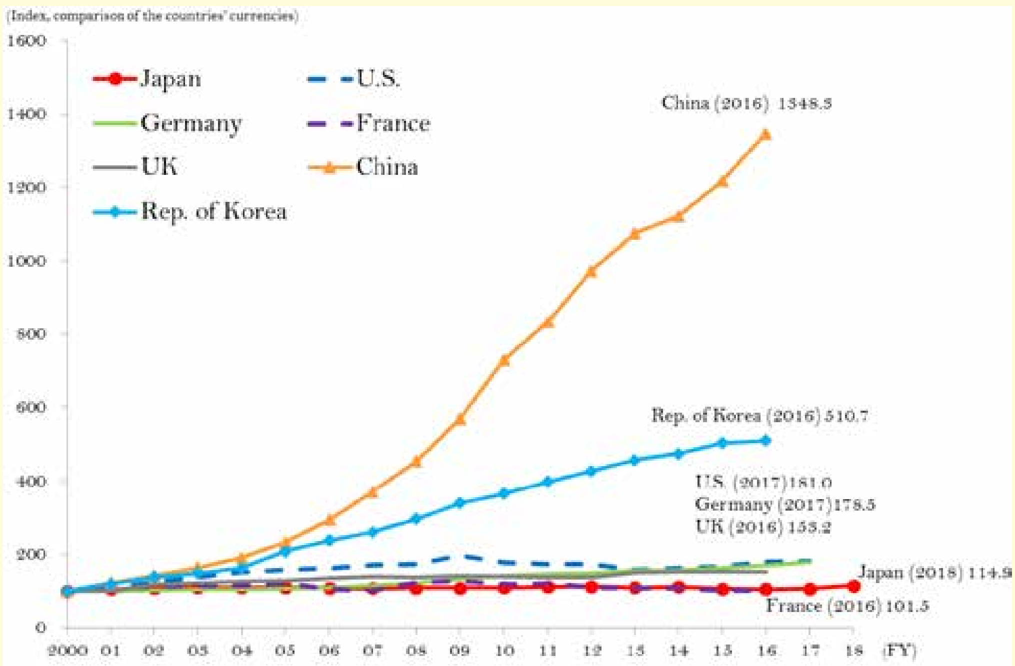
2 "World Economic Trend" published by the Cabinet Office (July 2017)

Figure 1-1-4 **Changes in science and technology-related government budgets of the major countries**



Note: Initial budgets of all countries
Source: Prepared by MEXT for China, based on "China Science and Technology Statistics" released by the Chinese Ministry of Science and Technology, and for others, based on the OECD's "Main Science and Technology Indicators" (February 2017)

Figure 1-1-5 **Changes in the major countries' science and technology-related budgets, using the base figure of 100 for fiscal 2000**



Source: Prepared by MEXT for China, based on "China Science and Technology Statistics" released by the Chinese Ministry of Science and Technology, and for others, based on the OECD's "Main Science and Technology Indicators"

(February 2017)

E. Tax systems for research and development

All major countries but Germany have adopted tax systems for research and development as incentives to promote corporate R&D programs. The systems deduct corporate income and other taxes in accordance with investment amounts and other expenses spent by enterprises on R&D programs and are utilized by the countries as effective means of creating innovation (Table 1-1-6 and Figure 1-1-7).

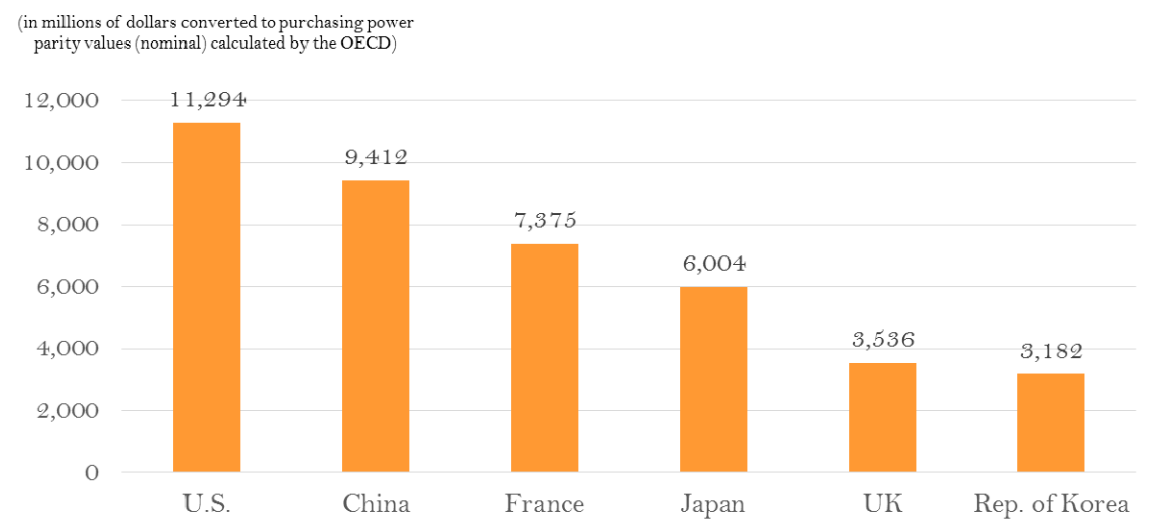
Table 1-1-6 Comparison of the countries' tax systems for research and development

Country	Gist and deduction rate	Cap on deduction	Carry-over	No. of user enterprises
Japan	Amounts calculated by multiplying experiment and research expenditures (Note 1) by the following deduction rates can be deducted from corporate income taxes in the year concerned. ・Aggregate amount type: 6~14% (Rates above 10% are valid through FY2018) (12~17% for small and midsize enterprises, etc. Rates above 12% are valid through FY2018) (Note 2) ・Open innovation type: 20% or 30% <Additional rate> ・High level type: Varies depending on experiment and research expenditures	Up to 40% of corporate income tax (aggregate amount type: 25% (*), OI type: 5%, high level type: 10%) *Additional 10% applies through FY 2018 to small and midsize enterprise, etc. logging an increase of more than 5%. For an experiment and research expenditure ratio of more than 10%, an additional 0~10% is applied through FY2018. (Adoption of option with high level type (additional 10% or high-level type for small and midsize enterprise, etc.)	Banned	Aggregate amount and open innovation types FY2016 Aggregate amount type: 8,888 Open innovation type: 397 Incremental type or high-level type (additional rate) (Note 3) FY2016 Growth type: 2,827 High level type: 150
U.S.	Principle method: (R&D expenditures in the year concerned - the average of total revenues in the previous 4 years x fixed expenses) x 20% Simplified method: (R&D expenditures in the year concerned - the average of R&D expenditures in the previous 3 years x 50%) x 14% * Chosen from either of them	None (Combined with other business-related tax deductions, a cap of around 75% exists on corporate income taxes)	20 years	2013: 16,624
UK	Big enterprises: 12% (Also applicable to small and midsize enterprise commissioned by big enterprises) Small and midsize enterprise: Preferential treatment (inclusion in special expenses)	Big enterprises: None Small and midsize enterprises: 7.5 million euros	Unlimited (Refund is possible when certain conditions are met)	<Big enterprise scheme> Year ended in March 2016 (provisional): 4,385 <Small and midsize enterprise scheme> Year ended in March 2016 (provisional): 21,865
France	・Qualified R&D expenditures of less than 100 million euros: 30% ・Qualified R&D expenditures of more than 100 million euros: 5% For small and midsize enterprises: 20% high-level innovation expenditures in addition to the above-mentioned rates	None	3 years (refund is possible after lapse of the period)	2014: 15,609
China	Preferential treatment as inclusion in expenses instead of R&D tax reduction	None	5 years	2014: 63,676
Republic of Korea	1. Priority areas (aggregate amount type): 20~25% (30% for small and midsize enterprise) 2. Non-priority areas (option from (1) or (2)): (1) Aggregate amount type 2~5% (25% for small and midsize enterprise) (2) Incremental type 25~40% (50% for small and midsize enterprise)	Presence (Corporate income tax before tax deduction - minimum tax cut) None for small and midsize enterprises	5 years	・Cases excluding tax system for capital investment in development of research personnel 2014: 19,627

Notes: 1. Applicable to experiment and research expenditures included in expenses in calculating income
2. For the aggregate amount type, deduction rates vary depending on experiment and research expenditures
3. Incremental type was abolished at the end of FY2016

Source: Prepared by MEXT, based on the "Fact-Finding Survey of Research and Development Tax Systems, etc. of Major Overseas Countries" by the Ministry of Economy, Trade and Industry (February 2017) and the Finance Ministry's "Report on Results of Fact-Finding Survey of Special Taxation Measures (submitted to the Diet in February 2018),"

Figure 1-1-7 **Indirect government support for corporate research and development programs in the major countries)**



Note: Indirect support represents an amount deducted from corporate income tax through preferential tax measures for corporate R&D programs.
Figures for France, the U.S. and China are as of 2013 while those for Republic of Korea, the UK and Japan are as of FY2014.
Source: Prepared by MEXT based on the OECD's "R&D Tax Incentive Indicators" (February 2017)

(2) International comparison of principal indexes

A. Indexes for creation of science, technology and innovation

Principal indexes used to internationally compare the creation of innovation are taken up to outline Japan's creation of science, technology and innovation. Specifically, trends of the major countries are mentioned through reference to (A) innovation rankings in the Global Competitiveness Report published by the WEF[1], (B) intellectual property rights and (C) comparison of top 10 Japanese and U.S. companies in terms of market capitalization.

(A) Innovation rankings (WEF Global Competitive Report)

The World Economic Forum (WEF) publishes the competitive rankings of countries, based on the Global Competitiveness Index, in its Global Competitiveness Report.[2]

According to the 2017 Global Competitiveness Report published at the end of 2017, Japan ranked 8th in "innovation," one of the 12 pillars of competitiveness. Although the ranking remained unchanged from the previous year, Japan's innovation is considered to be declining in comparison with other countries as it had ranked 4th to 5th each year through 2016. An analysis of the indexes, which consist of the rankings, shows that Japan dropped in rankings in all indexes but the number of applications for patents per

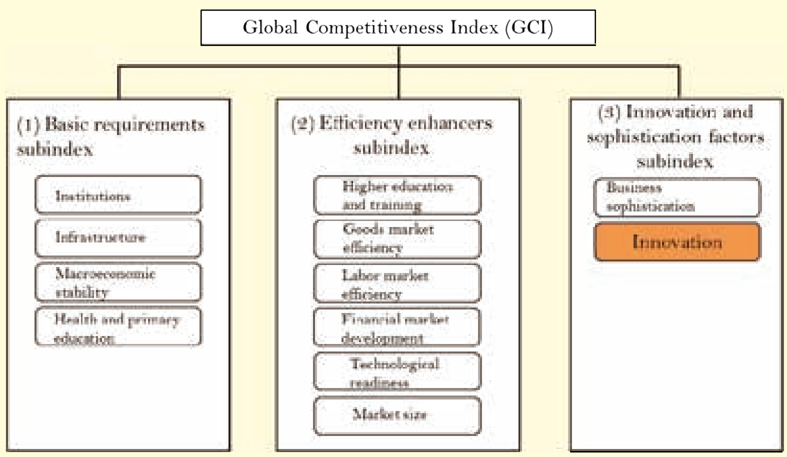
1 World Economic Forum: The WEF is a nonprofit organization consisting of leading enterprises in the world, especially those of the U.S. and Europe. Established in 1971 and headquartered in Colony, a municipality in the Canton of Geneva, Switzerland; the WEF holds its annual meeting in Davos.

2 Defining competitiveness as "the set of institutions, policies and factors that determine the level of productivity of a country," the annual Global Competitiveness Reports ranks 137 countries and regions based on published statistical data and results of a questionnaire covering more than 12,000 corporate executives. The rankings are based on comprehensive evaluation calculated by weight-averaging assessment scores given to the three components of the 12 pillars, seen in Table 1-1-8. Rankings of indexes in "Innovation," one of the 12 pillars, are dubbed the innovation ranking.

population of 1 million in which it retained the No. 1 position. In particular, the report showed Japan's relative weakness in the indexes of "corporate capacity for innovation," "university-industry collaboration in R&D" and "government procurement of advanced technology products." (Figure 1-1-8)

There are various reasons for ups and downs in rankings in each index. For example, the steep drop in "capacity for innovation" is considered attributable to changes in the survey items for the index, according to an analysis by the Cabinet Office[1]. Which each index in the pillar is measured by a questionnaire of corporate managers, the question was changed from how enterprises of home country acquire technologies in order to ask about proprietary capacity for R&D to how much capacity for innovation enterprises of home country maintain in order to check the capacity for innovation. The Cabinet Office concluded that the change caused Japan's ranking to fall. In other words, the fall was possibly ascribable to a decline in the assessment of Japan by corporate managers of the country and reflects Japan's weakness in capacity of leading R&D achievements to social values and in open innovation.

Figure 1-1-8 Indexes in WEF Global Competitive Report



Japan's rankings in 12 pillars

	2017 (137 countries)		(2016)	[2015]
(1)	1. Institutions	17	(16)	[13]
	2. Infrastructure	4	(5)	[5]
	3. Macroeconomic stability	93	(104)	[121]
	4. Health and primacy education	7	(5)	[4]
(2)	5. Higher education and training	23	(23)	[21]
	6. Goods market efficiency	13	(10)	[11]
	7. Labor market efficiency	22	(19)	[21]
	8. Financial market development	20	(17)	[19]
	9. Technological readiness	15	(19)	[19]
	10. Market size	4	(4)	[4]
(3)	11. Business sophistication	3	(2)	[2]
	12. Innovation	8	(8)	[5]

Indexes in the pillar of "innovation"

Category	Index	Ranking	(Previous year)	[Second previous year]	Questionnaire
Innovation	Capacity for innovation	21	(21)	[14]	○
	Quality of science research institutions	14	(13)	[7]	○
	Company spending on R&D	3	(4)	[2]	○
	University-industry collaboration in R&D	23	(18)	[16]	○
	Government procurement of advanced technology products	23	(16)	[14]	○
	Availability of scientists and engineers	8	(3)	[3]	○
	PCT patents applications/million population Average in 2013-2014	1	(1)	[1]	

Source: Prepared by MEXT based on the WEF's "The Global Competitiveness Report 2017-2018," "The Global Competitiveness Report 2016-2017" and "The Global Competitiveness Report 2015-2016"

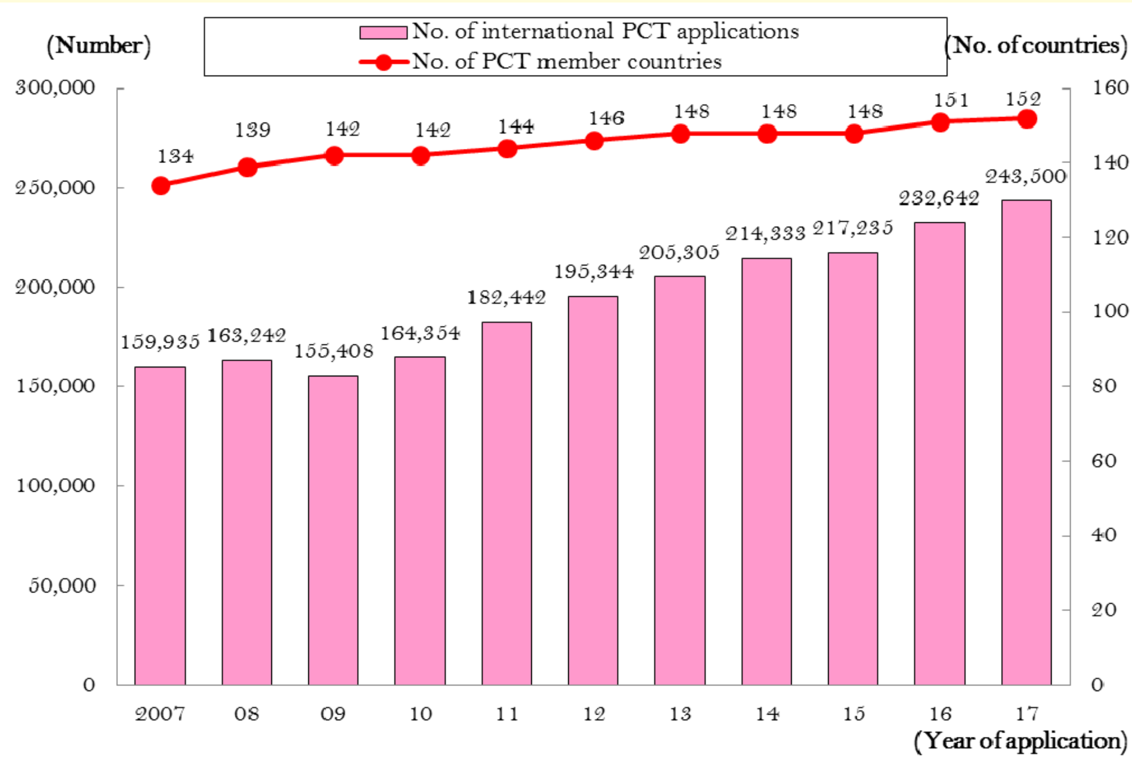
1 Reference material distributed at the Council on Investments for the Future's the meetings for the thorough promotion of structural reforms "Fourth Industrial Revolution (Society 5.0) and Innovation" meeting (Innovation)

(B) Intellectual property rights

The following is an account of movements concerning intellectual property rights, using international trends with regard to the number of international PCT patent applications[1].

The number of patent applications in the world, tallied based on the number of international PCT applications, has basically kept increasing and Japan shows a sharper upward trend in comparison with the numbers of international PCT applications by other major countries (Figure 1-1-9 and Figure 1-1-10). The increase in the number of international PCT applications by Japan is considered ascribable to the further globalization of activities by Japanese companies, etc. and an increase in the recognition of merits of international PCT applications.[2]

Figure 1-1-9 Changes in the number of PCT member countries and number of PCT applications



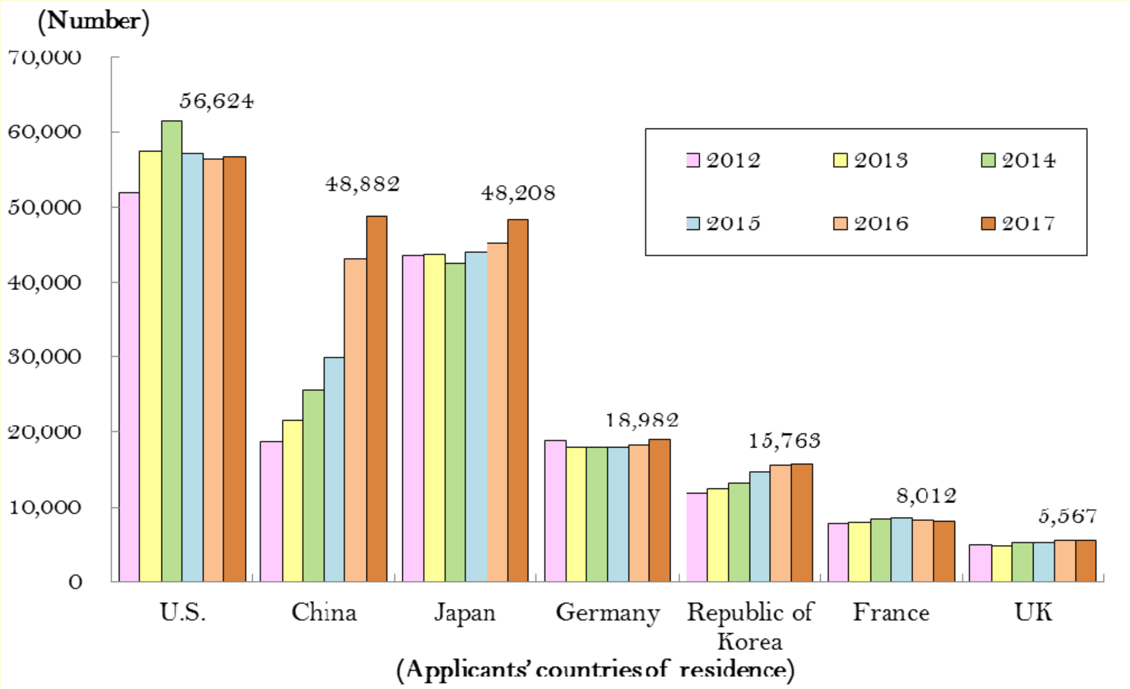
Source: Prepared by MEXT based on the "WIPO Intellectual Property Statistic" on the website of the WIPO[3].

1 An international application based on the Patent Cooperation Treaty means that an application submitted in accordance with the PCT has the same effect as applying to all PCT member countries (Japan Patent Office homepage (URL: https://www.jpo.go.jp/seido/s_tokkyo/kokusai1.htm))

2 The Japan Patent Office's "2017 Annual Patent Administration Report" (June 2017)

3 World Intellectual Property Organization

Figure 1-1-10 No. of international PCT applications by country of residence of applicants.



Note: The number of applications each year is as of the date of international applications and countries of residence are those where head applicants reside.

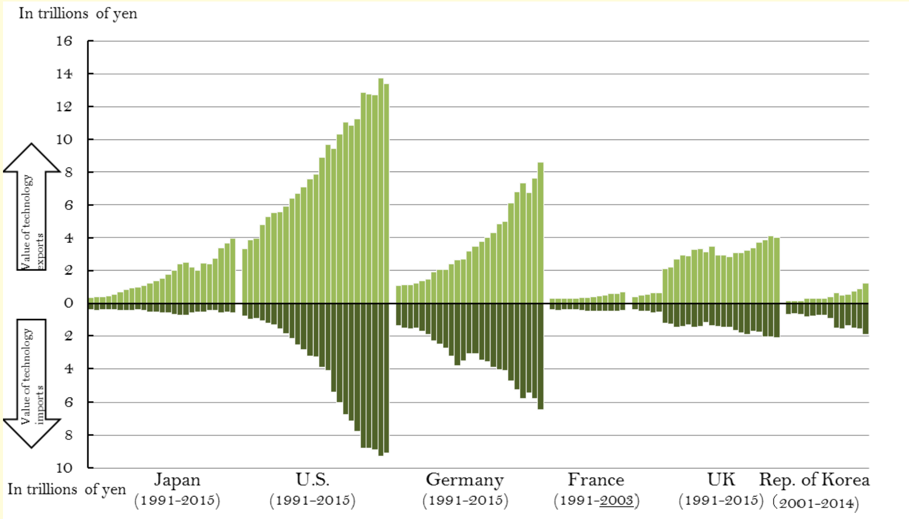
Source: Prepared by MEXT based on the WIPO website "WIPO Intellectual Property Statistics"

As mentioned above, the number of international PCT applications by Japan shows an upward trend and its intellectual property right activities, led by patents, remain high even in comparison with other major countries. Enterprises and others not only use such achievements on their own but also engage in international transactions, including the transfer of their rights and permission for their use. The transactions are called technology trade and the balance of trade in technology serves as an index to measure each country's international level of technology.

According to Figure 1-1-11 tracing trends in the value of technology trade, technology exports from Japan are smaller in scale than those from the U.S. and Germany but are increasing. As a feature of Japan's technology trade when compared with other major countries', exports far exceed imports in value[1], showing that Japan's technology, etc. are used by enterprises and individuals overseas more frequently than other major countries.

1 The "2017 Science and Technology Indicators" (August 2018) published by the National Institute of Science and Technology Policy states that technology exports generally means to "provide rights to use technology, etc. to overseas enterprises and individuals in return for fees paid" and that technology imports (technology introduction) generally means to "receive the rights from overseas enterprises and individuals by paying fees."

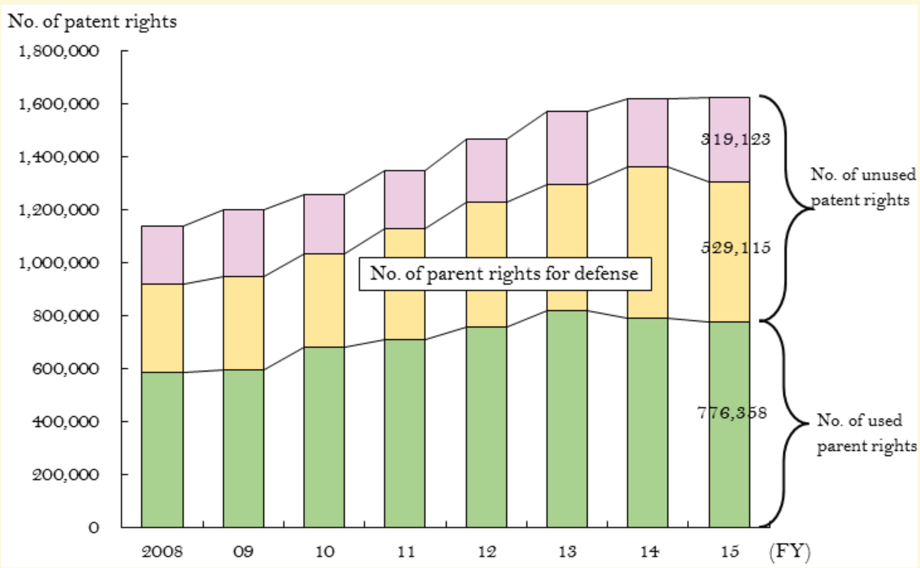
Figure 1-1-11 **Changes in the value of technology trade by the major countries**



Source: The "2017 Science and Technology Indicators" (August 2018) prepared by the National Institute of Science and Technology Policy (NISTEP) based on the OECD's "Main Science and Technology Indicators" (February 2016)

While Japan, as mentioned above, maintains a high level of intellectual property right activities among the major countries, it should be noted that more than half of all patent rights it owns are unused patents[1] and that patents for the purpose of defense[2] account for about 60% of them (Figure 1-1-12). The presence of many unused patents suggests the possibility that technologies given rights as patents have not been utilized effectively and is seen as a challenge to Japan's creation of innovation.

Figure 1-1-12 **Changes in the number of patent rights held in Japan**



Source: Prepared by MEXT based on the Japan Patent Office's "2017 Annual Patent Administration Report" (June 2017) ("2016 Intellectual Property Activities Survey Report")

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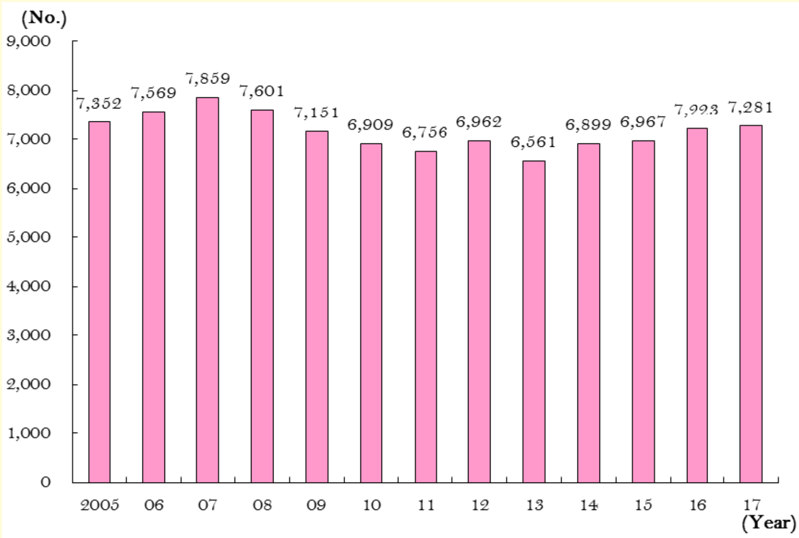
1 Unused patents are those that have neither been used by enterprises on their own nor permitted for other enterprises' use (the Japan Patent Office's "2017 Annual Patent Administration Report" (June 2017))

2 Of unused parents, those for the purpose of defense by enterprises are rights designed to prevent protect their own businesses by preventing other enterprises from using them.

The Following is the number of patent applications and licenses by Japanese universities, etc. To lead achievements of basic studies by universities, etc. to their commercialization, application studies in cooperation between them and private enterprises and creation of venture businesses originated from universities and others are needed. In any case, the acquisition of rights for inventions as achievements of studies is important and the number of patents acquired by universities, etc. is a key index to show the creation of innovation.

While the number of patent applications by universities and others have leveled off in recent years (Figure 1-1-13), the number of licenses granted by universities and others has steadily increasing (Figure 1-1-14) due possibly to the acceleration of open innovation, etc.

Figure 1-1-13 Changes in the number of patent applications made by universities, etc.

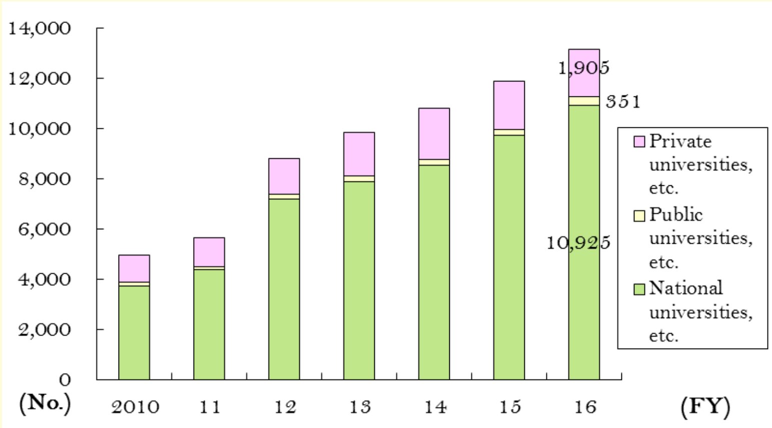


Note: The above data were retrieved and compiled by the Japan Patent Office with regard to the number of applications under the names of university presidents or educational corporation holding universities as well as TLO[1]-authorized applications. The tally includes joint applications with enterprise, etc.

Source: Prepared by MEXT based on the Japan Patent Office's "JPO Status Report 2018"

1 TLO is short for Technology Licensing Organization, a corporation tasked with winning patents for research results by university scholars and transferring them to enterprises. It serves as a bridge between industry and academia (according to METI's homepage).

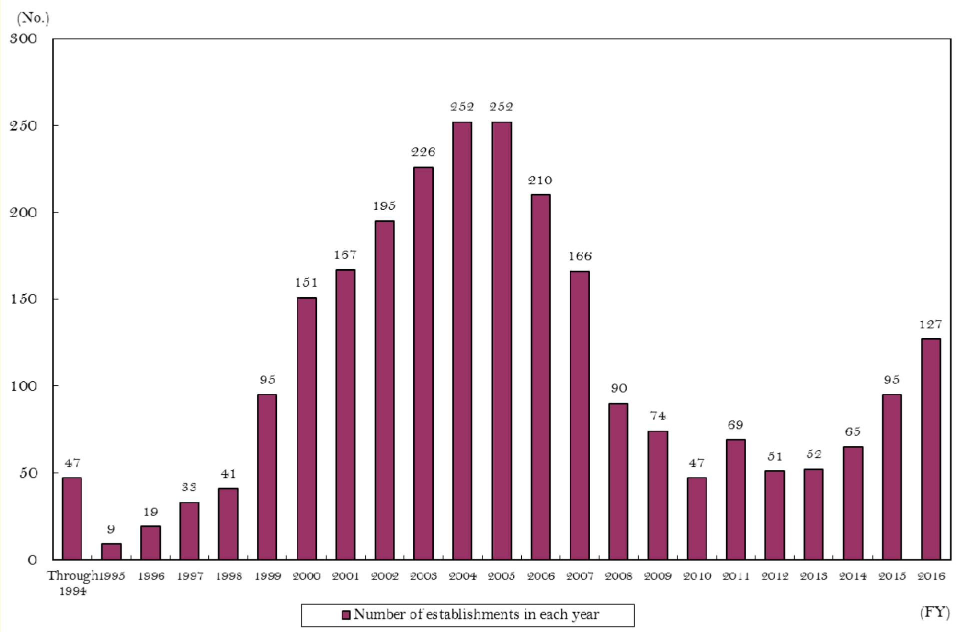
Figure 1-1-14 Changes in the number of patents granted by universities, etc.



Note: The figure covers only patents (including rights to receive them) and tallies the number of patents granted or sold
Source: Prepared by MEXT based on the ministry's "Report on the Implementation of Business-Academia Collaboration by Universities, etc. in fiscal 2016" (February 2018)

Along with the increase in the number of patents granted by universities and others, venture businesses originated from universities and others are expanding activities. While the establishment of venture business has decreased in number from its peak but been showing an upward trend in recent years (Figure 1-1-15), programs for the social implementation of research results have steadily made headway (Figure 1-1-16), such as the market capitalization of 36 listed venture businesses, originated from universities, etc., topping 1 trillion yen. But the U.S., in particular, has mega-venture businesses, such as Google LLC (Alphabet Inc.) and Facebook Inc., which have seized positions in the top 10 list in market capitalization (See C). It is therefore fair to say that venture businesses originated from universities, etc. in Japan are still smaller than those in other major countries.

Figure 1-1-15 Changes in the number of venture businesses established from universities, etc.



Note: Venture businesses originated from universities, etc. in this survey mean enterprises founded by faculty members and others of universities, etc. in case they were launched on the basis of patents given to faculty members, students and others of universities, etc. as inventors. There were 1,698 venture businesses, originated from universities, etc. as of March 31, 2017

Source: Prepared by MEXT based on the ministry's "Report on the Implementation of Business-Academia Collaboration by Universities, etc. in fiscal 2016" (February 2018)

Table 1-1-16 Main venture businesses originated from universities, etc.

Company name	Date of establishment	Date of listing	University, etc. where seed was created	Market capitalization	Principal business
PeptiDream	July 2006	June 2013	University of Tokyo	351,305	R&D, etc. of drug candidate materials
CYBERDYNE	June 2004	March 2014	Tsukuba University	217,284	Development, etc. of HAL robotic exoskeleton suit
Euglena	August 2005	December 2012	University of Tokyo	97,183	Healthcare and energy businesses based on microalga Euglena, etc.
Healios	February 2011	June 2015	Riken	69,873	R&D, etc. of regenerative medical products
SanBio	February 2001	April 2015	Keio University	56,591	R&D, etc. of regenerative cellular medicine for central nervous system-related diseases
⋮					
Total value of listed 36 venture businesses				1,260,084	

Note: Total market value is as of May 1, 2017 (in millions of yen)

Source: Prepared by MEXT and the Japan Science and Technology Agency based on published materials (excluding delisted enterprises)

(C) Comparison between top 10 Japanese and U.S. enterprises in market capitalization

Table 1-1-17 compares top 10 Japanese and U.S. enterprises in market capitalization as of 2000 and 2018. In the U.S. technology-intensive startups are growing rapidly, suggesting a fast metabolism among leading companies. In Japan, top-ranked companies have remained unchanged since 2000 and few startups have emerged. NTT Docomo Inc., ranked first in Japan as of 2000, had a market value equivalent to that of Walmart Inc., ranked sixth in the U.S. But the gap between U.S. and Japanese enterprises in market capitalization has since widened because Toyota Motor Corp., ranked first in Japan as of 2008, was smaller than Bank of America Corp., ranked sixth in the U.S., by market value.

Given these facts, the creation of innovation by startups in Japan is considered less active in Japan.

Table 1-1-17 Comparison between top 10 Japanese and U.S. enterprises in market capitalization (as of 2000 and 2018)

Japan

Ranking	Company name (2000)	Market capitalization (in 100 millions of dollars)	Ranking	Company name (2018)	Market capitalization (in 100 millions of dollars)
1	NTT Docomo Inc.	2,472	1	Toyota Motor Corp.	2,101
2	Nippon Telegraph and Telephone Corp.	1,892	2	NTT Docomo Inc.	999
3	Toyota Motor Corp.	1,705	3	Nippon Telegraph and Telephone Corp.	969
4	Sony Corp.	804	4	Mitsubishi UFJ Financial Group Inc.	914
5	Seven-Eleven Japan Co.	737	5	SoftBank Group Corp.	825
6	Takeda Pharmaceutical Co.	607	6	Keyence Corp.	758
7	Fujitsu Ltd.	556	7	KDDI Corp.	663
8	SoftBank Group Corp.	505	8	Nintendo Co.	626
9	Panasonic Corp.	488	9	Honda Motor Co.	625
10	Murata Mfg. Co.	414	10	Sony Corp.	615

U.S.

Ranking	Company name (2000)	Market capitalization (in 100 millions of dollars)	Ranking	Company name (2018)	Market capitalization (in 100 millions of dollars)
1	General Electric Co.	5,203	1	Apple Inc.	8,513
2	Intel Inc.	4,167	2	Alphabet Inc.	7,192
3	Cisco Systems Inc.	3,950	3	Microsoft Corp.	7,028
4	Microsoft Corp.	3,228	4	Amazon. com Inc.	7,007
5	Exxon Mobil Corp.	2,899	5	Berkshire Hathaway Inc.	4,921
6	Walmart Inc.	2,567	6	Facebook Inc.	4,642
7	Oracle Corp.	2,040	7	J.P. Morgan Chase & Co.	3,774
8	International Business Machines Corp.	1,925	8	Johnson & Johnson	3,438
9	Lucent Technologies Inc.	1,833	9	Exxon Mobil Corp.	3,162
10	Merck & Co. Inc.	1,729	10	Bank of America Corp.	3,072

Data as of 2000 are from "Corporate Metabolism and Birth of Crazy Entrepreneurs" by Sheiichiro Yonekura (2017) in the 2017 spring edition, 70-71, of the "Hitotsubashi Business Review," Toyo Keizai Inc. Data as of 2018 are from a survey by MEXT.

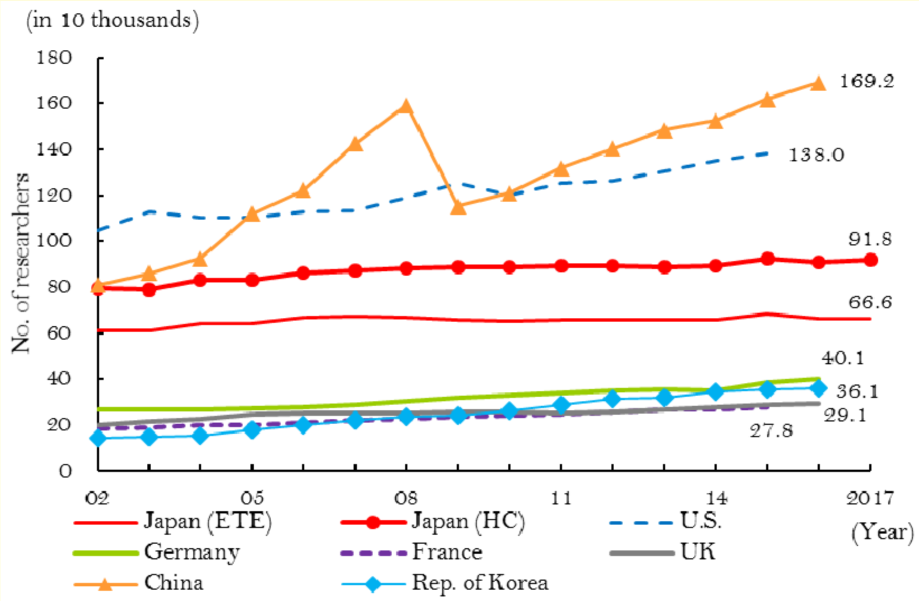
B. Fundamental capability indexes

To analyze human resources, intellectual foundation and R&D capital as the next step, principal quantitative indexes that are related to them and needed to be recognized in advance will be compared internationally. Summary accounts from four points of view -- (A) Number of researchers, (B) Number of papers, (C) R&D expenditures and (D) University rankings -- are made as follows.

(A) Number of researchers

Japan had 666,000 researchers on an ETE[1] basis in 2017. In real HC[2] terms, the number was 918,000, the third largest in the world after China and the U.S., and has remained level. Japan thus has maintained a large number of researchers among the major countries (Figure 1-1-18). The number of researchers in the corporate sector stood at 489,000, accounting for more than 70% of the total tally (Figure 1-1-19).

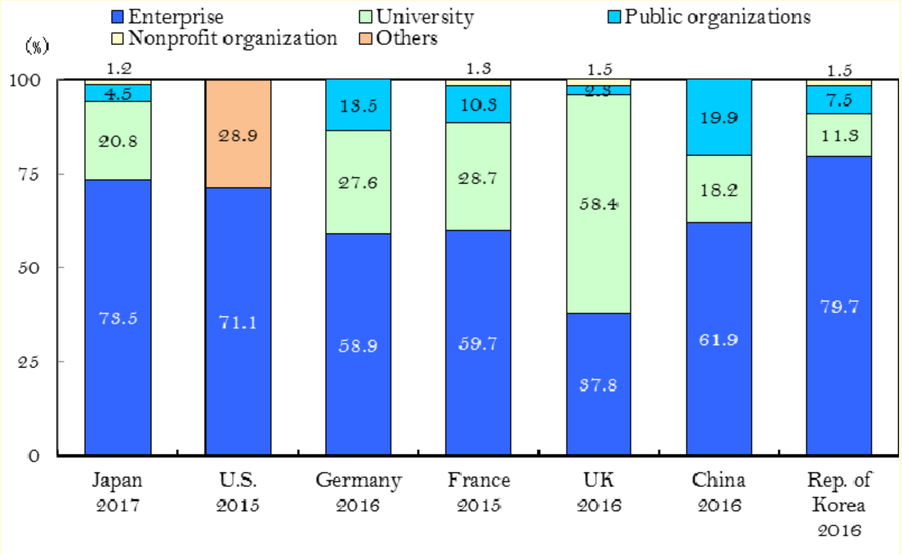
Figure 1-1-18 Changes in the number of researchers in Japan



Note: The figures for Japan are as of March 31.
China changed its calculation method in 2009 as the old method used through 2008 has not fully complied with the OECD's definition.
Source: Prepared by MEXT based on the OECD's "Main Science and Technology Indicators" (February 2017)

1 Full-time equivalent: A measure that separates R&D activities from other activities and uses hours and the ratio of those actually spent on R&D activities to calculate the number of researchers.
2 Head count

Figure 1-1-19 Sector-by-sector numbers of researches in the major countries



Note: The figures for Japan are as of March 31. The number of researchers at nonprofit organizations in each country represents the figure after subtracting researchers of enterprises, universities and public organizations from the total tally.

Source: Prepared by MEXT based on NISTEP's "Science and Technology Indicators 2017" (August 2017) and the OECD's "Main Science and Technology Indicators" (February 2017)

(B) Number of papers (number of papers, number of adjusted top 10% papers and number of adjusted top 1% papers)

This section summarizes papers, which serve as a major index to measure the fundamental STI capability from the standpoints of (i) overview, (ii) number of sector-by-sector papers produced and (iii) number of category-by-category papers.

(i) Overview

As a global trend of papers, the number of them included in the Web of Science[1] has kept increasing[2] (roughly 1.41 million annually in recent years). In particular, the number of papers jointly compiled by research institutes of multiple countries (hereinafter referred to as "international joint papers") are increasing noticeably, meaning that cross-border production and sharing of knowledge are becoming active[3].

By contrast, the number of papers produced in Japan has shown a decreasing trend over the past 10 years and the phenomenon is seen only in Japan among the major countries (Figure 1-1-20 and Table 1-1-21). In global citation rankings, Japan has also dropped in almost all categories, including the number of citations, adjusted top 10% papers[4] and adjusted top 1% papers, which are qualitative indexes (See (iii)).

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1 A database of academic literature provided by Clarivate Analytics (previously the intellectual property and science business of Thomson Reuters). It stores journals selected on the basis of conditions such as the presence of peer reviews, regular publication as well as topic titles, abstracts and keywords by authors in English.

2 While journals used for analyses are changed in sequence in the database, the number of journals is increasing. These factors are considered to be contributing to the increase in the number of papers.

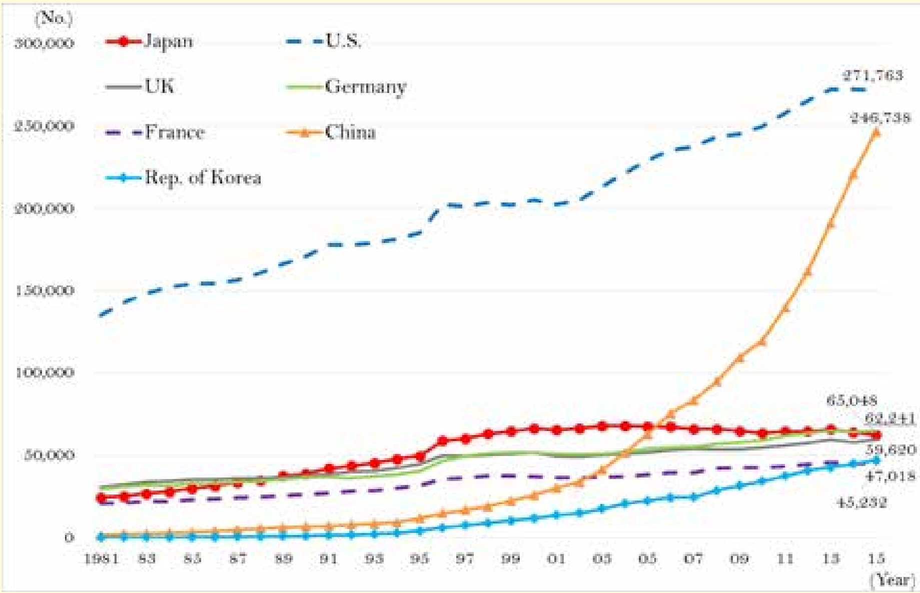
3 The National Institute of Science and Technology Policy's "Benchmarking Scientific Research 2017" (August 2017) Research material 262

4 The number of adjusted top 10% papers is the top 10% papers cited in each field in each year, corrected to represent 1 / 10 of the real number of papers.

As shown in Figure 1-1-22, meanwhile, the Q factor[1] or the ratio of the adjusted top 10% papers to the total number of papers has been rising marginally in recent years, testifying to a slight increase in the ratio of high-quality papers which are produced in Japan and draw global attention. But other major countries have logged larger increases.

To recognize trends of article numbers, however, attention should be paid to features and other factors of research categories because they include those in which results, other than papers such as intellectual property rights, are principal achievements of work.

Figure 1-1-20 Changes in the number of papers in the major countries



Note: Papers and reviews are subject to the analysis. The fractional counting method was used to count the number of papers. A 3-year moving average was used for annual tallies by means of publication (publication year, PY)
Source: Prepared by MEXT based on NISTEP's "Benchmarking Scientific Research 2017" (August 2017)

1 For the Q factor analysis, the integer counting method, adopted as indexes, etc. in the Science and Technology Basic Plan, was used.

Table 1-1-21 **Number of papers and number of adjusted top 10% papers by country/region: top 10 countries/regions**

All fields	2003-2005 (PY) (Average)		
	Number of papers		
Country/region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	221,367	26.1	1
Japan	67,888	8.0	2
Germany	52,315	6.2	3
China	51,930	6.1	4
UK	50,862	6.0	5
France	37,392	4.4	6
Italy	30,358	3.6	7
Canada	27,847	3.3	8
Spain	21,527	2.5	9
India	20,319	2.4	10

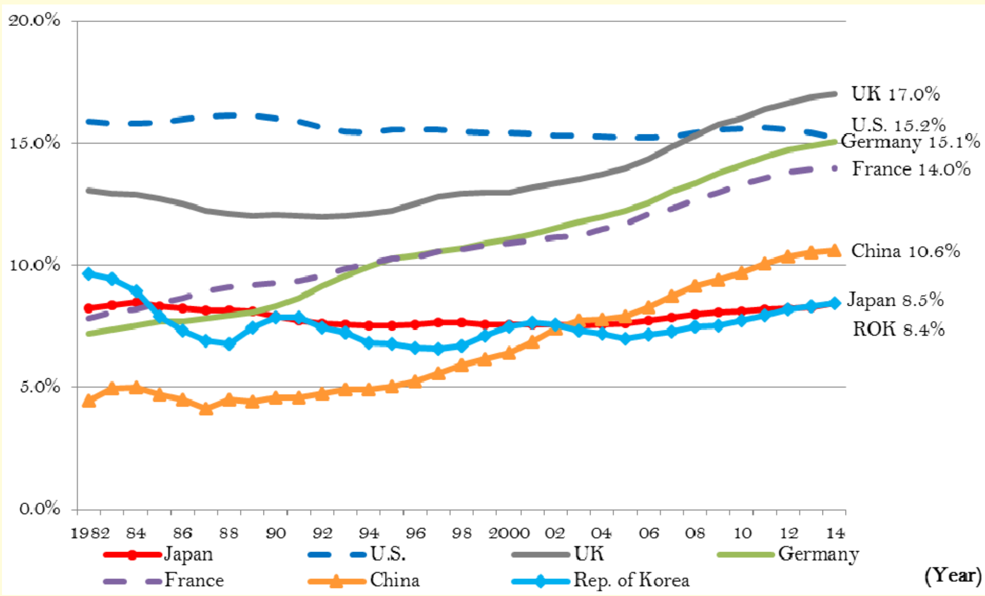
All fields	2013-201505 (PY) (Average)		
	Number of papers		
Country/region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	272,233	19.9	1
China	219,608	16.0	2
Germany	64,747	4.7	3
Japan	64,013	4.7	4
UK	59,097	4.3	5
India	49,976	3.7	6
France	45,315	3.3	7
Rep. of Korea	44,822	3.3	8
Italy	43,804	3.2	9
Canada	39,473	2.9	10

All fields	2003-2005 (PY) (Average)		
	Number of adjusted top 10% papers		
Country/region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	33,242	39.4	1
UK	6,288	7.5	2
Germany	5,458	6.5	3
Japan	4,601	5.5	4
France	3,696	4.4	5
China	3,599	4.3	6
Canada	3,155	3.7	7
Italy	2,588	3.1	8
Netherland	2,056	2.4	9
Australia	1,903	2.3	10

All fields	2013-201505 (PY) (Average)		
	Number of adjusted top 10% papers		
Country/region name	Fractional counting		
	Number of papers	Share	Ranking
U.S.	39,011	28.5	1
China	21,016	15.4	2
UK	8,426	6.2	3
Germany	7,857	5.7	4
France	4,941	3.6	5
Italy	4,739	3.5	6
Canada	4,442	3.2	7
Australia	4,249	3.1	8
Japan	4,242	3.1	9
Spain	3,634	2.7	10

Note: Fractional counting method was adopted.
Source: Prepared by NISTEP ("Benchmarking Scientific Research 2017" (August 2017)) based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version)

Figure 1-1-22 **Ratio of adjusted top 10% papers to article numbers in the major countries (Q factor)**



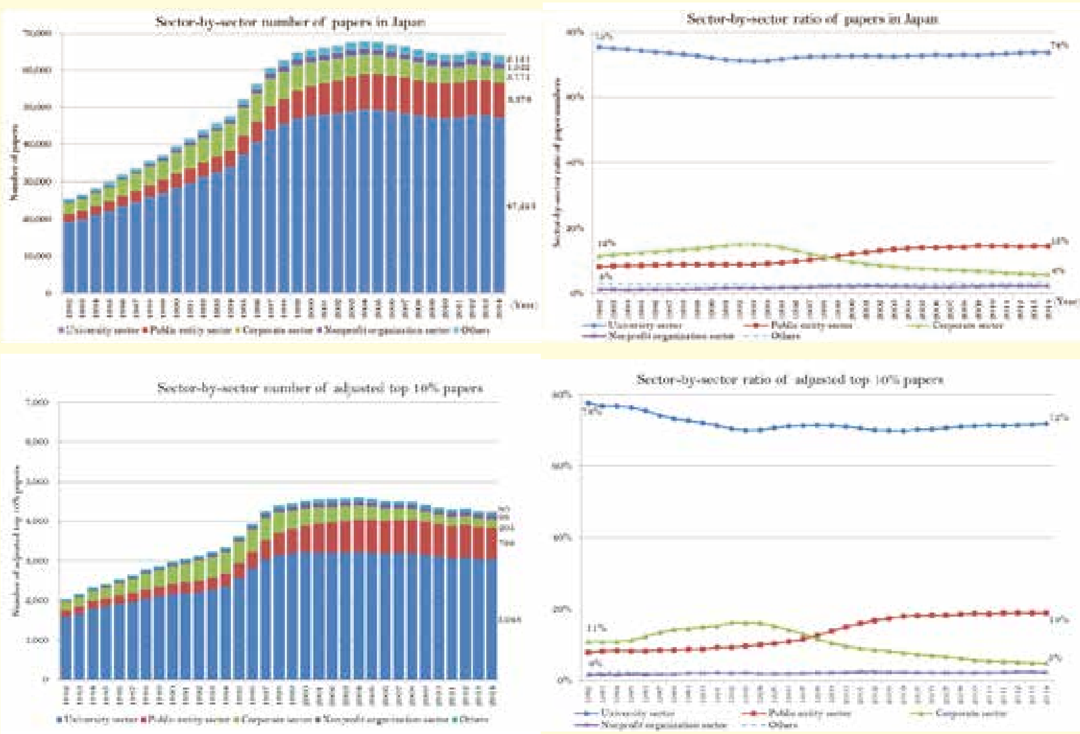
Note: Papers and reviews are subject to the analysis adopting the integer counting method. Figures for each year are 3-year cumulative numbers

Source: Prepared by NISTEP ("Benchmarking Scientific Research 2017" (August 2017)) based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version)

(ii) Sector-by-sector number of papers produced

Figure 1-1-23 shows the sector-by-sector number of papers produced in Japan. Amid the decreasing trend in the total number of papers produced in Japan as mentioned in (i), the ratio of papers produced in the university and public entity sectors is rising while the ratio in the corporate sector is declining. The stalled growth of the number of papers in Japan, which is often discussed recently in the context of the fall in research capacity, it is partly attributable to the slowed growth of the number of papers in the university sector. It is also considered affected by the drop in the number of papers in the private sector.

Figure 1-1-23　Sector-by-sector number of papers in Japan and sector-by-sector ratio of papers in Japan



Note: Papers and reviews are subject to the analysis adopting the fractional counting method. As figures are 3-year moving averages, those for 2014 are averages of 2013, 2014 and 2015.
The university sector includes national universities, public universities, private universities, higher professional schools and institutes jointly used by universities.
The public entity sector includes national entities, special public corporations, independent administrative bodies (excluding higher professional schools) and local government-affiliated organs.

Source: Prepared by NISTEP ("Benchmarking Scientific Research 2017" (August 2017)) based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version)

The U.S. National Science Board[1] said in its "Science & Engineering Indicators 2018"[2] that the ratio of

1 An organ established by the Congress in 1950 as a national science policy institution to supervise and lead the National Science Foundation (from the homepage of the Ministry of Education, Culture, Sports, Science and Technology)

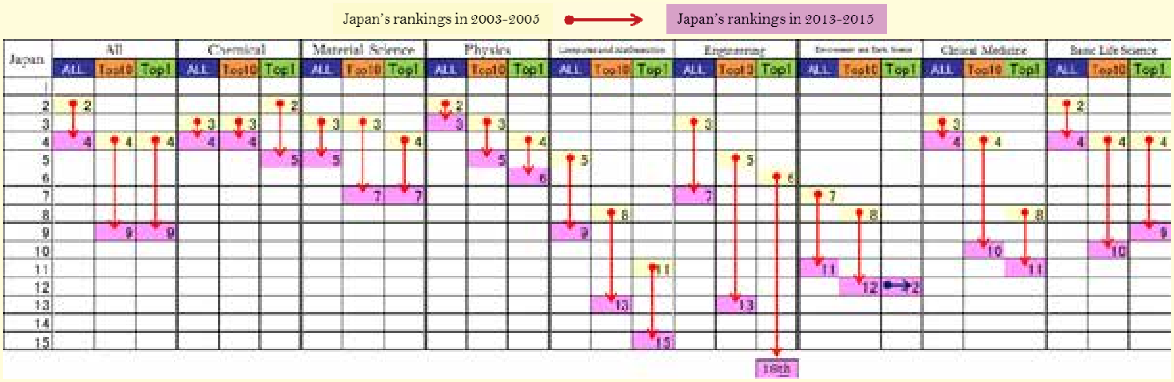
2 A collection of numerical data that show outputs in the categories of science and engineering, employment situation, educational activities, etc. ("Outline of the U.S. National Science Board "Science and Engineering Indicators 2017) by the Center for Research and Development Strategy of the Japan Science and Technology Agency (February 2014)

the corporate sector in sector-by-sector production of papers in the U.S. is showing a declining trend, as in the case of Japan, while the ratio of the university sector is rising slightly. In other words, changes in the number of papers produced in Japan are not a trend unique to Japan. The findings possibly suggest that the production of papers as output of corporate research activities are receiving less weight.

(iii) Category-by-category number of papers produced

The ranking of Japan is falling in almost all categories when it comes to the number of papers and the number of papers drawing strong attention (adjusted top 10% papers and adjusted top 1% papers) (Figure 1-1-24), although conditions differ in accordance with categories. The figure is the global ranking of papers in number, arousing concern about the fall in the presence of Japan in the world.

Figure 1-1-24 Changes in Japan's global rankings in the number of papers and number of papers drawing strong attention (top 10% and top 1%)

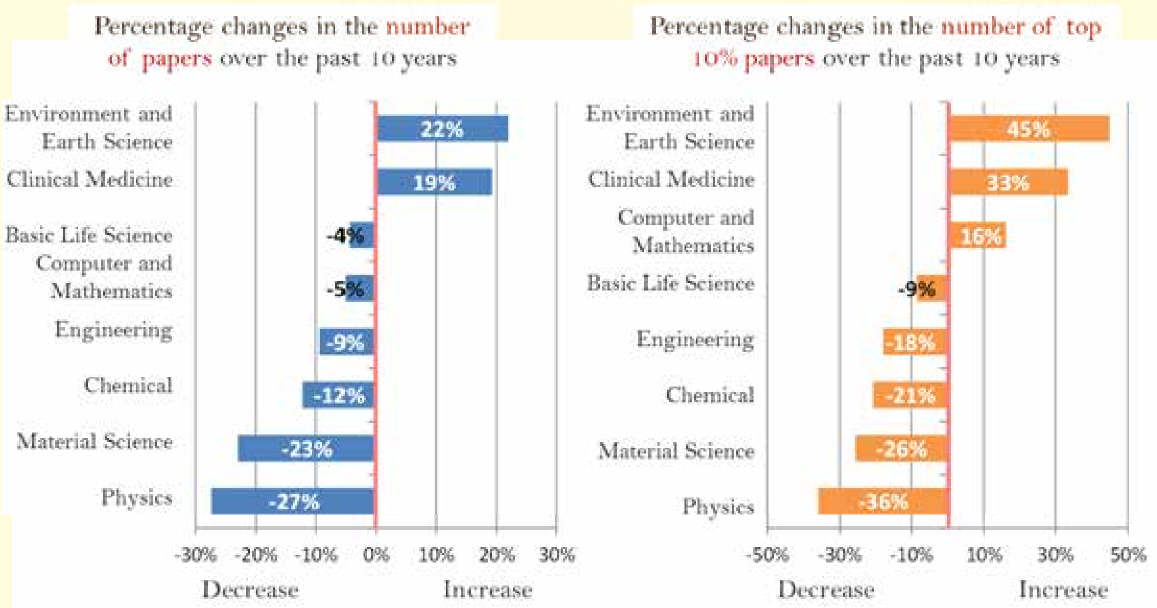


Note: All - Global ranking in the number of papers. Top 10 - Global ranking in the number of adjusted top 10% papers. Top 1 - Global ranking in the number of adjusted top 1% papers. Rankings at the end of arrows were those in 2003-2005 while those at the tip of arrows were those in 2013-2015. The fractional counting method was used to mark the rankings.

Source: Prepared by NISTEP ("Benchmarking Scientific Research 2017" (August 2017)) based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version)

When it comes to the absolute number of papers, there have been decreases in chemical, physics and other categories Japan have been strong in, while increases are seen in some others (Figure 1-1-25). Nevertheless, the relative position of Japan is falling in all categories as the number of papers and the number of adjusted top 10% papers in other major countries and others are increasing faster than in Japan.

Figure 1-1-25 **Percentage changes in the number of papers and number of adjusted top 10% papers over the past 10 years**

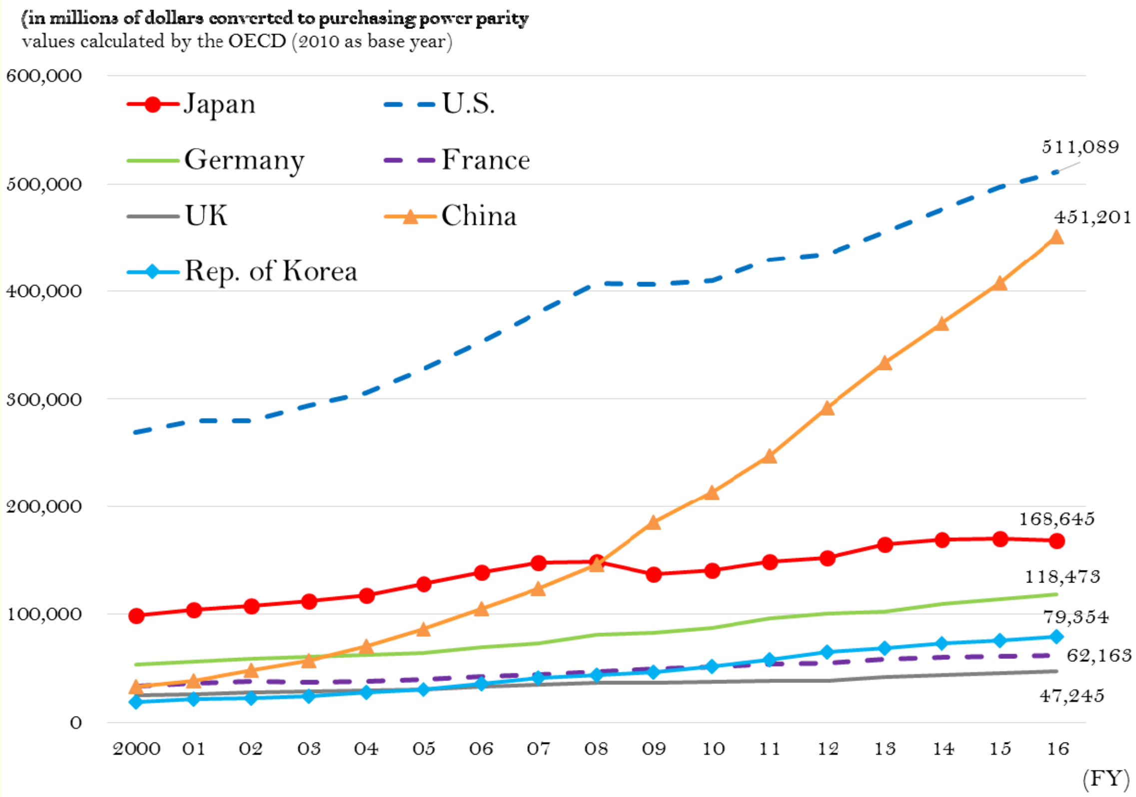


Note: Papers and reviews are subject to the analysis adopting the fractional counting method.
Source: Prepared by NISTEP based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version)

(C) Research and development expenses

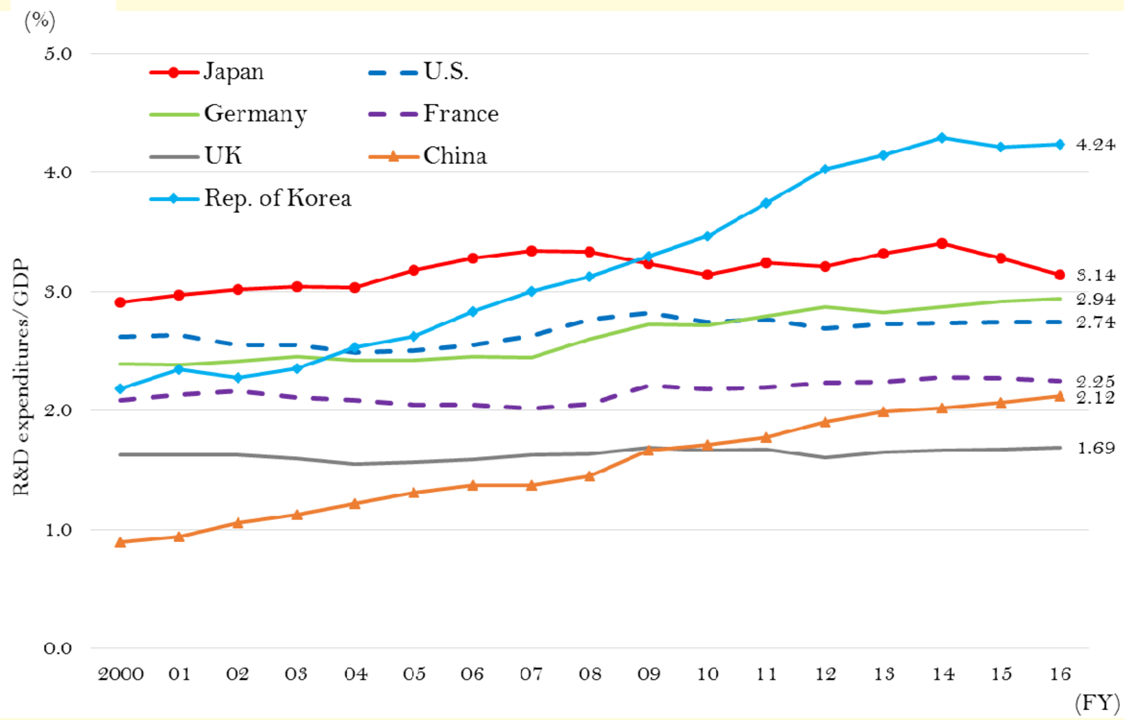
Japan's total research and development expenses have maintained a gradually increasing trend in the long run and shown a top-level figure over the past 20 years (Figure 1-1-26). While leveling off in recent years, they rank third among the major countries and second among them in terms of ratio to gross domestic product (Figure 1-1-27). Although, however, Japan maintains a higher level of R&D expenses than most of other major countries, their growth rates are slower than those of the U.S. and China, leaving Japan farther behind the two countries. The corporate sector leads R&D activities in Japan as it accounts for some 70% of total R&D expenditures in the country. In other major countries, the corporate sector is also the biggest spender, contributing more than 60% of total R&D expenditures in all countries (Figure 1-1-28).

Figure 1-1-26 Changes in R&D expenditures in the major countries



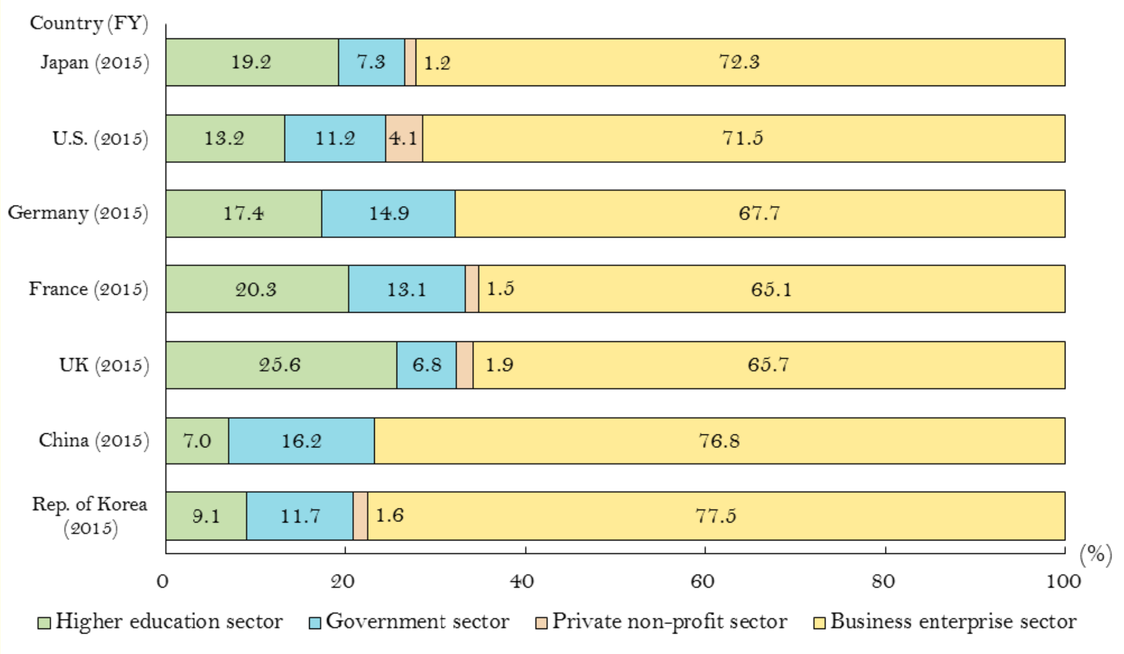
Source: Prepared by MEXT based on the OECD "Main Science and Technology Indicators" (February 2017)

Figure 1-1-27 Changes in the ratio of R&D expenditures to GDP in the major countries



Source: Prepared by MEXT based on the OECD "Main Science and Technology Indicators" (February 2017)

Figure 1-1-28 Sector-by-sector ratios of R&D expenditures used



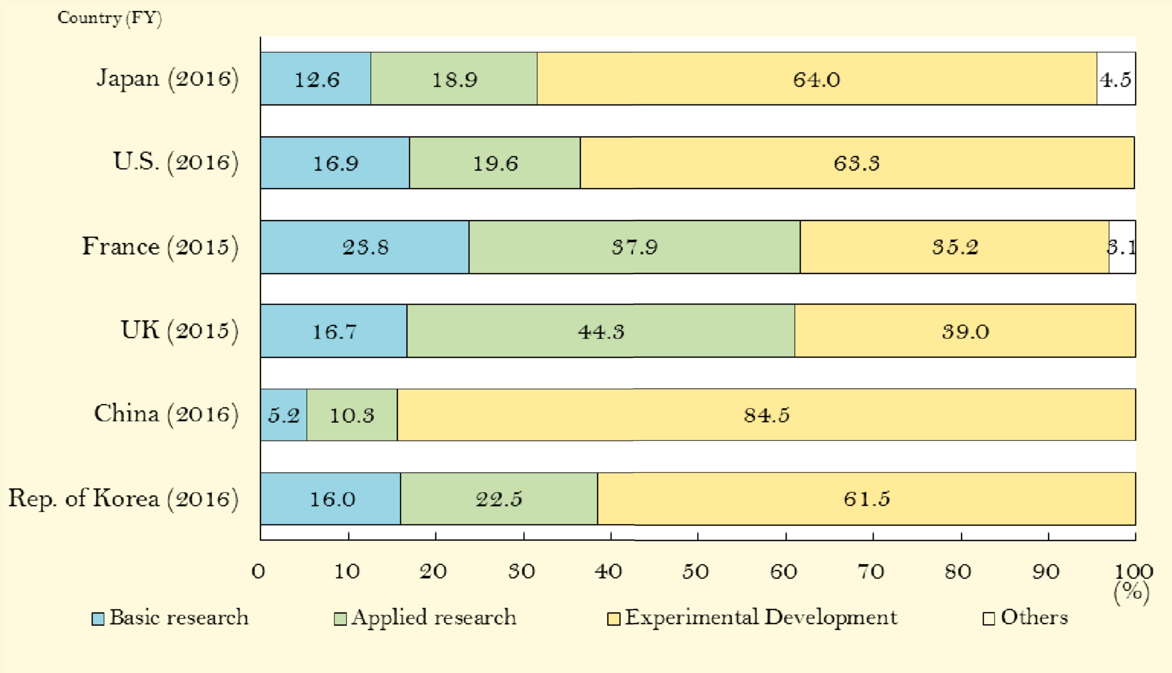
Note: Germany includes R&D expenditures in the private non-profit sector in the government sector.
Source: Prepared by MEXT based on the OECD "Main Science and Technology Indicators" (January 2017)

Figure 1-1-29 shows purpose-based ratios of research and development expenditures in the major countries, suggesting that phases of research they attach weight to differ. While, for example, the ratio of applied research is high in France and the UK, China shows a high ratio of experimental development.

Although the U.S. has similar ratios to those of Japan, prioritized areas in experimental development differ greatly between them. A high ratio of appropriation for defense in the science and technology-related budget means active investment in experimental development for defense technology[1]. Japan, meanwhile, launched a system to promote studies for defense technology in fiscal 2015. In its Science and Technology Basic Plan, furthermore, it stated that "science and technology are diverse and, given the fact that achievements of research and development for a certain purpose can be applied to other purposes … their proper utilization is important."

1 "Overview Report on Research and Development: R&D Strategies by Major Countries (2018)" (March 2018) by the Center for Research and Development Strategy of the Japan Science and Technology Agency

Figure 1-1-29 Purpose-based ratios of R&D expenditures in the major countries



Note: All countries but Japan include humanities and social science.
R&D expenditures by enterprises, non-profit organizations, public institutions, universities, etc. are included.
Germany is excluded as it does not disclose purpose-based ratios of R&D expenditures
Source: Prepared by MEXT based on the OECD "R&D Database" (February 2017)

(D) University rankings

The "Japan Revitalization Strategy" approved by the Cabinet on June 14, 2013, adopted a KPI[1] of having more than 10 Japanese universities join the top 100 of the World University Rankings in the following 10 years. Table 1-1-30 shows the world rankings of major universities recognized by MEXT. THE[2]'s World University Rankings (hereinafter referred to as THE Rankings) and Quacquarelli Symonds Ltd.'s rankings (hereinafter referred to as QS Rankings), which are widely used as indicators are taken up here (Table 1-1-31).

In the THE Rankings, universities are ranked on the basis of their achievements, questionnaires of researchers and other means concerning (1) research (quantity, income and reputation), (2) education (educational environments), (3) citation (influence of research), (4) internationality (faculty members, students and research) and (5) income from industry (knowledge transfer). Problems of Japanese universities include low assessment for citations and for international outlook such as low ratios of foreign students and faculty members.

The QS Rankings rank universities based on its six own evaluation points such as external academic assessment (assessment of quality of research) and assessment by employers (assessment of students employed after graduation).

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1 Key Performance Indicator
2 Times Higher Education

The number of universities in the top 100 varies because different indexes and information are used to rank them. But in both rankings, the number of universities in Japan in the top 100 is small in comparison with other countries, suggesting that the presence of Japanese universities is weaker than that of other universities.

The top 100 of the THE Rankings has only two Japanese universities (University of Tokyo and Kyoto University). In the latest assessment, the ranking of Kyoto University jumped to 74th from 91st while the University of Tokyo fell to 46th from 39th. But Japan maintains an advanced quality of higher education as a whole because, among other data, it has 89 universities in the top 5% or so (1,102 schools) of the world's higher education institutions, trailing only the U.S. and U.K.

Rankings of universities do not need to be taken excessively seriously because they change greatly depending on methods of assessment and rating organs. But as an analysis of objective indexes for ranking offers a variety of suggestions, it is important to continue following and interpreting findings through the objective indexes.

Table 1-1-30 Status of Japanese universities in main world university rankings

Implementing entity	Country	Name of ranking	No. of universities
Times Higher Education	UK	World University Rankings 2018	2
Times Higher Education	UK	World Reputation Rankings 2017	6
Quacquarelli Symonds Ltd	UK	World University Rankings 2018	5
Shanghai Jiao Tong University	China	Academic Ranking of World Universities 2017	3
Reuters	UK	Reuters Top100 The World's Most Innovative Universities 2017	8
Center for World University Rankings	UAE	CWUR 2017-World University Rankings	6

Note: The number of universities is the number of Japanese universities in the top 100.
Source: Prepared by MEXT based on the rankings mentioned above.

Table 1-1-31 Differences between THE Rankings and QS Rankings

Category	THE Rankings	QS Rankings
Research	◇Research [30%] ・Research reputation (18%) ・Research income to academic staff (6%) ・Papers to academic staff (6%) ◇Cited papers (average number of citations per article held by each university) [30%]	◇Survey of researchers on reputation [40%] (Survey of experts on the quality of research and education) ◇Citation of papers per teacher [20%]
Education	◇Education [30%] ・Teaching reputation (15%) ・Staff to student ratio (4.5%) ・Doctorates to bachelor's degrees awarded (2.25%) ・Doctorates to academic staff (6%) ・Income to academic staff (2.25%)	◇Staff to student ratio [20%]
Possibility of employment:	—	◇Survey of employers on reputation [10%] (Global survey asking employers whether universities produce competent graduates)
Internationality	◇Internationality [7.5%] ・International to domestic staff (2.5%) ・International to domestic student (2.5%) ・Publications with international author (2.5%)	◇International to domestic staff [5%] ◇International to domestic student [5%]
Income from industry	◇Income for research expenses from industry [2.5%]	—

Source: Prepared by MEXT based on each ranking page

(3) For Analysis in the following section

The major countries' moves regarding science, technology and innovation policies have so far been reviewed and compared internationally by means of main indexes, finding that the creation of science, technology and innovation has continued in the major countries. The work also noted a decline in Japan's fundamental capability to create science, technology and innovation at a time when the major countries are making efforts, recognizing the importance of the fundamental capability. The white papers in recent years have discussed the situation of science, technology and innovation and measures to reinforce them, among others. This white paper takes note of fundamental capability as the source of science, technology and innovation and will analyze it, based on (1) human resources, (2) foundation of knowledge and (3) research funds as set forth in the Science and Technology Basic Plan, in the following section.

2 Analysis of Japan's fundamental capability and extraction of problems

This section will analyze the current state of Japan's fundamental capability for science, technology and innovation by taking note of human resources, foundation of knowledge, capital for research and other matters to extract problems. The analysis will focus on universities and national research and development corporations which are principal implementation entities for science, technology and innovation.

2-1 Human resources

People are the bearers of science, technology and innovation. While global competition to secure highly competent people is intensifying, the population of youth has continued to decrease in Japan. Under the circumstances, it has become more important than ever to improve the quality of people involved in science, technology and innovation and let them exercise their capacity. But Japan is in a crisis situation when it comes to the question of human resources involved in science, technology and innovation, especially regarding the young researchers who are the key bearers of science, technology and innovation. Students and other young people of high ability have become reluctant to work for doctoral degrees and play central roles in science, technology and innovation, posing a grave problem for Japan to sustainably retain its power in science, technology and innovation. To maximize the possibility of creating innovation from Japan, it is necessary to promote not only the active involvement of women, foreigners and various other human resources but also the fusion of knowledge and social implementation of study results through the flow of human resources beyond areas, institutions, sectors and national borders. But programs taken to date have hardly produced sufficient fruits. In this section, therefore, the condition of young researchers, including doctoral students, as human resources that support fundamental capability and the diversity and mobility of human resources will be outlined.

(1) Doctoral students and young researchers

A. Analysis of current state

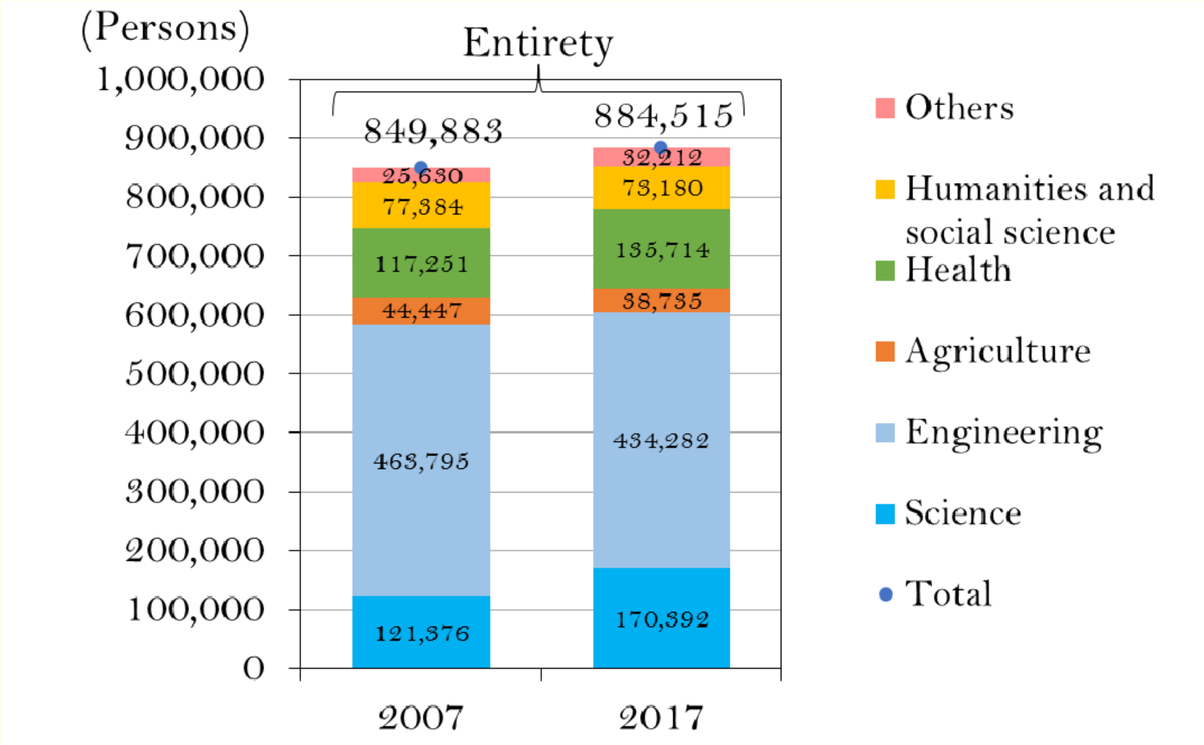
Japan retains the third-largest number of researchers in the world after China and the United States, as mentioned above (Figure 1-1-18). In the 10 years from 2009 through 2018, the number of researchers at universities, etc. and business enterprises increased. The number of researchers, divided by the area of expertise, in 2017 was largest in the field of engineering at a population of about 430,000, followed by 170,000 in science and 140,000 in health. Among researchers at universities and others, the field of health had the largest number of about 110,000, followed by 63,000 in humanities and social science, 43,000 in engineering and 32,000 in science. In the corporate sector, engineering and science formed the two largest populations of approximately 380,000 and 130,000 researchers, respectively. Nonprofit organizations and public organs had around 14,000 engineering, 11,000 agricultural, 9,000 science and 6,000 health researchers (Figure 1-1-32). Approximately 60% of graduate students were in the master's course and 30% in the doctor's course. The number of graduate students has almost remained level since 2006 but has shown a decreasing trend in recent years (Figure 1-1-33). To promote science, technology and innovation under the circumstances, people with doctoral degrees, who have advanced expertise and excellent knowledge: the source of innovation, are expected to play active roles.

The number of students in the doctoral course in Japan more than doubled[1] in the 10 years or so during which the quantitative improvement of graduate schools was made under a program to intensively reinforce graduate schools, starting in 1991. The number peaked in FY2003 and has since declined gradually. This means that although people entering graduate schools from the workforce has been on the

1 "Education Reform for Graduate Schools to Lead the Future: Cultivation of Intellectual Professionals via Joint Work with Society (Summary of deliberations) (September 2015)" by the University Subcommittee, the Central Council for Education, MEXT.

increase, those who advance to doctoral programs after completing the master's course have been decreasing at a faster pace (Figure 1-1-34).

Figure 1-1-32 Changes in the sectoral number of researchers in Japan

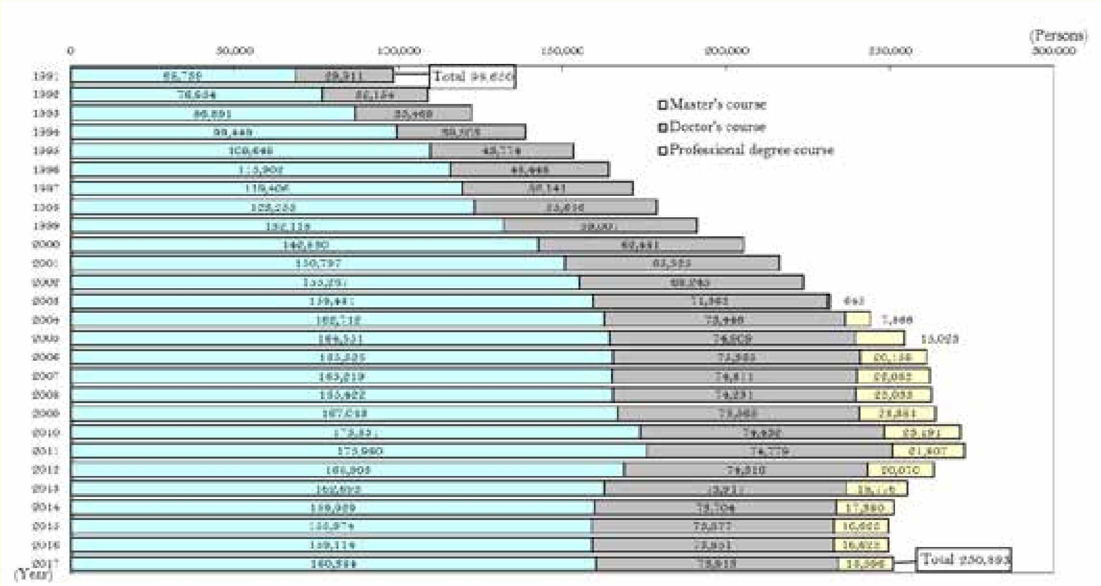


Notes: 1. Number of researchers as of March 31

2. The total number consists of all persons primarily engaging in research activities at universities, etc., all researches at enterprises and all researchers at nonprofit organizations and public organs. The discrepancy between the number of researchers in Japan as of 2017 and the number of persons primarily engaging in research activities -- 918,000 and 885,000, respectively -- shown in Figure 1-1-18 represents researchers at universities, etc. who concurrently and primarily engage in research activities outside of them.

Source: Prepared by MEXT, based on the "Survey of Research and Development (2007 and 2017)" by the Statistics Bureau of the Ministry of Internal Affairs and Communications

Figure 1-1-33 Changes in the number of graduate students



Note: Number of graduate students (as of May 1 each fiscal year)

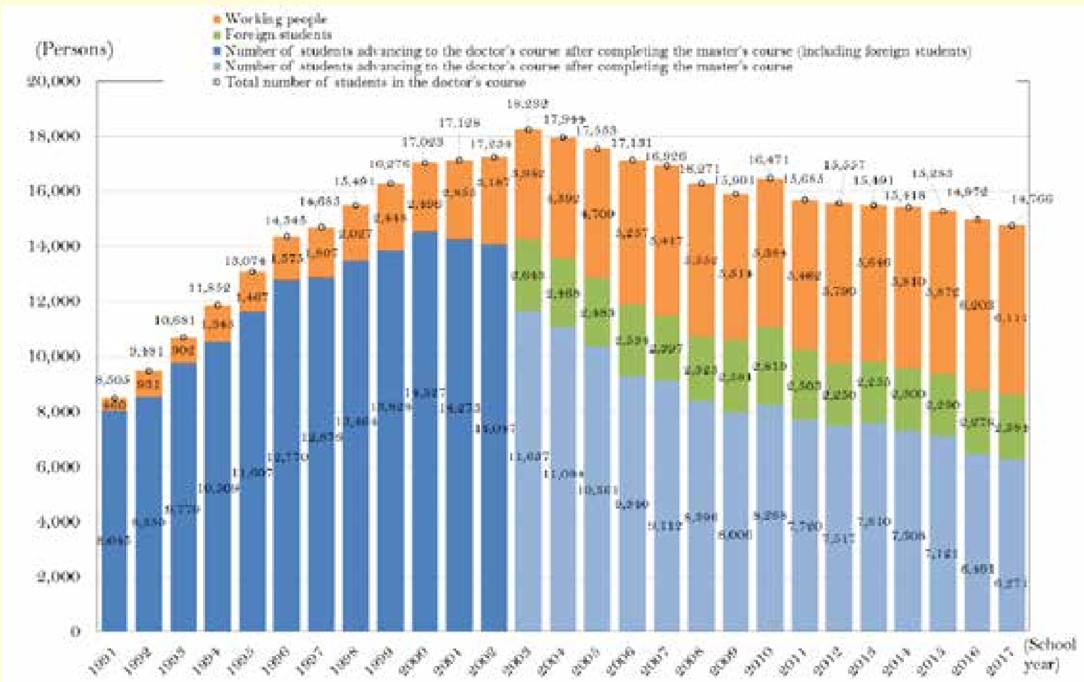
Master's course: Master's course, sectoral doctoral course (2-year first-term doctoral course) and 5-year full-term doctoral course (first and second terms)

Doctor's course: Sectional doctoral course (3-year second-term doctoral course), medical science, dentistry and pharmacy (4 years), doctoral course for dentistry and veterinary medicine and 5-year full-term doctoral course (third to fifth terms)

Correspondence education programs are excluded.

Source: Prepared by MEXT, based on the ministry's "Report on School Basic Survey"

Figure 1-1-34 Changes in the number of students enrolling in the doctor's course

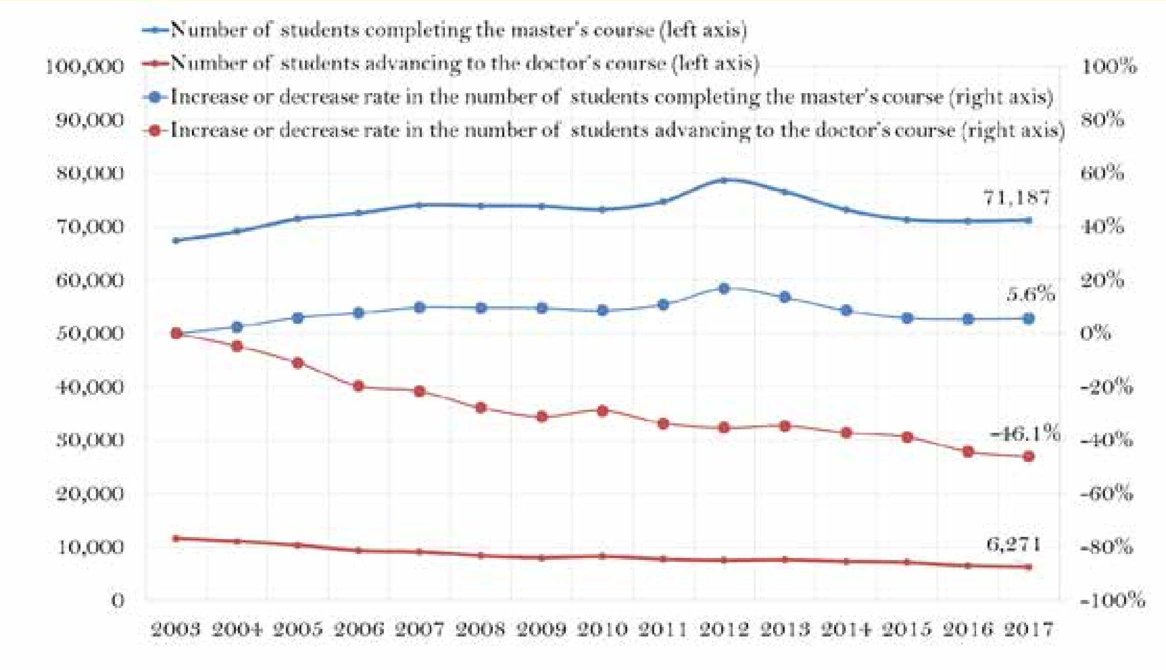


Note: The number of enrollees after completing the master's course is the total number of students in the doctor's course minus working people and foreign students and consists mainly of students advancing to the doctor's course after completing the master's course. Their number was recorded as the number of students advancing to the doctor's course after completing the master's course (including foreign students) up until the FY 2002 because the number of foreign students had not been surveyed before then.

Source: Prepared by MEXT, based on the ministry's "Report on School Basic Survey."

A comparison between the number of students completing the master's course and the number of students advancing to the doctor's course shows that the number of students completing the master's course has almost leveled off since FY 2013. In contrast, the number of students advancing to the doctor's course has declined as a trend since FY 2013, logging a fall of more than 40% since FY2003 (Figure 1-1-35).

Figure 1-1-35 Changes in the number of students completing the master's course and the number of students advancing to the doctor's course[1]

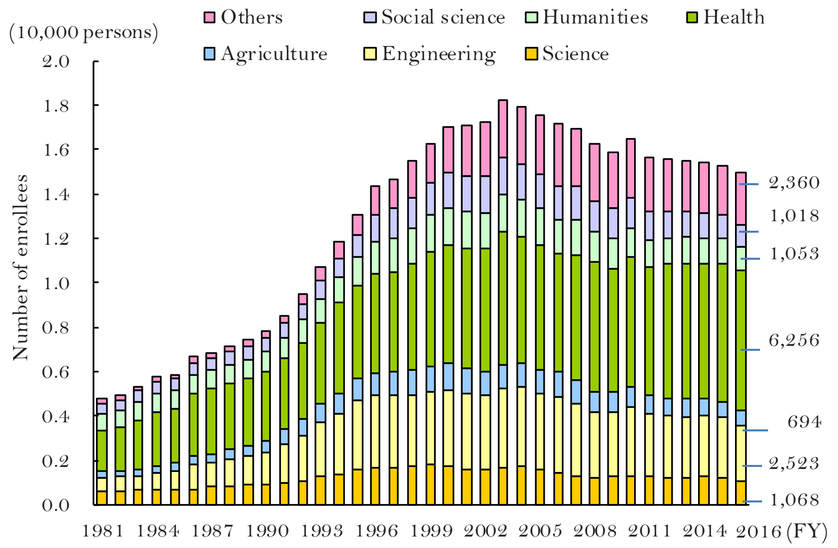


Source: Prepared by MEXT, based on the ministry's "Report on School Basic Survey"

The number of enrollees in the doctor's course in FY2016 had some 6,256 health-course students, the largest by the field of study accounting for 41.8% of the total and followed by 2,523 engineering students (16.9%). There also were some 1,000 students each in the fields of science, humanities and social science. Since 2003, the number of enrollees has either decreased or leveled off in all fields but health and others, contributing to a decrease in the total number of students advancing to the doctor's course (Figure 1-1-36).

1 Students advancing to the doctor's course in Figure 1-1-35 are those who advanced to the doctor's course after completing the master's course and are the same students advancing to the doctor's course after completing the master's course as mentioned in Figure 1-1-34.

Figure 1-1-36 Changes in the sectoral number of enrollees in the doctor's course

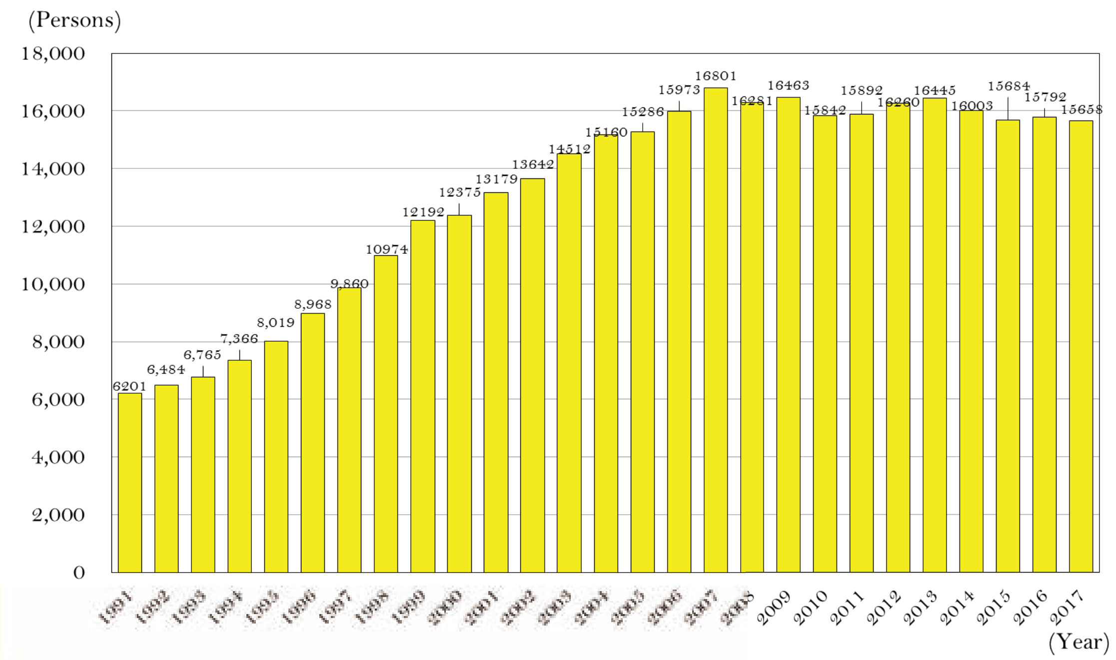


Increase or decrease the period from FY2000 till FY2016 (persons)	
Science	-696
Engineering	-879
Agriculture	-498
Health	917
Humanities	-657
Social science	-563
Others	325

Note: Health: Medicine, dentistry, pharmacy, nursing science, etc.
Others: Mercantile marine, household management, education, art, etc.
Source: Prepared by NISTEP, based on MEXT's "Report on School Basic Survey" ("Japanese Science and Technology Indicators 2017 (August 2017)"

In addition, the number of people completing the doctor's course peaked in 2007 and has since leveled off. It stood at 15,658 as of March 2017 (Figure 1-1-37).

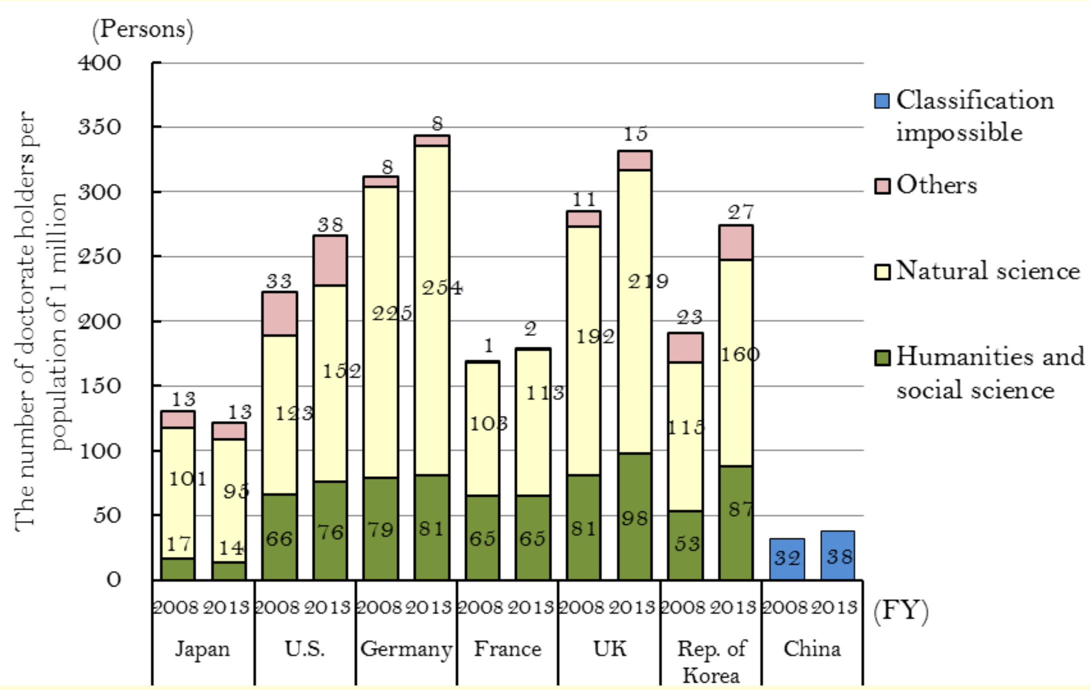
Figure 1-1-37 Changes in the number of people completing the doctor's course



Note: Data for each year are as of March. The number of people completing the doctor's course includes those who were in school for a prescribed number of years for completion of the doctoral program and received credits but left school without a doctoral degree.
Source: Prepared by MEXT, based on the ministry's "Report on School Basic Survey."

Japan has fewer doctorate holders per population of 1 million than other major countries, with the number standing at 121 in FY2013. According to the latest data, Germany has 344, the largest among the nations, and is followed by the United Kingdom with 331. Compared between FY2008 and FY2013, the number of doctorate holders increased in all countries but Japan. The number of doctorate holders in the field of humanities and social science tends to be smaller in Japan than in other major countries where their ratio in the field of natural sciences shows a rising trend (Figure 1-1-38).

Figure 1-1-38　International comparison of the number of doctorate holders per population of 1 million



Notes: <Japan> Number of people receiving doctoral degrees from April of a given year till March of the following year. "Others" include liberal arts, international relations, mercantile marine, etc.

<United States> Number of people receiving doctoral degrees in a fiscal year that starts in September. "Others" include "military science," "interdisciplinary studies" and other academic disciplines. Doctorate holders here represent the number of "doctor's degrees" listed in the "Digest of Educational Statistics" minus numbers in the fields of "law and economy," "medicine, dentistry, pharmacy and health" and "others" among those of primary professional degrees such as doctors of medicine and juris doctors.

<Germany> Number of people passing doctoral examinations in the winter semester of a given year and summer semester of the following year.

<France> Number of people receiving doctoral degrees (eight years in total) in a given year (calendar year)

<United Kingdom> Number of people receiving advanced academic degrees at universities and other higher educational institutions in a given year (calendar year). It represents data of the United Kingdom and includes foreign students. "Others" include mass communication and composite programs.

<Republic of Korea> Number of doctorate holders in February of a given year. For population in 2016, data of 2015 are used.

<China> Holders of doctoral degrees from research and other organs, in addition to higher educational institutions, with doctoral courses at graduate schools are included. The number of them, divided by the field of expertise, is unavailable.

Sources: <Japan> Survey of the Conferment of Degrees by MEXT

<United States> NCES, IPEDES and the "Digest of Education Statistics"

<Republic of Korea> Annual versions of the "Yearbook on Educational Statistics" by the Korean Educational Development Institute, the Ministry of Education of the Republic of Korea

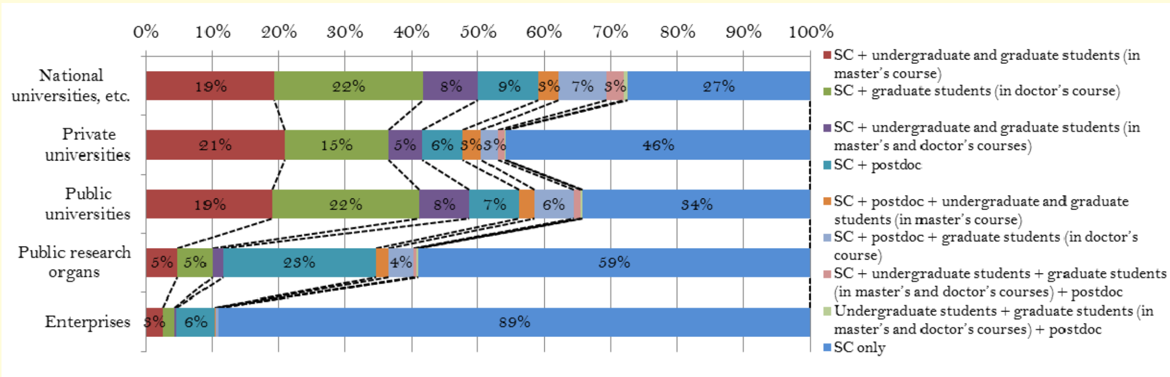
<Other countries> FY2008: The "International Comparison of Educational Indexes" by MEXT

The latest fiscal year: The "Educational Statistics of Various Countries" by MEXT

Prepared by NISTEP, based on the above-mentioned publications. (Japanese Science and Technology Indicators 2017 (August 2017))

Roles played by young researchers -- undergraduate students, graduate students[1] and postdoctoral persons -- are confirmed in this section. The National Institute of Science and Technology Policy (NISTEP) surveyed papers[2] to analyze the composition of research teams, focusing on positions and titles of authors, and found young researchers playing quantitatively important roles. While many teams at universities and other institutions had senior-class researchers, more than half of them had undergraduate students, graduate students or postdoc researchers as members. Teams exclusively consisting of senior-class researchers accounted for 59% of all teams at public research organs, postdoc and senior-class researchers were found working together in 23% of all teams. The finding means that young researchers play roles to a considerable extent at public research organs. In the corporate sector, teams exclusively made up of senior-class researchers accounted for 89% of all teams (Figure 1-1-39).

Figure 1-1-39 **Combination of article authors' positions and titles divided by entities they belong to (Ratio of research teams corresponding to combinations in 2004 to 2012)**



Note: SC means senior-class researchers who are those other than undergraduate and graduate students and postdoc researchers.
Source: Prepared by MEXT, based on NISTEP's "Research funds and teams of research activities that produced scientific publications (Discussion Paper No.146) (June 2017)

An analysis of relations between the structure of research teams at universities, etc. and public research organs and attention given to papers published by them shows that research teams involving young researchers account for roughly 70% (69.6%) of adjusted top 10% cited papers. The ratio for teams consisting exclusively of senior-class researchers is about 30% (Figure 1-1-40).

Q factor, which is the ratio of adjusted top 10% papers to the total number of papers, is 8.5% for research teams made up of senior-class researchers, postdoc researchers and undergraduate and graduate students (in the master's and doctor's courses), 8.4% for teams of senior-class and postdoc researchers and 7.9 for teams of senior-class and postdoc researchers and graduate students (in the doctor's course). As such, the Q factor tends to be higher for teams involving postdoc researchers (Figure 1-1-41).

1 Students in the master's course and in the doctor's course are included

2 A random-sampling questionnaire was conducted on papers whose representative authors belong to entities in Japan, among those published in 2004 to 2012 and stored in Clarivate Analytics' Web of Science, and some 11,000 cases that replied to it were analyzed.

Table 1-1-40 **Ratio (by structure of research teams) to the number of adjusted top 10% papers [research teams at universities, etc. and public research organs 2004-2012]**

Participation by undergraduate and graduate students and postdoc researchers	Ratio to the total number of adjusted top 10% papers
Without participation by undergraduate and graduate students and postdoc researchers (participated in only by senior-class researchers)	30.4%
Participated by undergraduate and graduate students and postdoc researcher	69.6%
Total	100.0%

Note: SC means senior-class researchers who are those other than undergraduate and graduate students and postdoc researchers.
Source: Prepared by MEXT, based on NISTEP's "Research funds and teams of research activities that produced scientific publications (Discussion Paper No.146) (June 2017)

Table 1-1-41 **Q factor for papers subject to the survey (by the structure of research teams [at universities, etc. and public research organs, 2004-2012]**

Participation by undergraduate and graduate students and postdoc researchers		Q factor
Without participation by undergraduate and graduate students and postdoc researchers (participated in only by senior-class (SC) researchers)		4.9%
Participated by undergraduate and graduate students and postdoc researchers		6.3%
Participated in by undergraduate and graduate students and postdoc researchers (breakdown)	SC researchers + postdoc researchers + undergraduate and graduate students (in the master's and doctor's courses)	8.5%
	SC researchers + postdoc researchers	8.4%
	SC researchers + postdoc researchers + graduate students (in the doctor's course)	7.9%
	Postdoc researchers + undergraduate and graduate students (in the master's and doctor's courses)	6.3%
	SC researchers + postdoc researchers + undergraduate and graduate students (in the master's course)	6.1%
	SC researches + graduate students (in the doctor's course)	6.1%
	SC researchers + undergraduate and graduate students (in the master's and doctor's courses)	5.9%
	SC researchers + undergraduate and graduate students (in the master's course)	4.5%
Total		5.8%

Note: 1. Q factor is the ratio of adjusted top 10% papers to the total number of papers.
2. SC means senior-class researchers who are those other than undergraduate and graduate students and postdoc researchers.
Source: Prepared by MEXT, based on NISTEP's "Research funds and teams of research activities that produced scientific publications (Discussion Paper No.146) (June 2017).

With regard to the Nobel Prize, an analysis of ages at researchers received the prize and those at which they made achievements based on study results (papers, etc.) that led to the prize shows that the laureates started studies, which paved the way for winning the prize, mainly in their 30s on the average, suggesting the importance of young researchers in research activities (Table 1-1-42). Given those findings, the decrease in the number of young researchers is expected to become a serious problem for the improvement of Japan's research capacity.

Table 1-1-42 Starting age of studies that led to the reception of the Nobel Price, years spent before winning the prize and average winning age

Decade of winning	Starting age of studies leading to Nobel Prize	Years spent before winning	Average age of winning
1940s	35.3	18.5	53.8
1950s	36.3	15.1	51.4
1960s	35.5	18.3	53.8
1970s	36.7	20.1	56.8
1980s	37.0	21.9	58.9
1990s	36.4	24.5	60.9
2000s	40.0 (37.9)	26.2 (30.3)	66.1 (68.1)
2010s	36.6 (42.3)	29.2 (25.3)	65.8 (67.5)
Total	37.1 (40.1)	22.0 (27.8)	59.0 (67.8)

Note: 1. Figures in parentheses are those for Japanese Nobel laureates
2. "Studies that led to the Nobel Prize" are studies posted on the Nobel Foundation's website[1] as candidates for the prize.
Source: Prepared by MEXT, based on a survey result[2] by NISTEP and the Science for RE-Designing Science, Technology and Innovation Policy (SciREX) Center of the National Graduate Institute for Policy Studies.

B. Extraction of problems

The number of students advancing to the doctor's course is decreasing possibly because the advancement has become less attractive to students in the master's course. The NISTEP has continued its "NISTEP Expert Survey on Japanese S&T and Innovation System (NISTEP TEITEN survey). To grasp the state of Japan's science, technology and innovation, the questionnaire survey annually asks the same questions to the same respondents -- a total of around 2,800 heads of universities, laboratories and facilities jointly used by universities and national R&D corporations as well as persons in charge of actual management, experts in industrial and other sectors and people working as a bridge between R&D and innovation.

With regard to the state of education for young people wishing to become researchers, the survey asks, "Do you think that young people with the desired ability are taking aim at the latter term of the doctoral program?" In the 2017 survey, replies fell below 3.5 on the six-stage index, expressing the "strong recognition of inadequacy." The degree of adequacy was raised from the previous year's survey by 8% of the respondents and lowered by 17%. Reasons for lowering the degree included "Competent people opt for employment at enterprises out of concern about their career path" and "Difficulty of staying at school

1 http://www.nobelprize.org/

2 "Nobel Prize and Science, Technology and Innovation Policy : An analysis for selection process of Nobel Laureates and their scientific carrier (May 2016)" (Akaike, Hara, Shinohara, Uchino, Nakajima) (SciREX Working Paper #3)

without economic worries." The reasons suggest reluctance to advance to the doctor's course (Table 1-1-43).

According to a survey conducted by the NISTEP on students enrolled in engineering master's programs for two years or more at 12 universities[1] in Japan in 2008, the largest number of respondents mentioned an expansion of economic support for students in the doctor's course as an important condition in considering whether to advance to the doctoral program. The finding suggests that economic burden while in school is a reason for increased reluctance to advance to the doctor's course (Table 1-1-44).

Table 1-1-43 Survey of education for young people wishing to become researchers

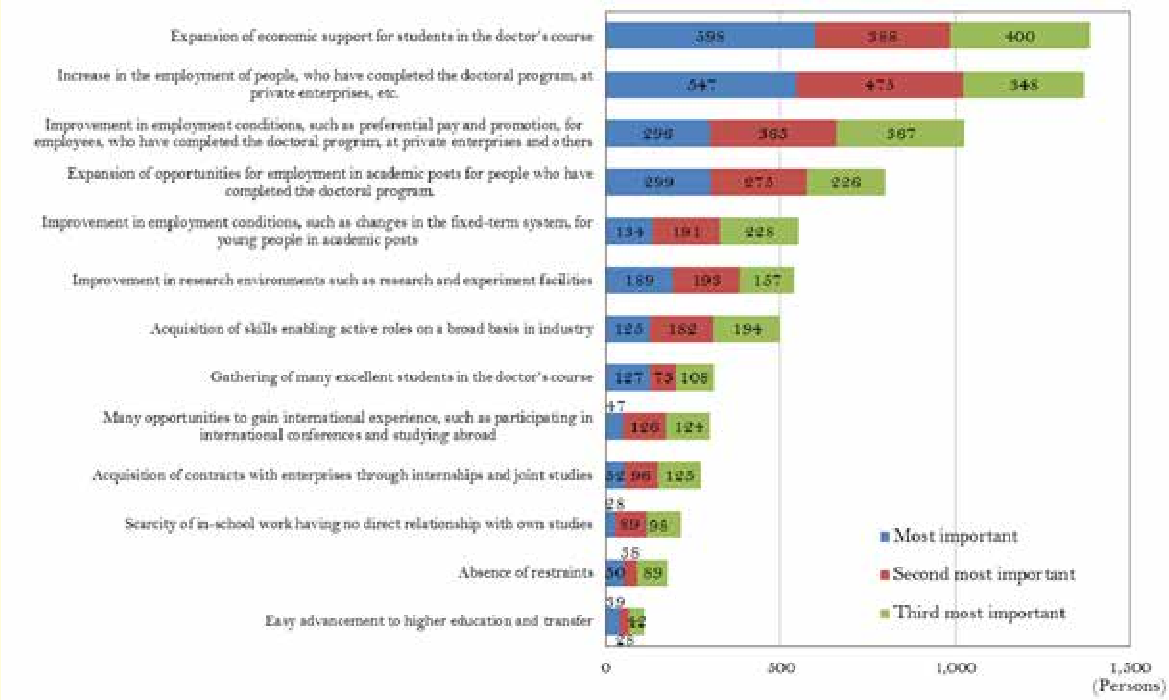
Question	Index figure: Extremely inadequate (Less than 2.5)	Strong recognition of inadequacy (2.5-3.5)	Inadequate (3.5-4.5)	Almost no problem (4.5-5.5)	No problem (More than 5.5)
Do you think that young people with desired ability are taking aim at the latter term of the doctoral program?		● 3.3 (2017 survey)	● 3.5 (2016 survey)		

Reasons for lowering the degree of adequacy
- Drop in the number of students taking aim at or advancing to the doctor's course
- Inclination toward employment at enterprises after completion of the master's course due to improved hiring in the private sectors on an economic pickup
- Competent manpower opting for employment at enterprises out of concern about their career path
- Negative images about the latter term of the doctoral program (such as failure in employment) remain strong.
- Overwhelming presence of young foreign students
- Difficulty of staying at school without economic worries
- Doctorate is not an attractive qualification.
- Medical students are so strongly inclined to become specialists so they do not feel merits in receiving degrees.

Source: Prepared by MEXT, based on NISTEP's "NISTEP Expert Survey on Japanese S&T and Innovation System (NISTEP TEITEN survey 2017) (April 2018)"

1 Hokkaido University, Tohoku University, University of Tsukuba, University of Tokyo, Tokyo Institute of Technology, Waseda University, Keio University, Kyoto University, Nagoya University, Osaka University, Hiroshima University and Kyushu University

Figure 1-1-44 Important conditions to take into account in considering whether to advance to the doctor's course



Source: "Attitude Survey on the Career Choices of Students in Master's Courses of Science and Engineering in Japan (March 2009)" by NISTEP

The Science and Technology Basic Plan has a target of providing an amount equivalent to living expenses to some 20% of students in (the latter term of) the doctoral program. As of FY2015, however, the actual provision of economic support[1] equivalent to living expenses (more than 1.8 million yen) covered 10.4 % of all students in (the latter term of) the doctoral program, about half of the (20%) target in the Science and Technology Basic Plan (Figure 1-1-45).

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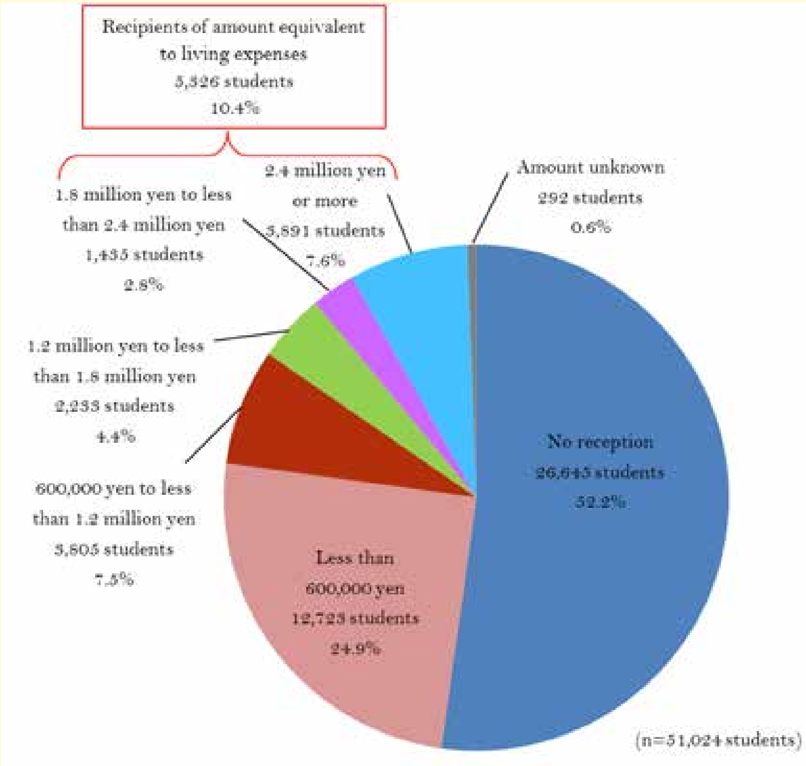
1 Excluding loan-type scholarships provided by Japan Student Services Organization to students studying at (universities, junior colleges, higher vocational schools and specialized training colleges (specialize course)) and graduate schools.

Figure 1-1-45 Amount provided per student in the doctor's course (as of FY2015)



Note: 1. Amount provided includes tuition exemption or exemption

2. As recipients among Young Scientists (DCs), who were excluded from the replies, were categorized as "no reception," the data were adjusted on the assumption of receiving 2.4 million yen per year.

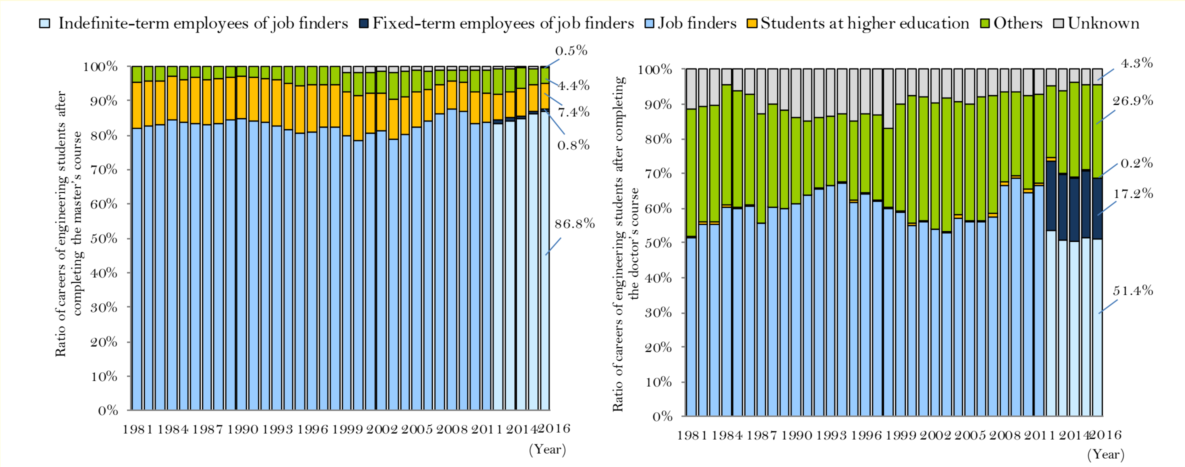
Source: Prepared by MEXT, based on the ministry's "Survey Research of Economic Assistance for Students in the Doctor's Course (March 2017)"

Backgrounds leading to concerns about career path, employment and economic conditions, as mentioned above, will be analyzed in the following section from the viewpoints of career and employment cases and income after completion of studies at graduate school.

(A) Careers after completion of studies at graduate school

An analysis of (37,128) engineering students who completed studies in the master's course in 2015 shows that some 90% of "job finders" were employed as "indefinite-term" employees. While about 70% of (4,809) students who completed studies in the doctor's course gained employment, roughly 50% of the "job finders" were employed as "indefinite-term" employees (Figure 1-1-46).

Figure 1-1-46 Careers of engineering students who completed studies in the master's course (left figure) and in the doctor's course (right figure)[1, 2]



Source: Prepared by NISTEP, based on MEXT's "Report on School Basic Survey." ("Japanese Science and Technology Indicators 2017 (August 2017)")

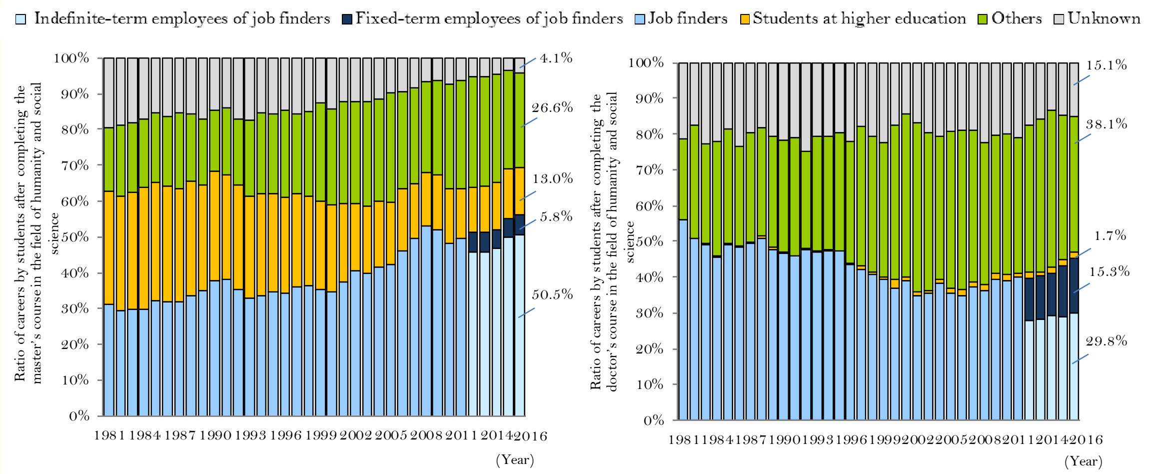
Of students who completed the master's course in the field of humanity and social science, the ratio of "job finders" has been on the rise, coming close to around 60% of the total (11,458 persons) in 2016. While about 50% of (2,135) students who completed the doctor's course were employed, the ratio of those employed as "indefinite-term" employees was only about 30% (Figure 1-1-47).

As mentioned above, the ratio of students employed after completing the doctor's course is lower than that of students who completed the master's course and only less than 50% of the former are employed on an "indefinite-term" basis.

1 Indefinite-term employees are those employed with no fixed period of employment. Fixed-term employees are those employed with a fixed term of employment and have prescribed work hours of around 30 to 40 hours per week.

2 "Others" represent a total of "clinical doctor-in-training," "enrollee at advanced vocational school and overseas school," "temporary employee," etc.

Figure 1-1-47 **Careers of students after completing the master's course in the field of humanity and social science (left figure) and the doctor's course (right figure)[1, 2]**



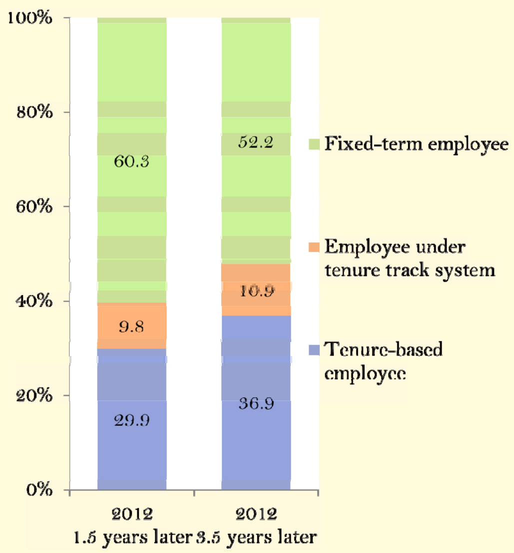
Source: Prepared by NISTEP, based on MEXT's "Report on School Basic Survey." ("Japanese Science and Technology Indicators 2017 (August 2017)")

The above data are as of May 1 or early in the year after completion of the master's or doctor's course. The continuous tracing of employment will show the accumulation of careers and changes in the situation of employment.

Fixed-term employment conditions of employees at universities, etc. and public research organs 1.5 and 3.5 years after their completion of the doctor's course in FY2012 were compared, finding that the ratio of fixed-term employment dropped to 52.2% from 60.3% while the combined ratio of employment on a tenure basis (lifetime employment) and tenure track basis[1] climbed to 47.8% from 39.7% (Figure 1-1-48). As some time is taken before a shift to tenure-based employment, employment conditions need to be considered on a long-term basis. Nevertheless, the finding suggests the gradual formation of career path to stable posts for people who have experienced postdoc and other positions.

1 The tenure track system is aimed at letting young researchers, selected in a fair manner, build up experiences as independent researchers before gaining stable posts.

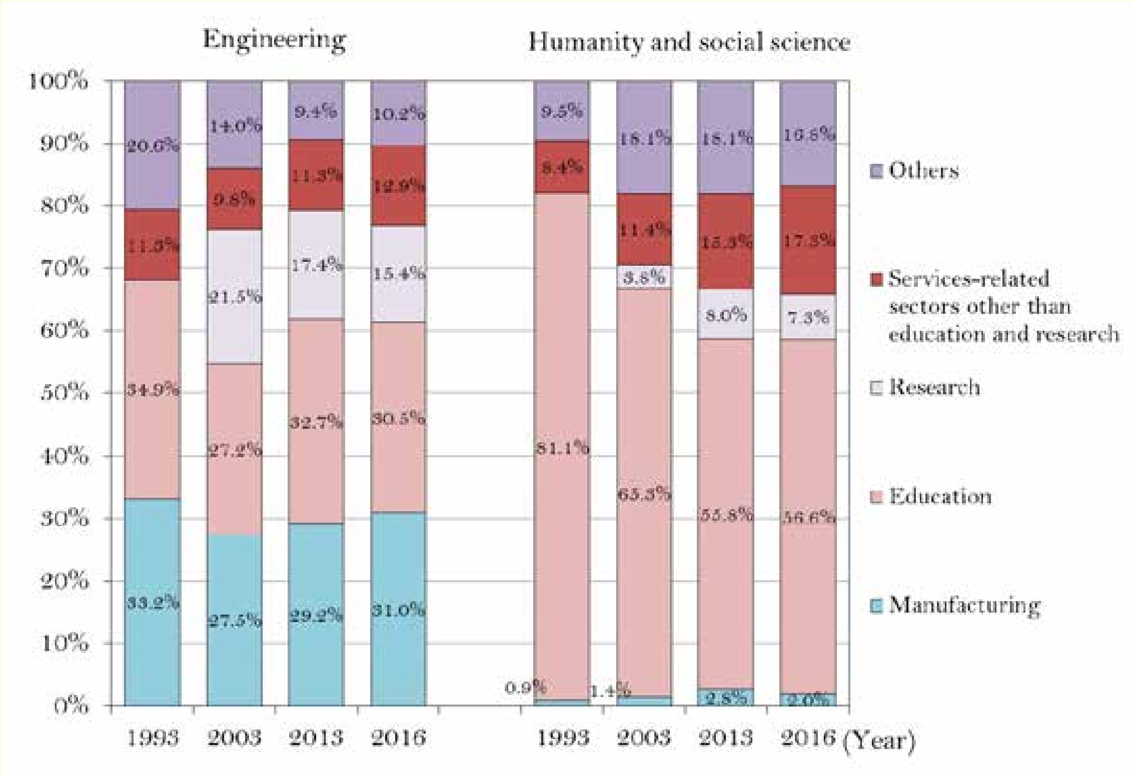
Figure 1-1-48 State of fixed-term employment of people employed at universities, etc. and public research organs



Source: Second report of "Japan Doctoral Human Resource Profiling (February 2018)" by NISTEP

Industry-by-industry employment of people after completing the doctor's course, as shown in Figure 1-1-46 and Figure 1-1-47, shows that the ratio of engineering postdoctoral employees in the "manufacturing" and "educational" sectors stayed at around 30% for more than 20 years from 1993 through 2016 while the ratio for "research" moved between 21.5% and 15.4%. As far as postdoctoral people in the field of humanity and social science is concerned, the ratio of employment in the sector of "education" dropped from 81.1% to 56.6% but retained a majority, while the ratio for the "manufacturing" sector stayed low. In addition, "services-related sectors, other than education and research" showed an upward trend, rising to 17.3% from 8.4%, while the ratio for "research" has remained 7% to 8% since 2013 (Figure 1-1-49).

Figure 1-1-49 **Changes in employment of people who have completed the doctor's course (industry-by-industry employment)**



Note: 1. The number of job finders included those who have advanced to higher education and gained employment at the same time.

2. 1993

Services sector-related: Services designated in the Japan Standard Industrial Classification (Revised in 1993)

Education: "Education" in the "services sector" designated in the Japan Standard Industrial Classification (revised in 1993)

2003

Services sector-related: "Information and communications," "eating and drinking services," "medical and welfare," "education and academic support," "compound services" and "services (not classified otherwise)" in the Japan Standard Industrial Classification (revised in 2002)

Education: "School education" of "education and academic support" in the Japan Standard Industrial Classification (revised in 2002)

Research: "Scientific and development research" of "services (not classified otherwise)" in the Japan Standard Industrial Classification (revised in 2002)"

2013 and 2016

Services sector-related: "Scientific research and professional and technology services," "accommodation, eating and drinking services," "living-related and personal services," "education and academic support," "medical and welfare services," "compound services," "services (not classified otherwise) and "information and communications" in the Japan Standard Industrial Classification (revised in 2017)

Education: "School education" of "Education and academic support" in the Japan Standard Industrial Classification (revised in 2017)"

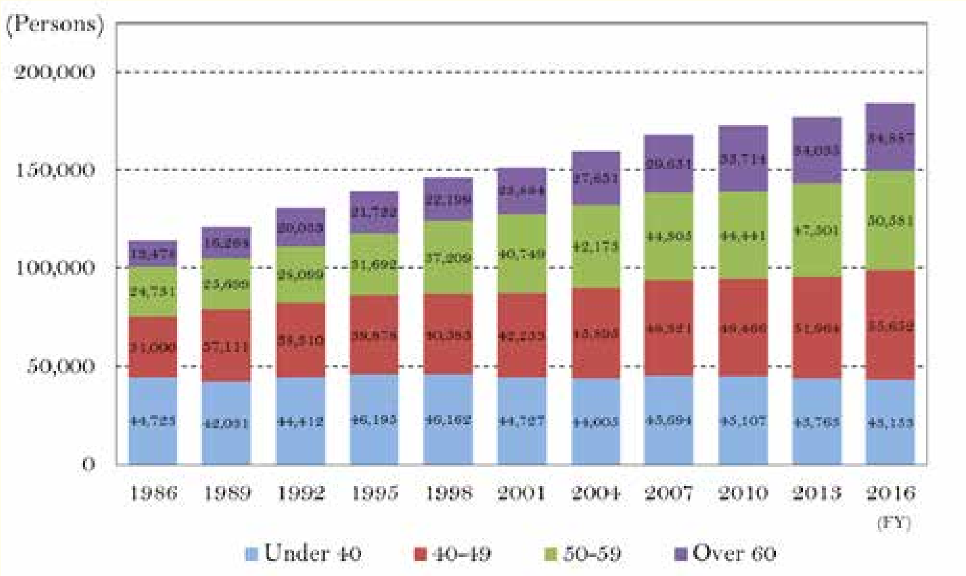
Research: "Scientific and development research" of "scientific research and professional and technology services" (revised in 2017)

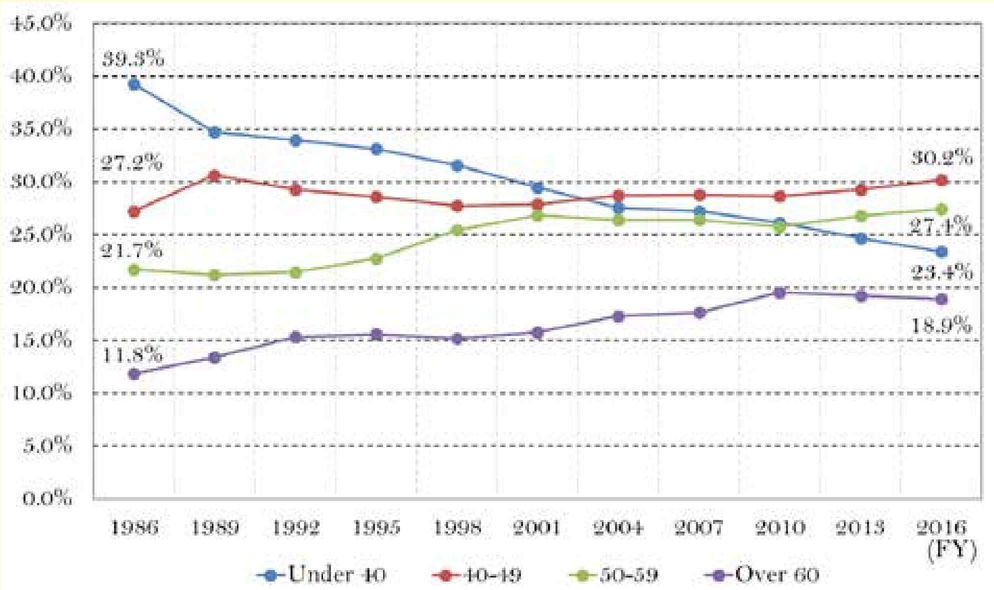
Source: Prepared by NISTEP and MEXT, based on MEXT's "Report on School Basic Survey"

(B) Employment of regular teachers at national, public and private universities

Next are changes in the actual age-based number of regular teachers[1] at national, public and private universities, where clear age-based and other statistical data are available, in the 30 years from 1986 till 2016 and increase-decrease rates, showing that while the number showed an increasing trend in all age brackets above 40, the ratio of teachers younger than 40 dropped to 39.3% of the total in 1986 to 23.5% in 2016. The ratios of teachers aged 40 to 49, 50 to 59, and 60 and older rose by several percentage points, suggesting advances in the aging of teachers (Figure 1-1-50).

Figure 1-1-50 Age-based structure of regular teachers at universities (upper figure: absolute number, lower figure: increase-decrease rates)



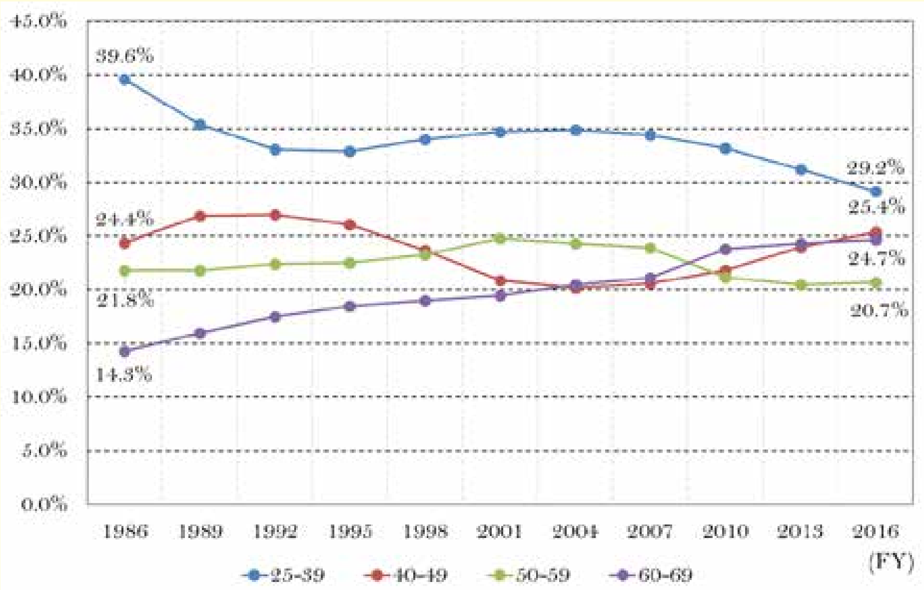


Source: Prepared by MEXT, based on the ministry's "Statistical Survey Report on School Teachers"

1 Regular teachers: Full-time teachers enrolled at universities concerned

In the meantime, the difficulty of securing young teachers under 40 years old is expected to continue as the ratio of people aged 25 to 39 to Japan's 25- to 69-year-old population is showing a declining trend (Figure 1-1-51).

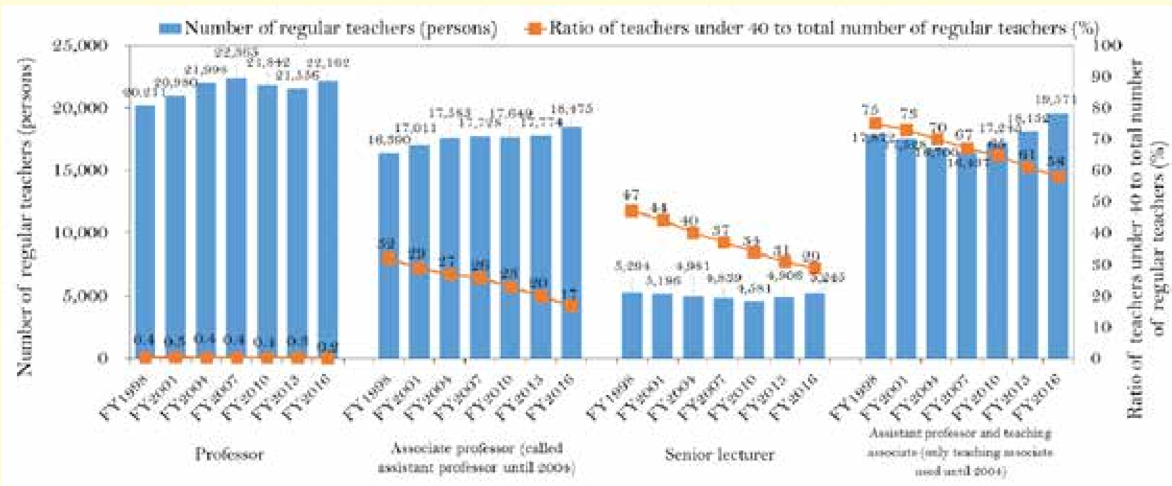
Figure 1-1-51 Age-based structure of Japan's population (25 to 69 years old)



Source: Prepared by NISTEP and MEXT, based on "Population Estimates" compiled by the Statistics Bureau of the MIC.

In addition, an analysis of changes in the position-based number of university teachers shows a decreasing trend in the ratio of young teachers (under 40) in all categories of associate professor, senior lecturer, assistant professor and teaching associate (Figure 1-1-52).

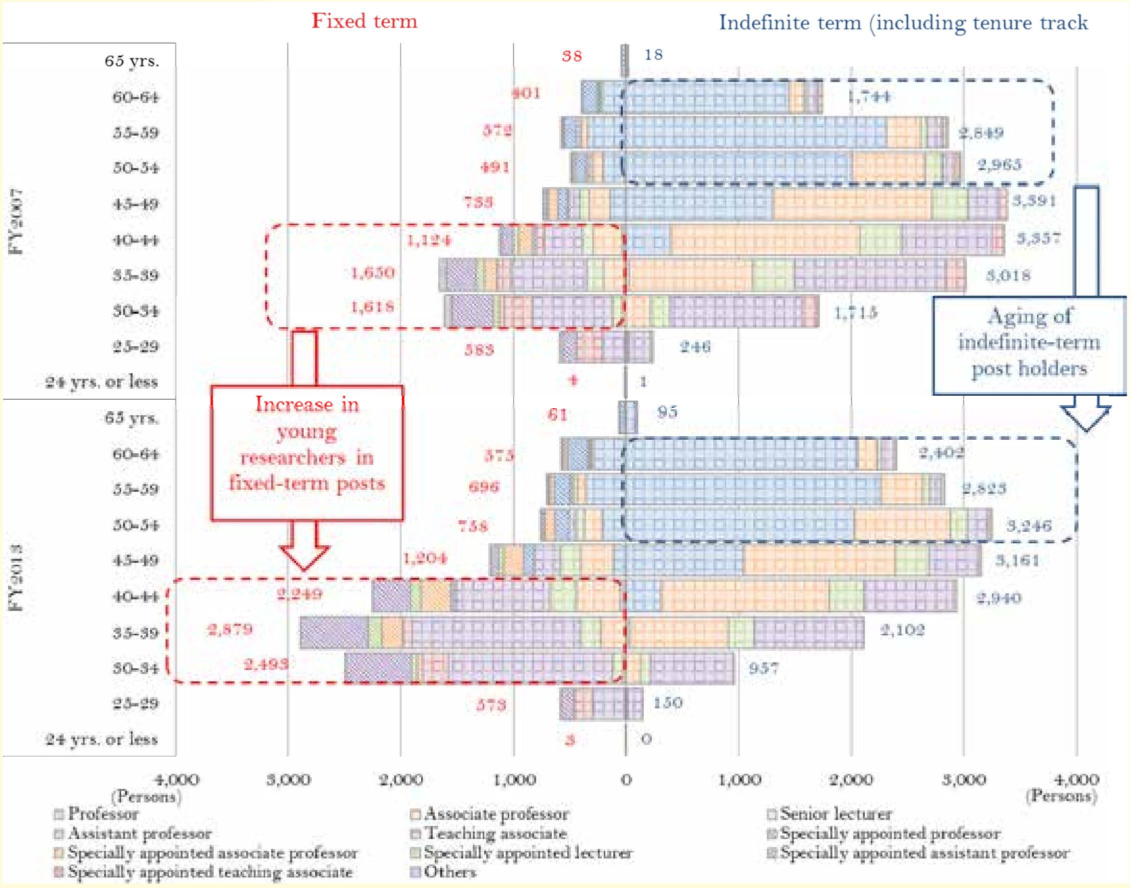
Figure 1-1-52 Employment situation of teachers at national universities



Source: Prepared by MEXT, based on the ministry's "Statistical Survey Report on School Teachers"

With regard to the form of employment, furthermore, the ratio of fixed-term employment for young teachers is reported to be increasing. A survey of RU11[1] found that the fixed-term employment of teachers aged 30 to 44 increased sharply between 2007 and 2013 while the ratio of indefinite-term employment increased for teachers aged 50 to 64 during the same period. The number of specially appointed teachers, hired for specific projects, is increasing especially among young teachers (Figure 1-1-53).

Figure 1-1-53 Existence or non-existence of fixed-term posts and age-based structure at RU11



Source: "The Employment Status of Instructional Staff Members at 11 Research Universities (RU11) (September 2015)" by NISTEP

In light of the above-mention situation, it is conceivable that universities will need to promote efforts, such as personnel system reforms and strategic nurturing of young researchers, to secure young researchers.

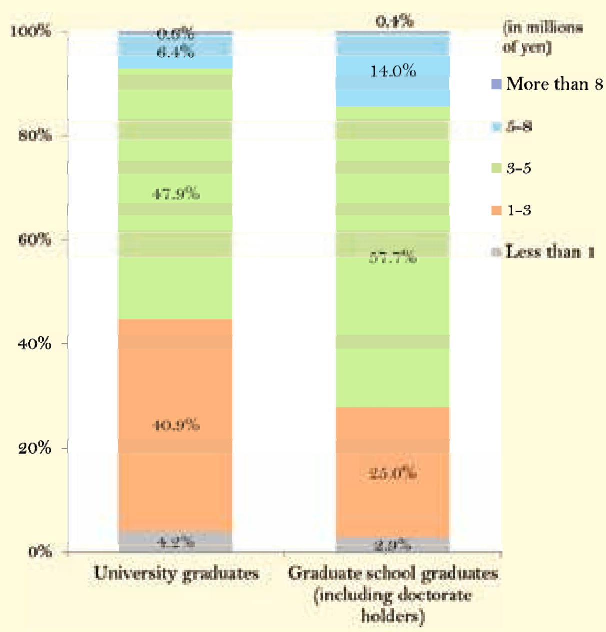
(C) Income after completion of graduate school

Using the MIC's "2012 Employment Status Survey," the NISTEP analyzed the one-year, tax-included

1 RU11 is a consortium of 11 research universities formed independently of whether they are national or private and is officially called the "11 principal research universities." It was founded in November 2009 by 9 universities (Hokkaido University, Tohoku University, the University of Tokyo, Waseda University, Keio University, Nagoya University, Kyoto University, Osaka University and Kyushu University, and the University of Tsukuba and the Tokyo Institute of Technology joined it in August 2010.

labor income of graduates from universities (hereinafter referred to as university graduates), aged 25 to 29, and graduates from graduate schools (hereinafter referred to as graduate school graduates) in 2012, finding that 7.0% of university graduates and 14.4% of graduate school graduates earned more than 5 million yen, respectively. While 27.9% of graduate school graduates earned less than 3 million yen, the ratio was much higher at 45.1% for university graduates. The survey thus found that the income level of graduate school graduate was higher as a trend than that of university graduates (Figure 1-1-54).

Figure 1-1-54 **1-year, tax-included labor income (university graduates and graduate school graduates)[1]**

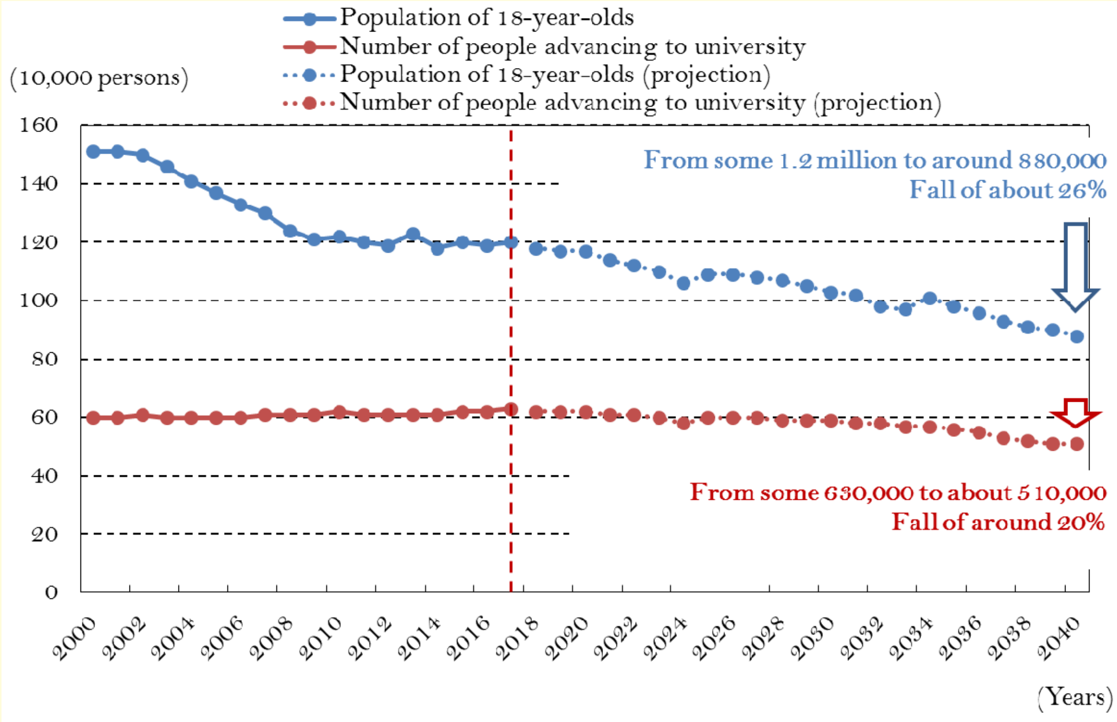


Source: Prepared by NISTEP, based on the "2012 Employment Status Survey" Table No. 40 BO40 (4) 25- to 29-year-olds, compiled by the Statistics Bureau of the MIC. (First Report of "Japan Doctoral Human Resource Profiling (November 2015)")

While decreases in the numbers of enrollees in the doctor's course and young researchers have been analyzed so far in this report, effects from the dwindling population of young people in Japan's demographics are also a matter of concern. The population of 18-year-olds has declined to around 1.2 million from approximately 1.37 million in 2005. There is even an estimate that the population will fall below 1 million in 2032 for the first time to some 980,000 and shrink further to about 880,000 in 2040, spelling a decrease of about 26% from the present. Accompanied by a decrease in the number of 18-year-olds, the number of people advancing to university is estimated to drop roughly 20% from about 630,000 at present to around 510,000 in 2040 (Figure 1-1-55). The projected changes in the number of people advancing to university are expected to affect the number of young researchers in the long run.

1 (1) Excluding "No income" (2) http://www.e-stat.go.jp/SG1/estat/GL08020103.do?_toGL08020103_&tclassID =000001048178&cycleCode=0&requestSender=search.

Figure 1-1-55 **Changes in the population of 18-year-olds and number of people advancing to university (Figures for FY2018 and thereafter are estimates)**



Sources: ○Population of 18-year-olds: (1) 1980-2017 … Prepared by MEXT, based on the ministry's "Report on School Basic Survey," (2) 2018-2029 … Estimated by MEXT, based on the ministry's "Report on School Basic Survey," (3) 2030-2034 … Estimated by MEXT by multiplying the number of births by the rate of survival in the "Vital Statistics" of the Ministry of Health, Labour and Welfare and (4) 2035-2040 … Prepared by MEXT (prorated in accordance with 2034 prefectural ratios), based on the National Institute of Population and Social Security Research's "Population Projection for Japan (Projection in 2017)" (medium fertility and medium mortality)
○Number of people advancing to university: (1) 1980-2017 … Prepared by MEXT, based on the ministry's "Report on School Basic Survey" and (2) 2018-2040 … Estimated by MEXT, based on the ministry's "Report on School Basic Survey"

C. Typical examples of efforts

Typical support measures for students in the doctor's course are introduced below.

The Science and Technology Basic Plan has a target of providing an amount equivalent to living expenses to some 20% of students in (the latter term of) the doctoral program. Efforts are being made to improve economic support from a variety of financial sources to meet the target (Table 1-1-56). In addition to the "Young Scientist (DC)" program, MEXT supports the reduction and exemption of tuitions at national and private universities, etc. through grants to the management of national university corporations and special subsidies, etc. of the subsidy program for current expenditures of private universities, etc. to enable students to continue studies even when it is difficult for them to pay tuitions, etc. for economic and other reasons.

In addition, the Japan Student Services Organization offers scholarships to students who, though competent, are unable to advance to higher education due to economic reasons. Under the scholarship program, students, who receive interest-free scholarships at graduate school, are exempted from repaying them if they accomplish excellent achievements while at school.

Table 1-1-56 **Main economic support programs for students in the doctor's course (number of students receiving support equivalent to living expenses)**

Name of financial source	No. of recipients
Young Scientist (DC)	2,882
Program for Leading Graduate Schools	637
Grants for management expenses, etc.	320
Government-sponsored foreign student	218
Scholarship programs by private organizations (enterprises, etc.) (excepted from repayments)	191
Subsidy program for science and technology expenses	33

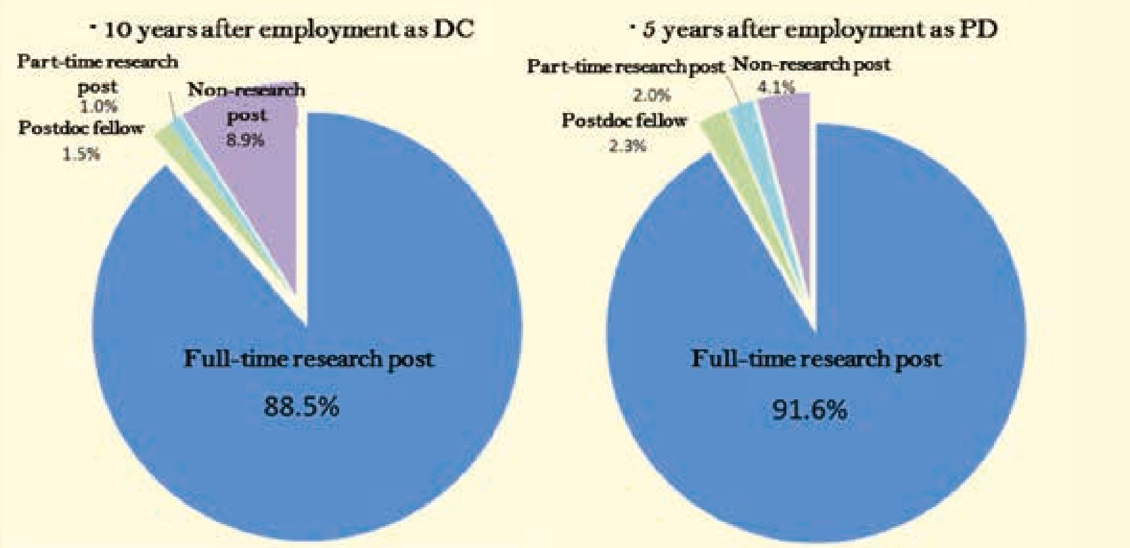
Source: Prepared by MEXT, based on the ministry's "Survey Research of Economic Assistance for Students in the Doctor's Course (March 2017)"

The "Research Fellowship for Young Scientists," which has been implemented for more than 30 years, is explained here. The system was introduced in 1985, based on the Science Council's report on "Basic Policies To Improve the Academic Research System" (February 6, 1984), to nurture and secure highly creative researchers, who would bear the future of Japan's academic research by giving young, competent researchers opportunities to voluntarily choose themes of study and devote themselves to studies at an early stage of their academic life. The system covers students in the doctor's course at universities, doctorate holders and others and hires those with advanced research capacity who wish to devote themselves to studies at universities and other research organs as "Young Scientists" and provides them with monetary incentives for research. It has carried out a "Young Scientist (DC) program" for students in the doctor's course at universities and a "Young Scientist (PD) program" for doctorate holders, etc.

Various economic support measures have been implemented for students in the doctor's course. As shown in Table 1-1-56, however, more than half of recipients of support equivalent to living expenses are DCs.

As the achievements of such efforts, 88.5% of DCs or students in the later term of the doctor's course assumed full-time research posts 10 years after the completion of employment as DCs. In the PD program for doctorate holders, 91.6% assumed full-time research posts 5 years after the completion of employment as PDs (Figure 1-1-57).

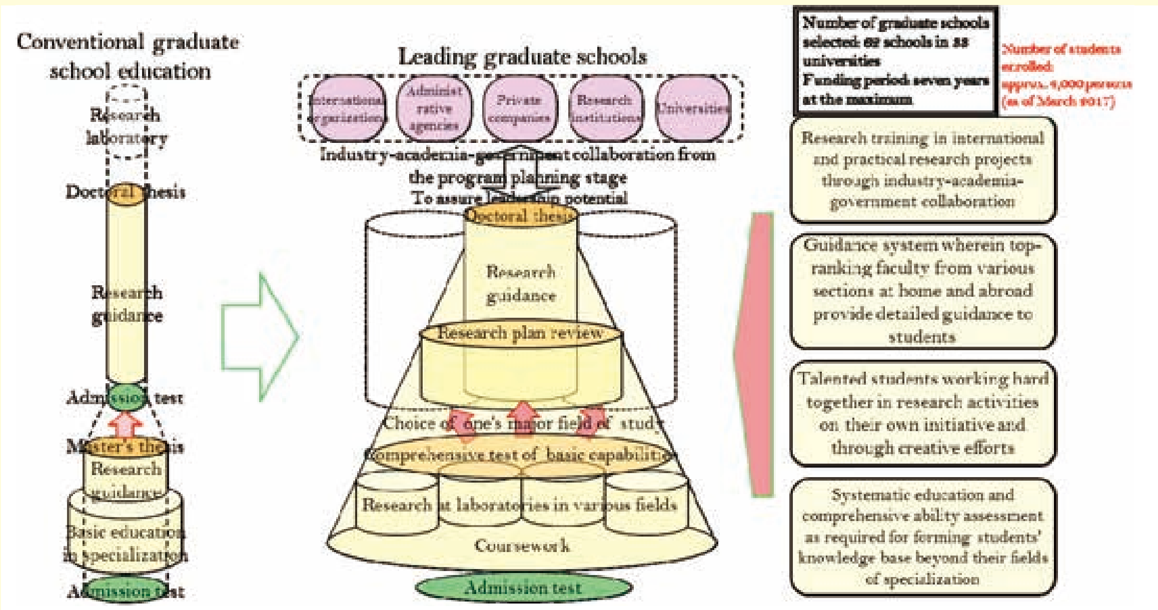
Figure 1-1-57 Employment of young scientists after completion of employment as DCs and PDs (as of April 1, 2016)



Source: Prepared by the Japan Society for the Promotion of Science, based on the society's "Fact-Finding Survey on the Employment of Young Scientists"

In FY2011, MEXT launched the Program for Leading Graduate Schools as an initiative in graduate school education reforms to cultivate doctorate holders and encourage them to play an active role in industry. This program aims to promote the development of excellent students who are both highly creative and internationally attuned beyond the boundaries of their fields of specialization and who will play leading roles in the academic, industrial and governmental sectors across the globe, establish career paths for doctoral graduates, and create a virtuous cycle that supports doctorate holders in playing an active role in diverse sectors (Figure 1-1-58).

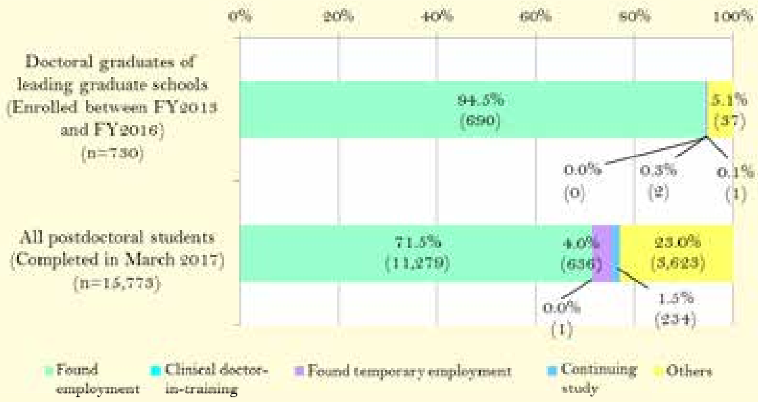
Figure 1-1-58 Outline of the Program for Leading Graduate Schools



Sources: Prepared by MEXT (FY2017)

In the Program for Leading Graduate Schools, among 730 students who completed the doctoral programs by the end of FY2016, 690 students (94.5%) gained employment, showing a higher rate of employment than among all postdoctoral students (71.5%) (Figure 1-1-59). About 40% of graduates of doctoral programs at leading graduate schools found a job and began playing an active role in various sections in their workplaces such as private companies and government agencies (Figure 1-1-60).

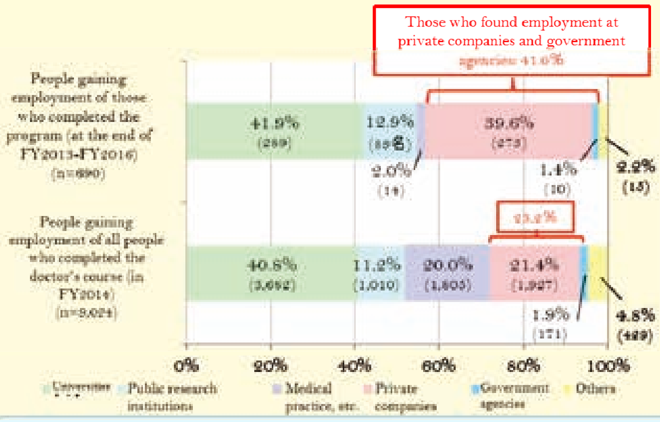
Figure 1-1-59 Careers after completion of the Program for Leading Graduate Schools



Note: 1. Doctoral graduates in the School Basic Survey include those who completed the required coursework but withdrew from their study before earning a doctoral degree.
2. Graduates who were "temporary employed" in the School Basic Survey are those who found employment for temporary income and engaged in work for a period of less than one year or in part-time work regardless of the period of employment.
3. "Employed people" of those who have completed the program include founders of business (3 persons).
4. All postdoctoral fellows are included in "Found employment."
5. "Others" include those who are searching for jobs.

Sources: Prepared by MEXT, based on the ministry's "FY2016 Basic School Statistics" and survey findings.

Figure 1-1-60 Employment of people who have completed the Program for Leading Graduate Schools



Breakdown of the number of postdoctoral fellows in universities and public research institutions

		Number of postdoctoral fellows
Doctoral graduates of leading graduate schools	Universities	158
	Public research institutions, etc.	43
	Total (Percentage of all those employed)	201 (29.1%)
All doctoral graduates	Total (Percentage of all those employed)	1,762 (19.5%)

[Major places of employment]

(Universities and public research institutions) Hokkaido University, Tohoku University, University of Tsukuba, Chiba University, University of Tokyo, Tokyo Institute of Technology, Tokyo Gakugei University, Nagoya University, Kyoto University, Osaka University, Kyushu University, Tokyo Metropolitan University, Keio University, Waseda University, Stanford University, University of Oxford, University of London, Massachusetts Institute of Technology, University of California, Columbia University, National Institutes of Natural Sciences, High Energy Accelerator Research Organization, RIKEN, National Institute of Advanced Industrial Science and Technology, New Energy and Industrial Technology Development Organization, NASA, NIH, Max Planck Society, etc.

(Private companies and government agencies) Chugai Pharmaceutical, Daiichi Sankyo, Astellas Pharma, Sumitomo Chemical, Hitachi, NEC, Mitsubishi Electric, MEXT, JPO, etc.

Note: 1. Doctoral graduates in the Graduate School Activity Survey include those who studied at graduate schools while maintaining their employment.
2. Doctoral graduates in the Graduate School Activity Survey include those who completed the required coursework but withdrew from their study before earning a doctoral degree.
3. The Graduate School Activity Survey does not provide necessary data for identifying the types of entities to which 1,762 postdoctoral fellows belong. Therefore, the data was obtained from the Survey on Postdoctoral Fellows Regarding Employment and Careers (December 2014; NISTEP; 75.6% in universities and 24.4% in other entities) and was proportionally divided between universities and public research institutions.

Source: Prepared by MEXT, based on the ministry's "FY2014 Survey on Graduate School Activities" and survey findings.

(2) Diversity and mobility of human resources

A. Analysis of present state

To maximize the possibility of innovation created in Japan, it is necessary to promote not only the empowerment of various human resources, such as women and foreigners, but also the fusion of knowledge and social implementation of research achievements under global environments in which human resources flow beyond barriers such as fields, institutions, sectors and national borders.

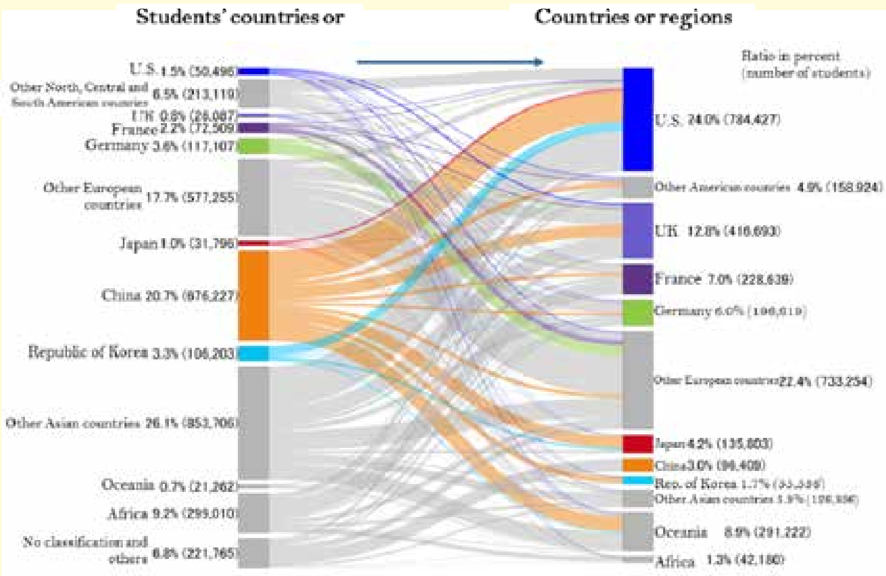
The flow of human resources beyond fields, institutions, sectors and other barriers, in addition to international research networks and female researchers, is analyzed below.

(A) Current state of international research networks

From the viewpoint of improving the quality of studies, the accumulation of international experiences and joint international authorship of papers are said to be important for production of papers that draw strong attention, such as adjusted top 1% and 10% papers.

The international acceptance and dispatch of students at and from higher educational institutions are analyzed here from the viewpoint of the international mobility of human resources. The dispatch of students from Japan to other countries is relatively small, accounting for 1.0% of total numbers in the world. While students from Asia form the largest number of foreign students accepted by Japan, the acceptance of foreign students by Japan is also limited in comparison with the U.S. and European countries, accounting for 4.2% of the world's total. China sends over a larger number of students abroad than any other country or region, capturing a share of 20.7%, while the U.S. accepts the biggest number of foreign students, having 24.0% of all students studying abroad. The U.K. trails the U.S. at an acceptance ratio of 12.8%. While the U.S. and the U.K. accept many students from abroad, the number of students going abroad from the two countries to study is limited (Figure 1-1-61). The number of students going overseas for studying from Japan peaked in FY2004 and has since been on the decline (Figure 1-1-62).

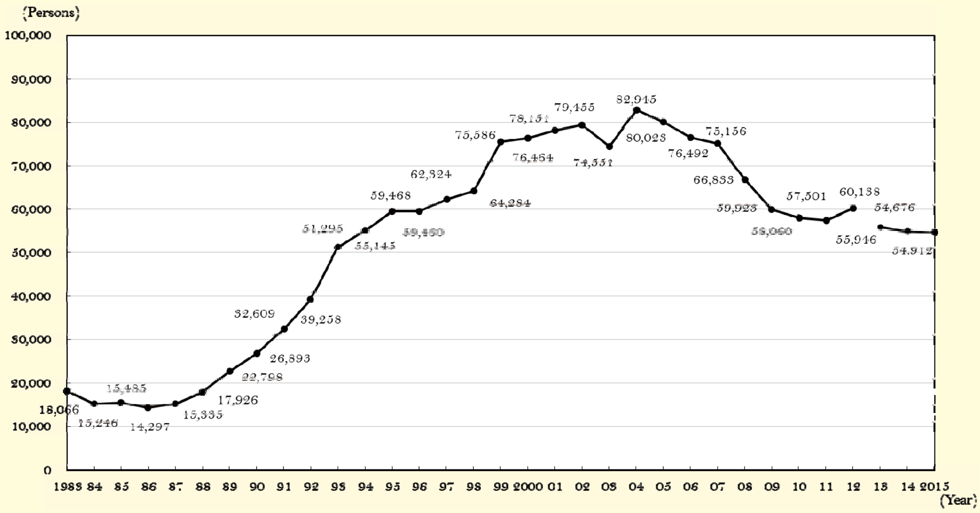
Figure 1-1-61 Countries and regions where foreign students come from and countries and regions accepting them (2013)



Note: 1. Students at Levels 5-8 of the International Standard Classification of Education, etc. (advanced vocational schools and universities (undergraduate, master and doctor's programs)) are covered.
2. Foreign students are those who do not have the nationality of the countries or regions accepting them.
3. China includes Hong Kong.

Source: Prepared by NISTEP, based on the OECD's "Educational and skills." ("Japanese Science and Technology Indicators 2017 (August 2017),"

Figure 1-1-62 Changes in the number of students going abroad from Japan for study

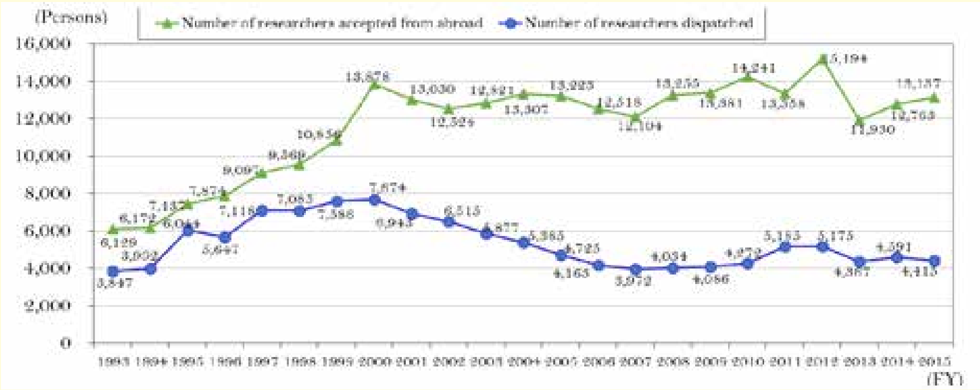


Note: Data compiled by the OECD and the UNESCO Institute for Statistics covered Japanese students counted as foreign students (students who do not have the nationality of the countries accepting them) until 2012 and began to cover Japanese students enrolled at higher educational institutions overseas (students who have moved to countries for study from the previous countries of residence or their countries of origin) in 2013. The comparison therefore has become impossible.

Sources: Prepared by MEXT, based on the OECD's "Education at a Glance," data compiled by the UNESCO Institute for Statistics, the IIE's "Open Doors," and surveys by the Education Ministry of the People's Republic of China and the Ministry of Education of Taiwan

The international mobility of researchers is confirmed next. The number of researchers from abroad accepted by Japan and the number of researchers dispatched overseas from Japan for a short-term (within 30 days) studies have shown an upward trend over the past 20 years. In FY2015, Japan accepted 26,489 researchers from abroad and dispatched 166,239 researchers (Figure 2-4-8 and Figure 2-49). The dispatch of researchers overseas for a medium- to long-term (for more than 30 days) studies dropped (to about 7,700) in FY2000 and has been hovering around 4,000 to 5,000 since FY 2008. While the number of foreign researchers accepted by Japan has varied greatly, although it has stayed between 12,000 and 15,000, which is more than twice as many as the number of dispatched researchers (Figure 1-1-63).

Figure 1-1-63 **Number of researchers accepted from abroad for medium- to long-term studies and number of researchers dispatched for medium- to long-term studies**

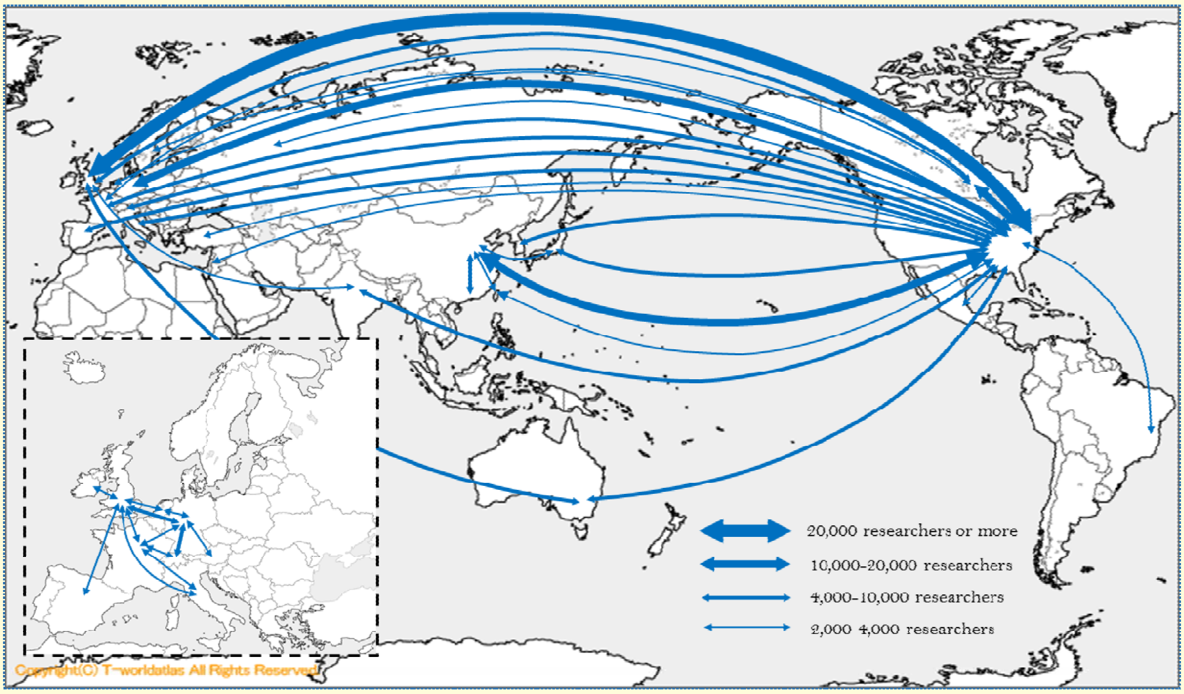


Source: “Survey on International Research Exchanges (June 2017)” compiled by MEXT

Main global flows of researchers, confirmed through the OECD[1]'s survey results, show that the U.S. is at the center of international research networks, followed by European countries, such as the U.K., Germany and France, where there are frequent moves made by researchers. In contrast, Japan is outside the international network of research as the mobility of researchers involving the country is extremely low (Figure 1-1-64).

1 Organization for Economic Co-operation and Development

Figure 1-1-64 Main flows of researchers in the world



Unit [researchers]

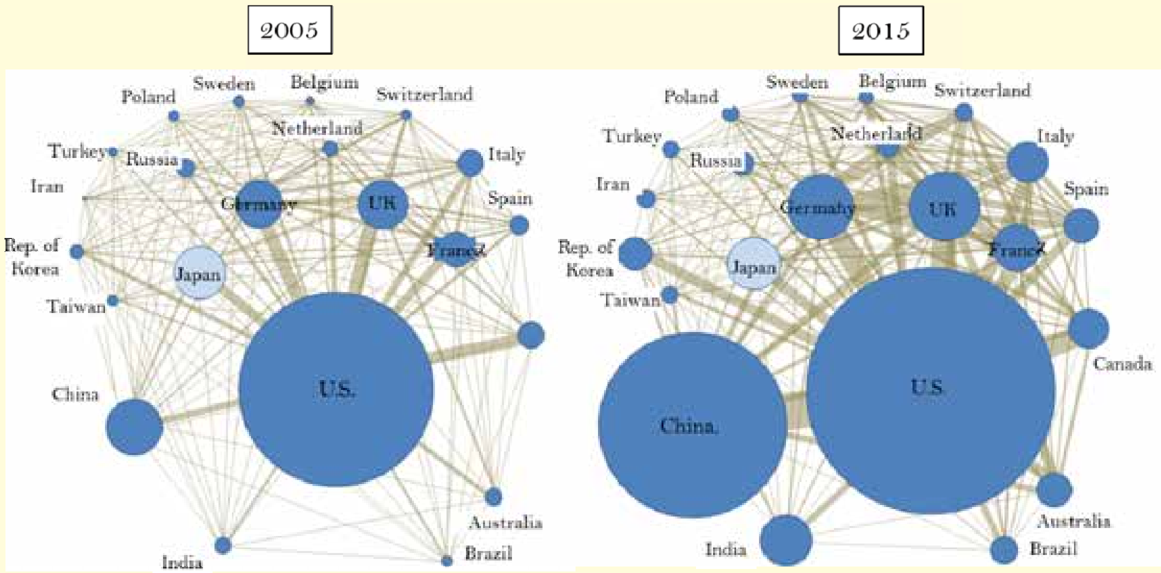
Country A	Country B	Country A→ Country B	Country B→ Country A	Total number
UK	U.S.	12,739	10,323	23,062
U.S.	China	8,537	7,978	16,515
Germany	U.S.	8,042	6,210	14,252
Japan	U.S.	5,668	4,039	9,707
France	U.S.	4,913	3,292	8,205
U.S.	Republic of Korea	4,769	2,942	7,711
Germany	UK	3,283	2,330	5,613
France	UK	2,212	1,698	3,910
Japan	China	2,418	875	3,293

Note: The thickness of arrows represents the "number of researchers in the OECD's "International flows of scientific authors, 1996-2011." The table above was made from excerpts from arrows each showing a total number of more than 2,000 researchers.

Source: Prepared by MEXT, based on the OECD's "Science, Technology and Industry Scoreboard 2013"

Changes concerning international joint papers are confirmed next. Figure 1-1-65 compares joint papers between countries or regions concerned between 2005 and 2015. The size of circles for countries or regions shows the number of papers and the thickness of lines, which connects circles, represents the number of international joint papers. The figure clearly shows that the number of papers in countries or regions increased between 2005 and 2015 as did the number of international joint papers. In particular, the number of papers in China increased together with the number international joint papers involving the country. The number of international joint papers involving the U.K., Germany, France and other EU member states has also increased as confirmed by the figure. As for Japan, meanwhile, the number of international joint papers has stalled amid the low international mobility and the relative presence of the country has been weakening. There may be problems concerning Japan's participation in the international brain environment.

Figure 1-1-65 Changes in the number of papers and trends concerning international joint papers



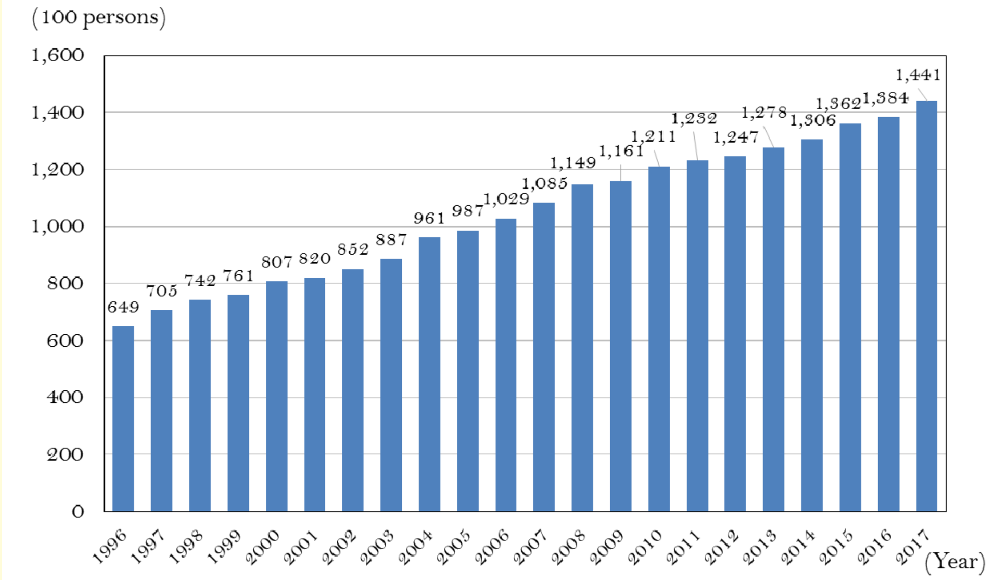
Note: 1. The size of circles represents the number of papers in countries or regions concerned
2. Lines connecting circles represent the number of international joint papers involving countries and regions concerned and the larger the number, the thicker the lines become.
3. Each figure shows the number of papers in the previous three years.
Source: Prepared by NISTEP, based on Elsevier Inc.'s Scopus.

(B) Current state of female researchers

To stimulate science, technology and innovation activities by incorporating a variety of viewpoints and excellent ideas, it is indispensable to create environments that enable women to exercise their ability to the maximum and encourage them to play active roles. An analysis of conditions surrounding female researchers in Japan shows that their number roughly doubled over more than 20 years from 1996 to 2017 (Figure 1-1-66).

Also, although the ratio of female researchers to the total number of researchers has been on the rise, it remained low at 15.7% in 2017, compared with around 30% in other countries (Figure 1-1-67).

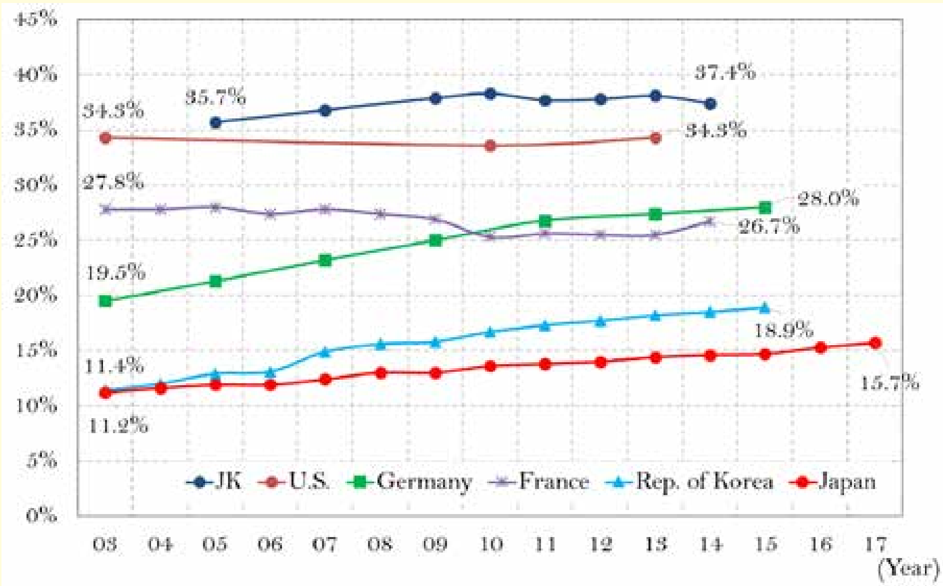
Figure 1-1-66 Changes in the number of female researchers in Japan



Note: This survey covers people who have completed courses at universities, excluding junior colleges, or who have expertise equivalent to or higher than such people and engage in studies on specific themes. Data on university researchers have been collected by surveying faculty members (professor, associate professor, senior lecturer and assistant professor) as well as medical staff and students enrolled in the doctor's course at graduate schools.

Sources: Prepared by MEXT, based on the "Report on the Survey of Research and Development" compiled by the Statistics Bureau of the MIC

Figure 1-1-67 Ratio of female researchers in other countries



Note: U.S. data cover scientists in S&E Occupations[1] and show the ratio of women to the number of employed people who have bachelor or higher degrees.

Sources: Prepared by MEXT, based on the "Report on the Survey of Research and Development" compiled by the Statistics Bureau of the MIC, the OECD's "Main Science and Technology Indicators" and the NSF's "Science and Engineering Indicators 2016"

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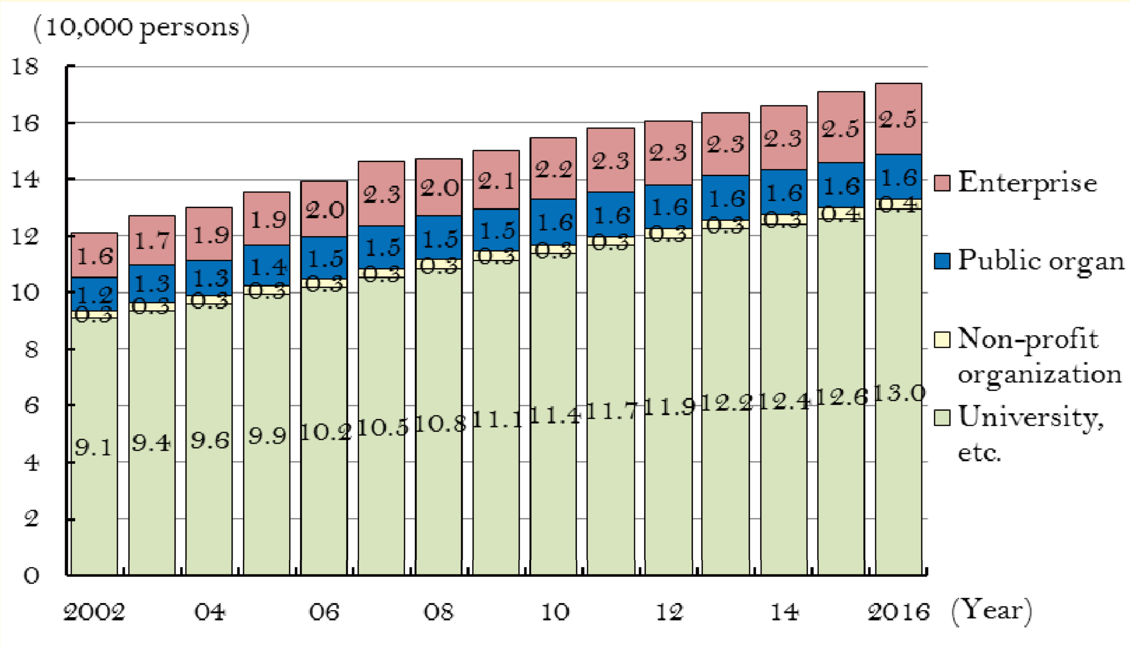
1 Science occupations include biologists and life scientists, computer and information scientists, mathematical scientists, physiochemical scientists, psychologists and social scientists. Engineering occupations include aviation engineers, scientific engineers, civil engineers, electrical engineers, industrial engineers, machinery engineers and other engineers as well as educationists of higher education (education for higher education)

(C) Flow of people beyond fields, institutions, sectors and other barriers

To promote the flow of human resources beyond fields, institutions, sectors[1] and other barriers in Japan is important to enable them to improve their qualifications and abilities and promote the creation of new knowledge and social implementation of research achievements through the fusion and inspiration of a variety of knowledge. As of 2015, the "university, etc." sector had the largest number of doctorate holders (about 130,000) and the number has kept increasing. The number of doctorate holders in the "public organ" and "enterprise" sectors is small (roughly 16,000 and 25,000, respectively) but has been increasing over an extended period (Figure 1-1-68).

Figure 1-1-68 Changes in the number of doctorate holders in each sector



Note: The number of researchers is headcounts.
Source: Prepared by NISTEP, based on the "Report on the Survey of Research and Development" compiled by the Statistics Bureau of the MIC. (Japanese Science and Technology Indication 2017 (August 2017))

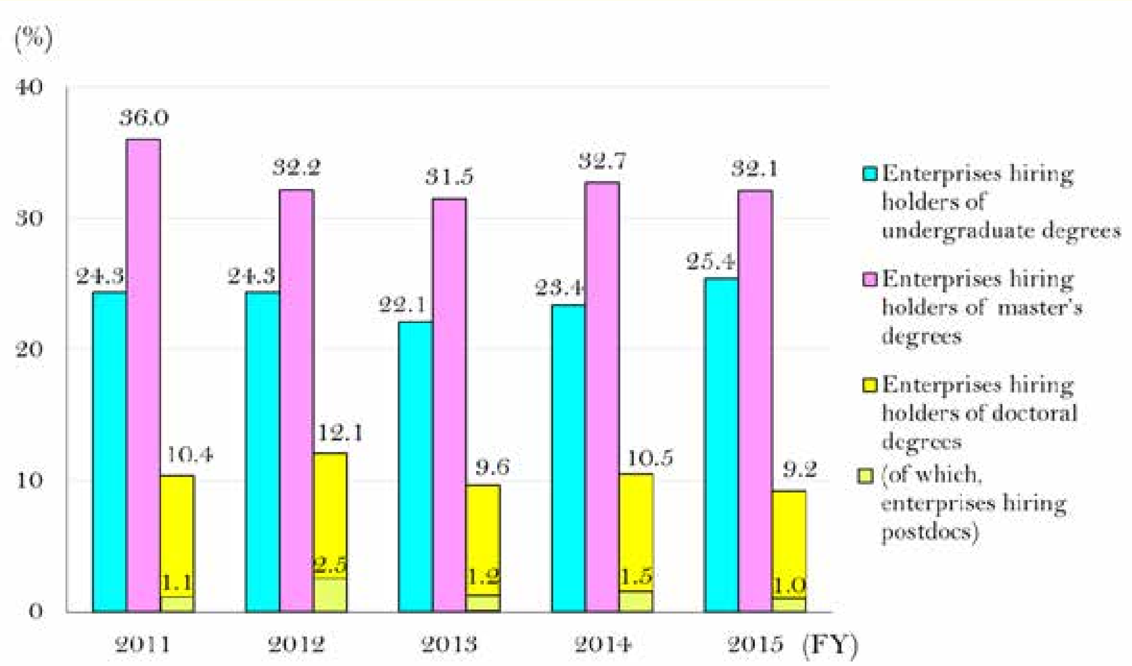
Following is the employment situation of people who have completed the doctor's course at private enterprises. According to the NISTEP's "Survey on Research Activities of Private Corporations" covering private enterprises[2] which are capitalized at 100 million yen or more and engaged in R&D activities, 9.2 of them employed people who had completed the doctor's course as R&D personnel[3] in FY 2015. More than 90% of private enterprises engaging in R&D activities did not employ people who had completed the doctor's course, as R&D personnel. Enterprises hiring people who have completed the doctor's course,

1 Sectors: Enterprise, public organ, non-profit organization, university, etc.
2 While the survey covers some 3,500 enterprises each fiscal year, replies come from about 1,000 of them.
3 People who have completed courses at universities (excluding junior colleges) or have expertise equivalent to or higher than such people, are engaged in studies on specific themes, and spend more than half of their work hours on R&D activities. R&D personnel at overseas bases are not included.

excluding people fresh out of school, such as those who have experienced postdoc careers, account for only 1.0% (Figure 1-1-69).

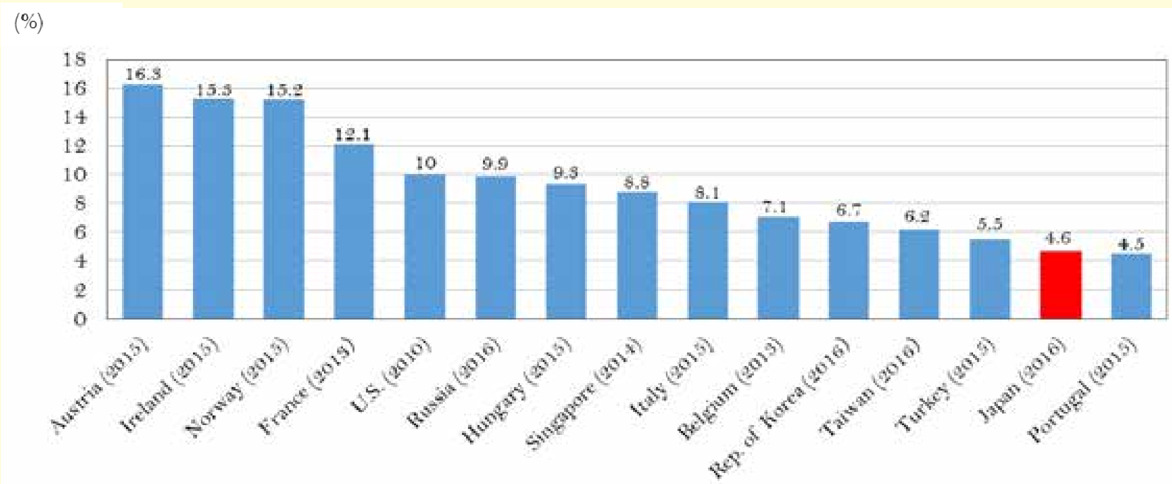
In addition, the ratio of doctorate holders to the number of researchers at enterprises in Japan is lower at 4.6% in comparison with other countries (Figure 1-1-70).

Figure 1-1-69 Ratio of enterprises hiring R&D personnel



Note: Dropouts after completion of the doctoral program are included in people who have completed the doctor's course and postdocs.
Source: Prepared by MEXT, based on NISTEP's "Survey on Research Activities of Private Corporations"

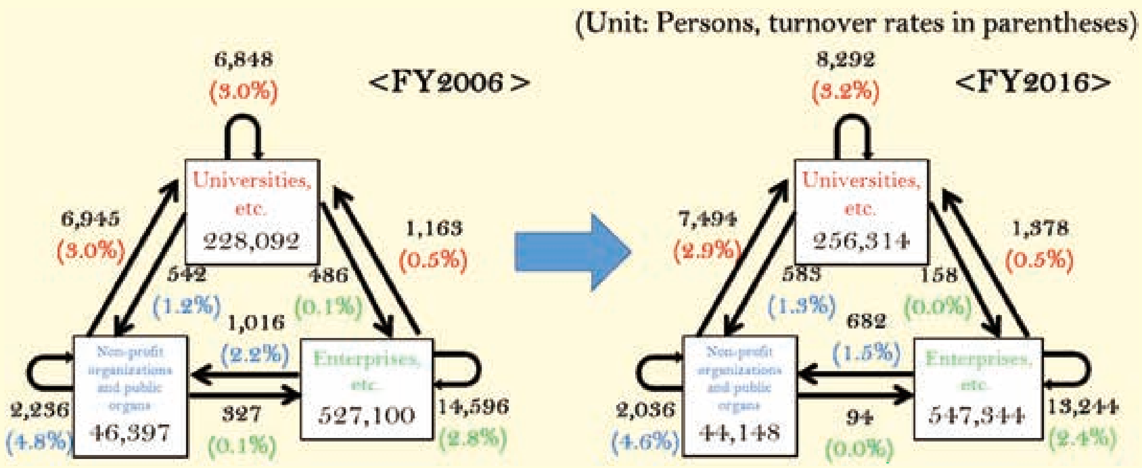
Figure 1-1-70 Ratio of doctorate holders to corporate researchers



Sources: Prepared by MEXT, based on the "Report on the Survey of Research and Development," compiled by the Statistics Bureau of the MIC, for Japan, the "NSF, SESTAT" for the U.S. and the "OECD Science, Technology, and R&D Statistics" for other countries.

Next, the ratio of people who moved between sectors stayed at the same level between FY2006 and FY2016 and the flow of people from universities and public organs, etc. to enterprises remained limited in comparison with that between other sectors (Figure 1-1-71).

Figure 1-1-71 Flow of human resources between sectors



Note: 1. Actual results (actual number of researchers) at the end of each fiscal year
2. The turnover rate is calculated by dividing the number of entrants into each sector by the number of researchers in the sector.
3. Universities, etc. exclude students enrolled in the doctor's course.
Source: Prepared by MEXT, based on the "Report on the Survey of Research and Development" compiled by the Statistics Bureau of the MIC

B. Extraction of challenges

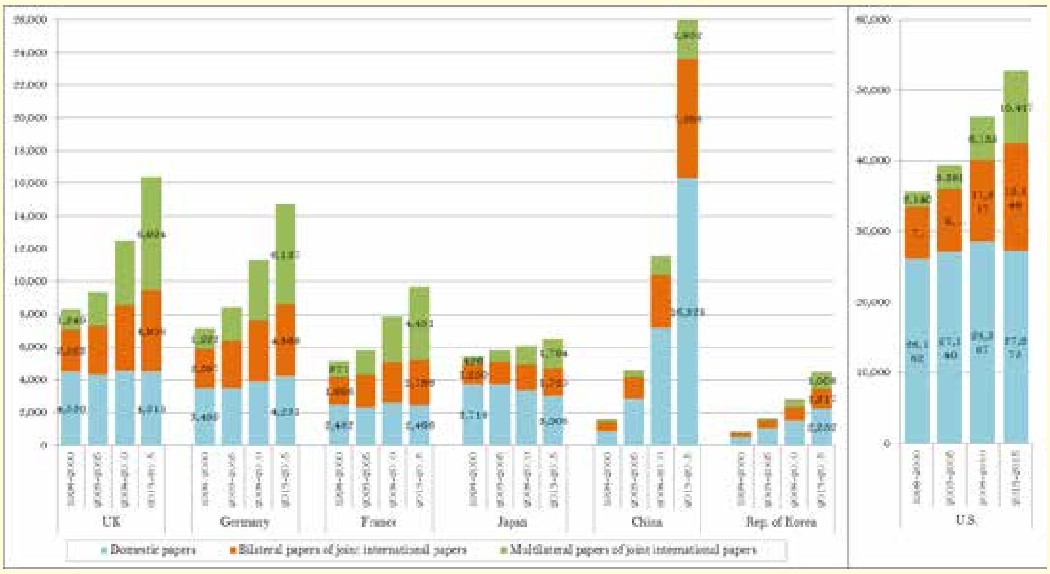
(A) Challenges to international networks of research

(i) Relativity between international joint authorships and quality of papers

An analysis of changes in the number of domestic papers in the major countries' adjusted top 10% papers and in the numbers of bilateral joint papers and multilateral joint papers among joint international papers (integer counting) shows that more than 70% of papers in the U.K., Germany and France were joint international papers in 2013 to 2015, with multilateral joint papers logging steep increases. If Japan, the U.K. and Germany were compared, the numbers of domestic papers were similar but the numbers of joint international papers showed differences (Figure 1-1-72).

In addition, a comparison of the major countries' Q factors: or the ratio of adjusted top 10% papers to the total number of papers in domestic and joint international papers, show that joint international papers have higher Q factors than domestic papers in all countries. When bilateral and multilateral joint papers are compared, multilateral papers have higher Q factors than bilateral papers in all countries. In Japan, the Q factor of domestic powers is falling but that of joint international papers is on the rise (Table 1-1-73).

Figure 1-1-72 **Changes in the number of domestic papers and the number of joint international papers in the number of adjusted top 10% papers**



Note: 1. Articles and reviews are subject to the analysis adopting the integer counting method. Figures are 3-year moving averages.
2. Adjusted top 10% papers represent the number of papers adjusted so as to become top 1/10 most cited papers in actual count among top 10% most cited papers in a given category in a given year.
3. Domestic papers include papers independently produced by a research institute in a given country and papers jointly produced by multiple research institutes in the country.
4. Multiple joint papers are papers jointly produced by research institutes in three or more countries.

Source: Prepared by NISTEP, based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version). ("Benchmarking Scientific Research 2017 (August 2017)")

Table 1-1-73 **Ratio of adjusted top 10% papers to domestic/joint international papers (2013-2015)**

		Total	Domestic papers	Joint international papers		
					Bilateral papers of joint international papers	Multilateral papers of joint international papers
UK	1998-2000	13.0%	11.0%	16.5%	14.9%	21.2%
	2003-2005	13.7%	11.3%	16.9%	14.5%	22.2%
	2008-2010	15.8%	12.1%	19.1%	15.3%	25.5%
	2013-2015	17.0%	12.2%	20.0%	14.8%	26.7%
Germany	1998-2000	10.9%	8.5%	14.9%	13.5%	18.8%
	2003-2005	12.0%	9.1%	15.5%	13.4%	20.2%
	2008-2010	13.8%	9.7%	17.7%	14.1%	24.1%
	2013-2015	15.1%	9.8%	19.2%	14.1%	25.9%
France	1998-2000	10.8%	8.5%	14.6%	12.8%	19.3%
	2003-2005	11.5%	8.6%	14.9%	12.3%	20.3%
	2008-2010	13.0%	8.9%	16.8%	12.7%	23.7%
	2013-2015	14.0%	8.6%	17.7%	12.0%	25.3%
U.S.	1998-2000	15.4%	14.7%	17.8%	17.0%	21.4%
	2003-2005	15.3%	14.5%	17.3%	16.0%	22.0%
	2008-2010	15.6%	14.2%	18.3%	16.0%	25.1%
	2013-2015	15.2%	13.0%	18.7%	15.8%	25.7%
Japan	1998-2000	7.6%	6.3%	13.2%	12.1%	18.2%
	2003-2005	7.6%	6.2%	12.4%	10.6%	19.2%
	2008-2010	8.1%	6.1%	13.7%	10.8%	22.1%
	2013-2015	8.5%	5.6%	15.2%	11.0%	23.7%
China	1998-2000	6.2%	4.6%	11.2%	10.4%	15.9%
	2003-2005	7.8%	6.2%	13.1%	11.8%	19.9%
	2008-2010	9.4%	7.6%	15.3%	13.9%	22.3%
	2013-2015	10.6%	8.6%	16.7%	14.8%	24.4%
Republic of Korea	1998-2000	7.1%	5.8%	11.4%	10.0%	18.4%
	2003-2005	7.2%	5.9%	11.1%	9.9%	16.5%
	2008-2010	7.5%	5.6%	12.9%	10.7%	21.2%
	2013-2015	8.4%	6.0%	14.6%	11.0%	24.1%

Source: Prepared by NISTEP, based on Clarivate Analytics' Web of Science XML (SCIE, end of 2016 version). ("Benchmarking Scientific Research 2017 (August 2017)")

Joint international papers are likely increasing in Europe and China due to the following reason[1].

In Europe, the EU's Framework Programmes for Research and Technological Development started in 1984 as a comprehensive R&D program through multilateral cooperation to address climate change and other problems that cannot deal with by a single country. The framework program is considered ascribable to an increase in joint international papers as it has promoted joint authorships between countries which have not done such work in the past. China, meanwhile, adopted a policy[2] in 1992 to "support overseas education, encourage returns and liberalize traffic." Under the policy, funds are provided to universities and students for learning and research in the U.S. and other advanced countries and Chinese overseas are encouraged to return to China. As a result, returnees from abroad to China have sharply increased due also to the country's rapid economic development. Returnees are said to support joint international studies by utilizing international networks of researchers. There are views that policy support for more than 20 years has contributed to a recent increase in joint international studies.

(ii) Relationship between experience of overseas research and quality of research

MEXT and NISTEP conducted a fact-finding survey[3] to gain clues to the improvement of Japan's research capacity, covering a network of science and technology experts consisting of "expert examiners" such as top-notch researchers, engineers and managers of industry, government and academia. To a question in the survey regarding whether the experiences of overseas research and joint international studies with overseas research organs are connected with an improvement in research results or the quality of papers, a total of nearly 80% or, to be specific, 79% of the respondents said they felt more or less connected -- 34% for "highly connected," 31% for "connected" and 14% for "somewhat connected" (Figure 1-1-74).

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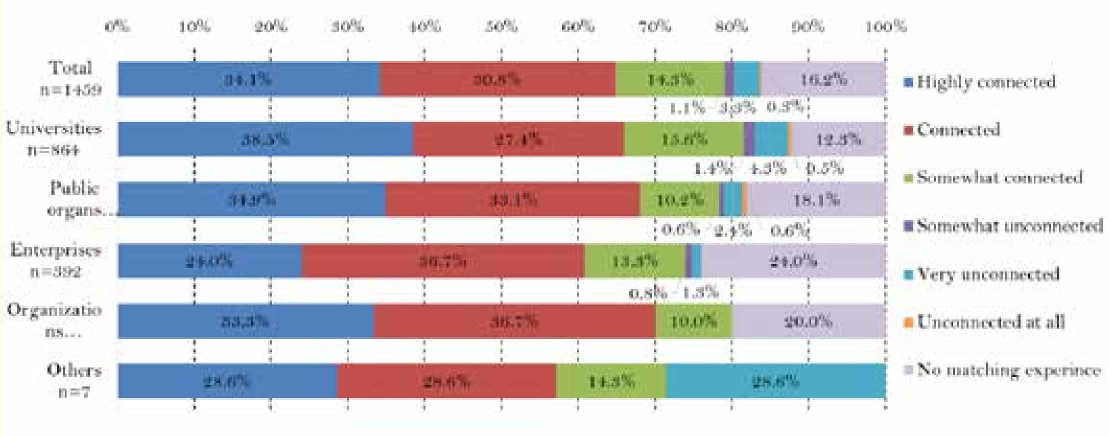
1 Yukiko Murakami, "Study Results of Joint International Studies and Suggestions for Japan's Policy," Research, Technology and Plan, Vol. 31 No. 2, 2016
Masatsura Igami, Ayaka Saka, Sadao Nagaoka, "State of Japan's Joint International Studies," Research, Technology and Plan, Vol. 31, No. 2, 2016

2 "Development and Reform of Universities in China (August 2014)" by the China Research and Communication Center, Japan Science and Technology Agency and

3 The survey was conducted on 1,951 expert examiners of the FY2017 network of science and technology experts and received replies from 1,459 of them (response rate of 74.8%)

Figure 1-1-74 **Answers to a question of whether the experiences of overseas research and joint international studies with overseas research organs are connected with an improvement in research results or the quality of papers**



Source: "STI Horizon 2018 Summer Edition[1] (2018)" by NISTEP

The survey thus found that the experience of overseas research is given weight from the viewpoint of improving the quality of papers. The scarcity of joint international papers is analyzed next.

(iii) Background of Japan's stagnated international mobility of human resources

The following factors are suggested as backgrounds for the relative shortage of Japan's joint international papers[2]. According to the OECD's 2012 data, Luxembourg, with a population of less than 600,000, had the world's highest ratio of joint international studies, which stood at 77.3%. Needs for joint international studies have possibly been low for Japan as it has a relatively large number of researchers. In addition, as joint international studies are said to be related to physical distance between countries as well as social distance of sharing language and culture, Japan may be facing higher hurdles for joint international studies than European countries because of its cultural factors backed by its geographical location and long history.

To know the reality of researchers, the question of "what hurdles did you or do you feel in returning to Japan? (multiple answers acceptable)" was posed to 302 researchers who have spent their postdoc life overseas, and findings were that they felt the presence of hurdles concerning their posts, procedures and timing of entry for the posts, etc. (Figure 1-1-75). There used to a model career path in which a competent young researcher accumulated experiences at advanced overseas research institutions during postdoc life and returned to universities and other places. Recently, they may be feeling reluctant to opt for research overseas because of various reasons such as the difficulty of securing posts when they return to Japan.

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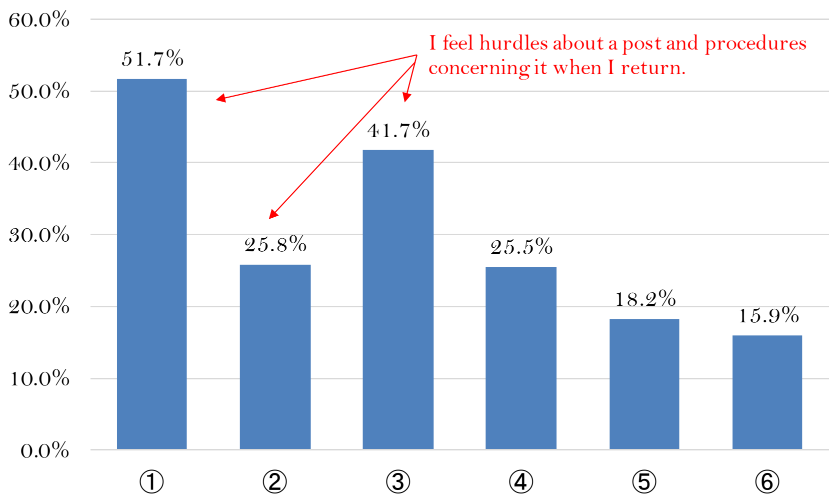
1 "Fact-Finding Survey on Researchers for Improvement of Japan's Research Capacity: From Survey on Network of Science and Technology Experts" STI Horizon 2018 Vol. 4 No. 2, http://doi.org/10.15108/stih.00132 by MEXT and NISTEP

2 Yukiko Murakami, "Study Results of Joint International Studies and Suggestions for Japan's Policy," Research, Technology and Plan, Vol. 31 No. 2, 2016
Masatsura Igami, Ayaka Saka, Sadao Nagaoka, "State of Japan's Joint International Studies," Research, Technology and Plan, Vol. 31, No. 2, 2016

Figure 1-1-75 Answers to the question of "what hurdles did you or do you feel in returning to Japan?"



① I feel there will be no post when I return.
② I feel my post will not be what I want when I return.
③ I feel it difficult to make an enry for a post I want when I return because of procedures, timing, etc.
④ Research enviroments overseas are so favorable that I do not feel that incentives to seek a post in Japan will work.
⑤ I do not feel any hurdles.
⑥ Others

Source: "STI Horizon 2018 Summer edition[1] (2018)" by NISTEP

The NISTEP TEITEN surveys[2] in 2013-2015 asked, "Do you think that there are enough young researchers who go abroad for research or employment?" Respondents who answered "no" wrote the following reasons on a free description basis.

- There are concerns about a decrease in employment opportunities and securement of jobs.
- Young researchers hired under fixed-term or tenure-track programs are so concerned about their assessment that they may lose or feel reluctant to grab opportunities to go abroad.
- They are too busy with lectures, etc. to secure time to study abroad.
- The number of young researchers dispatched abroad has been decreased to cost cuts.

Furthermore, the number of papers and publications and the number of competitive funds won are given priority for promotion to the post of professor, while overseas experiences are not greatly appreciated. Therefore, incentives to promote researchers' joint studies with overseas researchers are said to be unworkable[3].

The number of researchers dispatched overseas from Japan has stalled, as mentioned above, due to problems including the absence of posts for them when they return, testifying to the low international

1 "Fact-Finding Survey on Researchers for Improvement of Japan's Research Capacity: From Survey on Network of Science and Technology Experts" STI Horizon 2018 Vol. 4 No. 2, http://doi.org/10.15108/stih.00132 by MEXT and NISTEP

2 Questionnaire survey of some 1,000 persons from a group of universities and public research organs (researches and others recommended by university presidents, organ chiefs, bureau chiefs and others)

3 "A consideration on the series of university reforms and expansion of professors' diversity ~ Event history analysis on characteristics of researchers and promotion ~ (March 2017)" by NISTEP

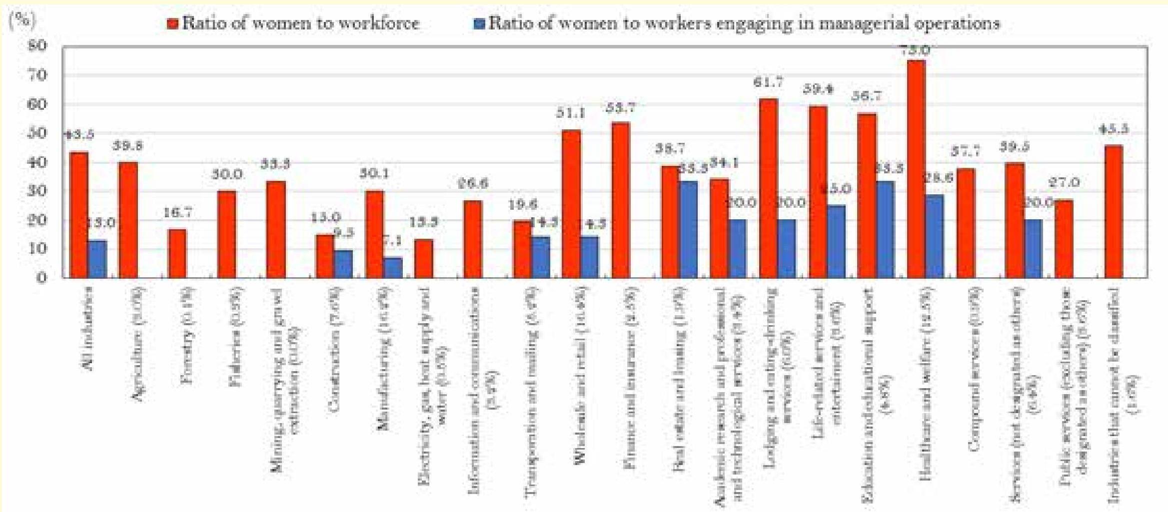
mobility of researchers. In contrast, European countries, China and other nations are forming international networks by promoting joint international studies. Reflecting Japan's low international mobility, the growth rate of joint international paper numbers is extremely low. While the number of adjusted top 10% papers is an indicator to show the high quality of papers, more joint international papers are included in them than domestic papers. The low level of Japan's participation in the international brain circulation is a grave problem for the country.

Science, technology and innovation activities go beyond national boundaries. The future of Japan's international competitiveness will be greatly affected by whether and how it can establish mechanisms to promptly and effectively utilize international research networks and globally spread intellectual resources. Japanese institutions and researchers should work to strengthen international brain environments through such means as strategically promoting joint international studies and building international networks of human resources so that Japan can be given a key position in global research networks and reinforce its presence in the world.

(B) Challenges to promotion of activities by female researchers

Women account for 43.5% of Japan's workforce, comparable with ratios in the U.S. and European countries. By industry, the ratio ranges from 75.0% in the field of healthcare and welfare services to 13.3% in the electricity, gas, heat supply and water industry (Figure 1-1-76). As shown in Figure 1-1-67, women account for a marginal 15.7% of researchers.

Figure 1-1-76 Industry-by-industry ratios of women to workforce and workers engaging in managerial operations



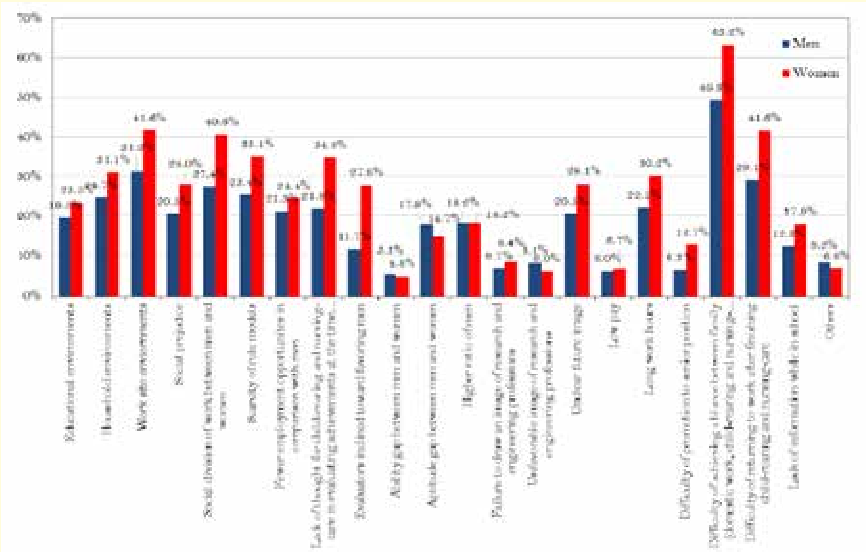
Note: 1. Workers engaging in managerial operations are corporate executives, holders of positions higher than department chiefs at enterprises, government workers in charge of managerial work, etc. among employed workers

2. The percentage in parentheses under each industry name is the ratio of workers employed in the industry to those in all industries.

Source: Prepared by MEXT, based on the "2017 White Paper on Gender Equality (June 2017)" by the Gender Equality Bureau of the Cabinet Office

According to the "Fourth Large-Scale Surveys on Gender Equality in STEM" released in August 2017 by the Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering, the largest number of both male and female respondents mentioned “the difficulty of achieving a balance between work and family” as a reason for the low ratio of women to researchers. “The difficulty of returning to the workforce after finishing child-rearing and nursing-care,” “work site environments” and “social division of work between men and women” followed as reasons, suggesting that both men and women are aware of the heavier burden on women in family life including child-rearing (Figure 1-1-77).

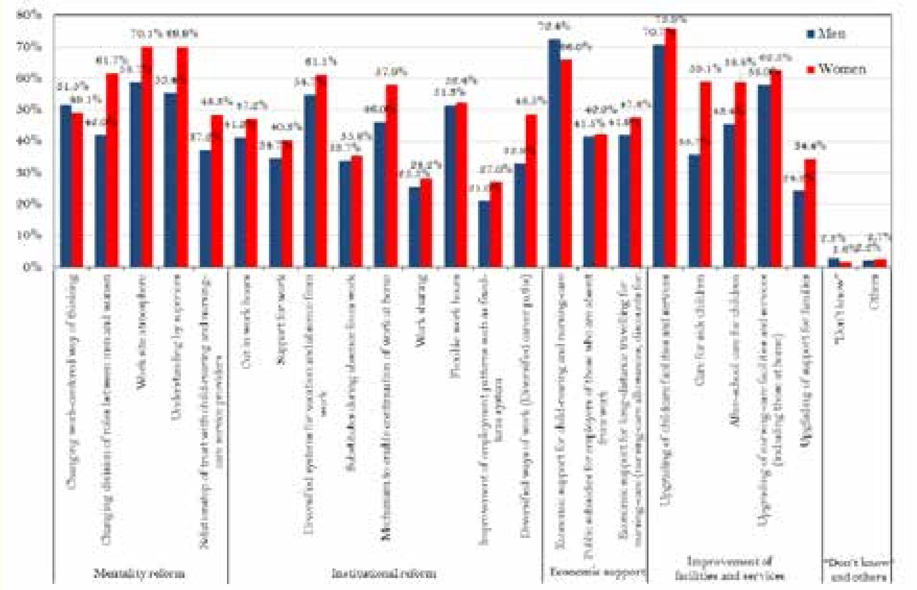
Figure 1-1-77 Reasons for the scarcity of female researchers (multiple answers)



Source: Prepared by MEXT, based on the “Fourth Large-Scale Surveys on Gender Equality in STEM (August 2017)” by the Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering

The survey also found that “an upgrading of childcare facilities and services” is what women want most to achieve a balance between family and work. The answer was followed by “an improvement in work site atmosphere,” “understanding by superiors” and “economic support for child-rearing and nursing-care” among others. “Economic support for child-rearing and nursing-care” was picked by the largest portion of male respondents, followed by “an upgrading of childcare facilities and services,” “work site atmosphere,” “an upgrading of nursing-care facilities and services,” etc. Many of both male and female respondents picked answers from wide-ranging perspectives such as those related to work site environments, social support and improvements in child-rearing and nursing-care services. While “economic support for child-rearing and nursing-care” was mentioned by more than 30% of respondents in the third survey, the ratio rose to around 70% for both men and women in the latest survey, revealing increased needs for support for child-rearing and nursing-care (Figure 1-1-78).

Figure 1-1-78 What is needed to achieve a balance between family and work (multiple answers)

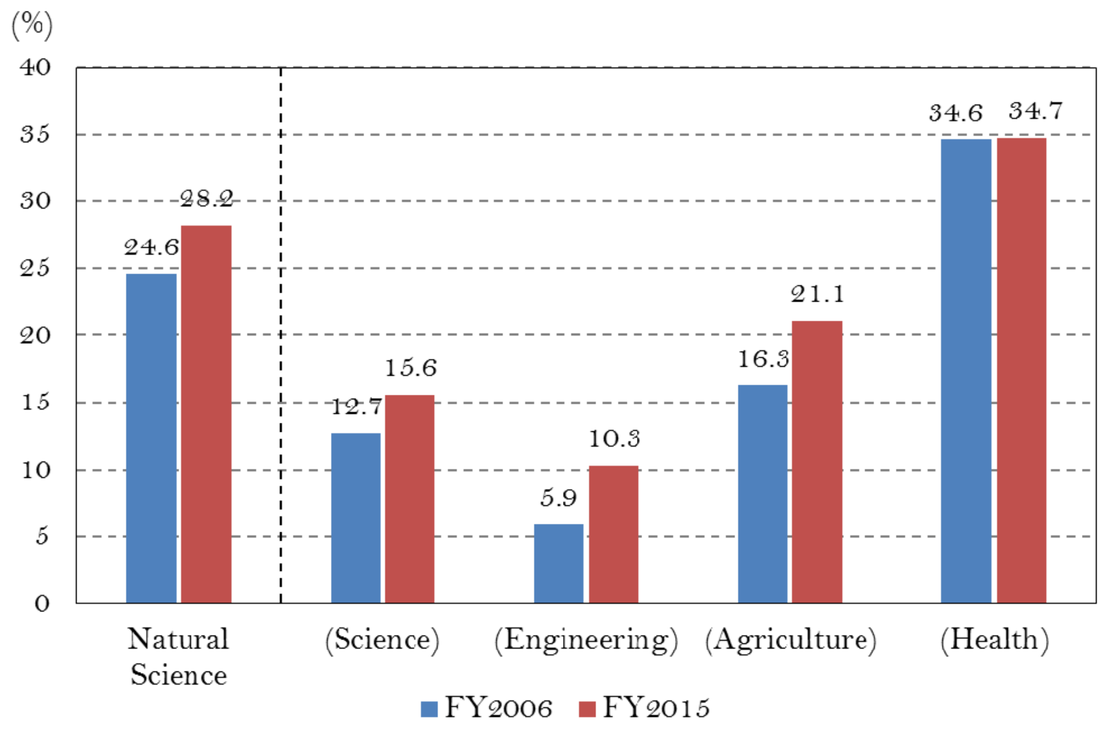


Source: Prepared by MEXT, based on the "Fourth Fact-Finding Survey on Gender Equality in Science and Technology Professions (August 2017)" by the Japan Inter-Society Liaison Association Committee for Promoting Equal Participation of Men and Women in Science and Engineering

The ratio of female faculty members at universities among women researchers is on the rise in all fields. In FY2015, it stood at 15.6% in science, 10.3% in engineering, 21.1% in agriculture and 34.7% in health. The ratio in the engineering field was the lowest[1] (Figure 1-1-79).

1 Targets of hiring female researchers are established under the 5th Science and Technology Basic Plan (30% for the entire field of natural science, 20% for science, 15% for engineering, 30% for agriculture and 30% for medical, dental and pharmaceutical sciences combined).

Figure 1-1-79 **Ratio of female faculty members at universities**



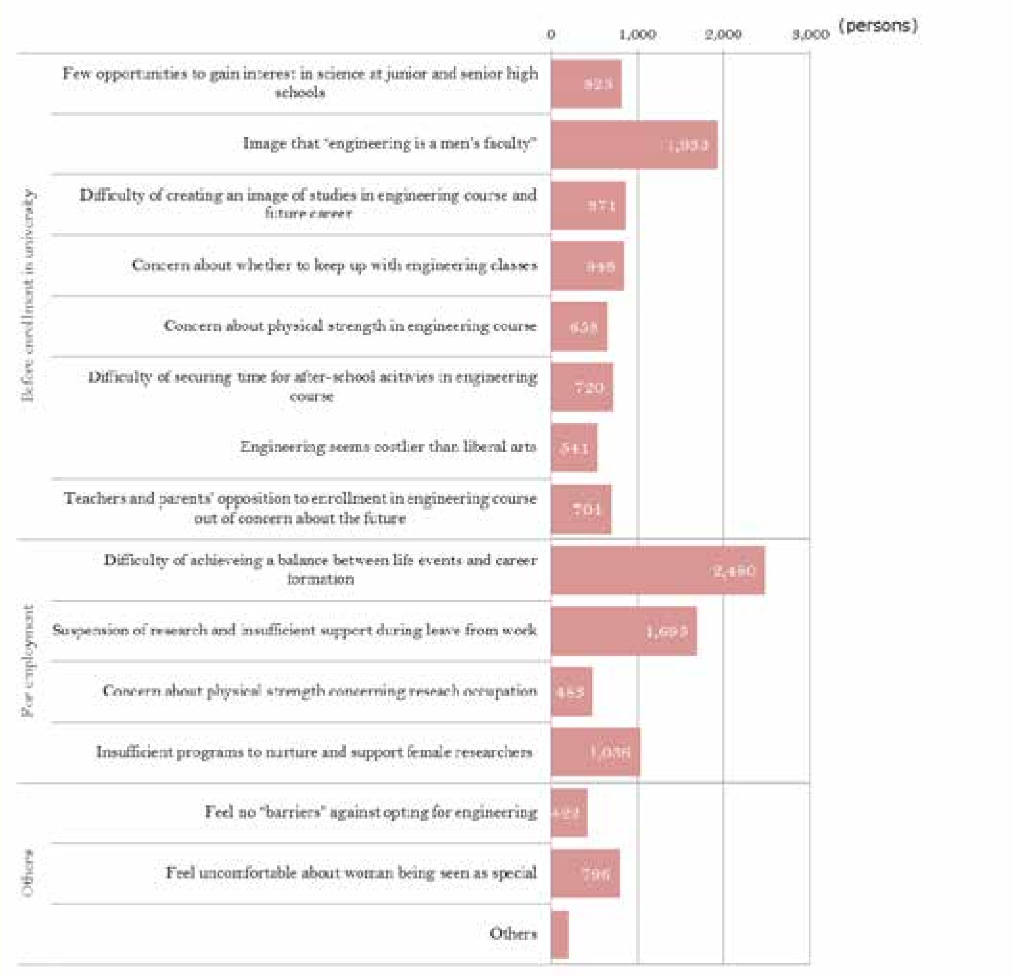
Note: 1. The employment ratio of female faculty members covers professors, associate professors, senior lecturers and assistant professors.

2. Natural science is a total of science, engineering, agriculture and health. Health covers not only medical, dental and pharmaceutical sciences but also other fields of health.

Source: Prepared by MEXT, based on the ministry's "Report on School Basic Survey"

A questionnaire survey was conducted on 3,231 students (1,189 men and 2,042 women), aged 18 to 30 and enrolled in undergraduate programs at universities, about factors deemed as "barriers" to women's option for engineering courses, finding that the "difficulty of achieving a balance between life events and career formation" was chosen by the largest number of respondents. The finding is considered to suggest that many students are concerned about the suspension of research activities or the absence of enough support during absence from work if life events, such as marriage, childbirth and child-rearing, occur in the course of career formation after receiving doctoral degrees. In addition, many students were found to have had an image, when they enrolled in universities, that "engineering is a faculty for men" (Figure 1-1-80).

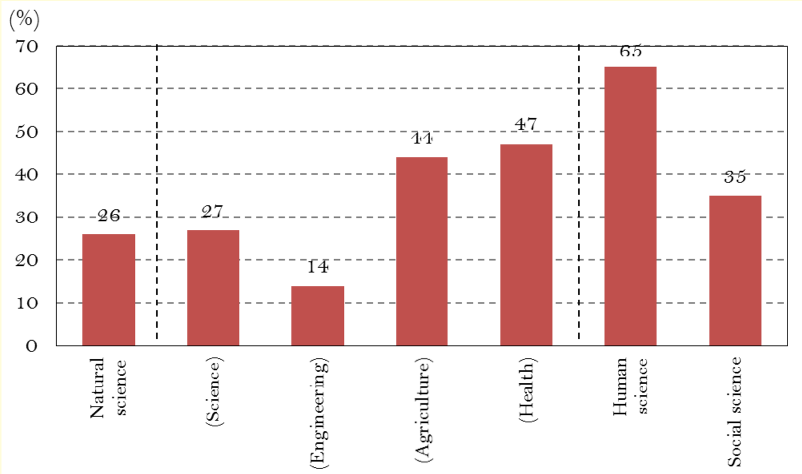
Figure 1-1-80 **Awareness survey on women's option for engineering course (multiple answers accepted)**



Source: "The awareness of undergraduates about scientific and technological information and their own career paths (March 2018)," Research Material-272, by NISTEP

The ratio of female science and engineering students in FY2016 was 27% in the faculty of science and 14% in the faculty of engineering. The ratio of female students in the faculty of natural science, including science, engineering, agriculture and health, was lower than those of women in the faculties of human and social sciences (Figure 1-1-81).

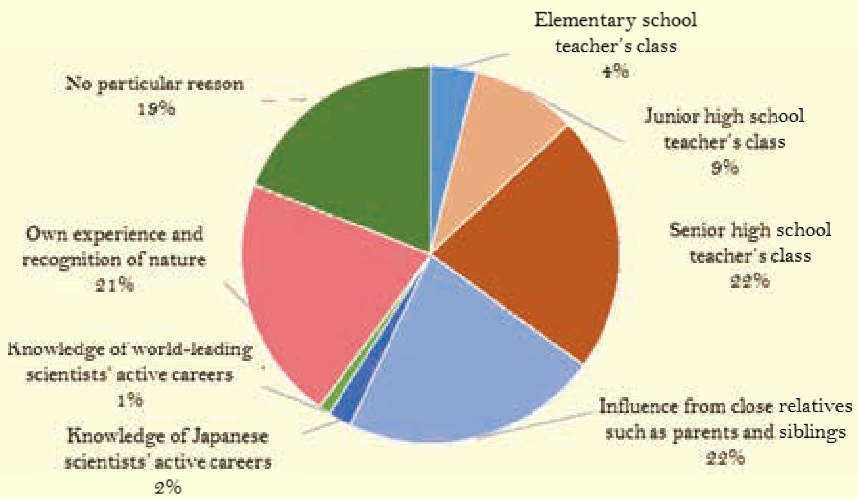
Figure 1-1-81 **Ratio of women in university faculties related to natural science**



Note: Natural science is a total of science, engineering, agriculture and health. Health covers not only medical, dental and pharmaceutical sciences but also all other fields of health.
Source: Prepared by MEXT, based on the ministry's "Report on FY2016 School Basic Survey"

To enable women, who will bear the next generation, to play more active roles than before in the field of science and technology, it is necessary to promote programs to let small girls and female pupils as well as their parents, teachers, etc. become more interested in and knowledgeable about the pursuit of careers in science and technology-related fields. In particular, the survey found that female students' choice of science-related careers was greatly affected by not only their experience and recognition of nature and but also influence from close relatives such as parents and siblings (Figure 1-1-82).

Figure 1-1-82 **Reasons for female students' choice of science-related careers**



Source: Prepared by MEXT, based on Nihon L'ORÉAL K.K.'s "Awareness Survey of Female Science Students' Satisfaction (August 2014)"

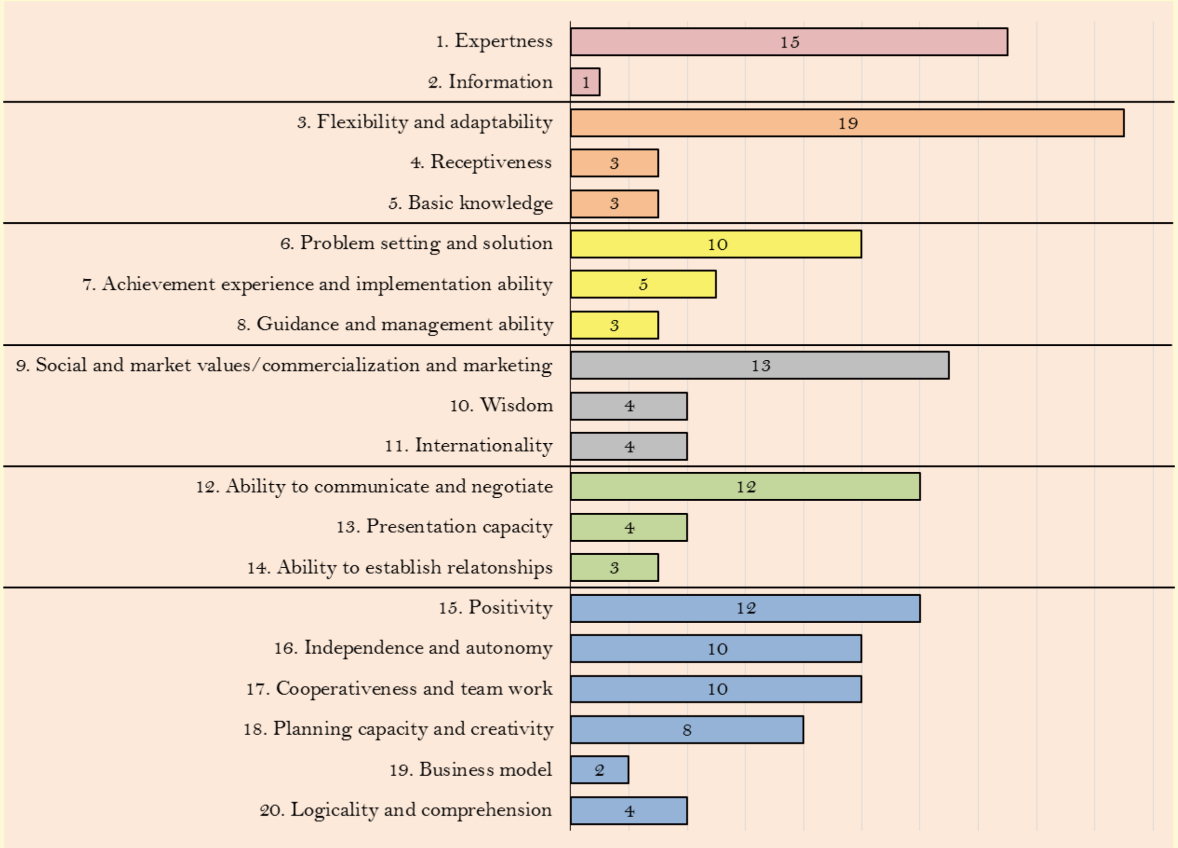
(C) Challenges to the flow of human resources beyond fields, organizations, sectors and other barriers

The flow of human resources between sectors, such as universities, public research institutions and enterprises, is said to be marking time. In particular, the number of transferees from academia, such as universities and public research organs, to the private sector does not increase. With regard to this problem, NISTEP conducted an interview survey of 25 "Research and Development- and investigation and research-oriented" private enterprises[1] about what they expect out of doctorate holders' ability and skills. The survey found that many enterprises expect doctorate holders to have "flexibility and adaptability" and ability to discern "social and market values," in addition to "expertise" (Figure 1-1-83). The survey report mentioned that enterprises, while appreciating doctoral holders' expertise, are worried if doctoral holders' adherence to their expertise may hamper "flexibility", which is in greater demand. Active utilization and employment of doctoral holders matching needs in industry are expected. It is considered necessary for people who have completed the doctor's course, to deepen their understanding of the types of people needed in society by recognizing the abilities and skills enterprises expect them to have.

Also, while, globalization and aging population combined with the dwindling number of children will continue to advance, a society in which roles played by humans will greatly change due to advances in artificial intelligence and other developments, is about to come. Under these circumstances, students in the doctor's course should not only rely on high expertise reliant on knowledge they have accumulated but also develop cognition to pursue scientific logicality more strongly than before. Scientific logicality is the source of solving problems and creating values even if students move to other fields. In demand are highly advanced doctorate holders who are expected to have a wide view beyond humanities and sciences, based on expertise, create and develop new values and play active roles in society while having a consciousness that lead to problem solutions.

1 The 25 enterprises are 19 private research and development-oriented companies which have hired people who have completed the doctor's course and six think tanks and consulting companies that are investigation and research-oriented enterprises.

Figure 1-1-83 Ability and skills enterprises expect doctoral holders to have



Sources: "Consideration based on the focus group interview (FGI) about the career path of doctoral course students. (September 2017)" by NISTEP

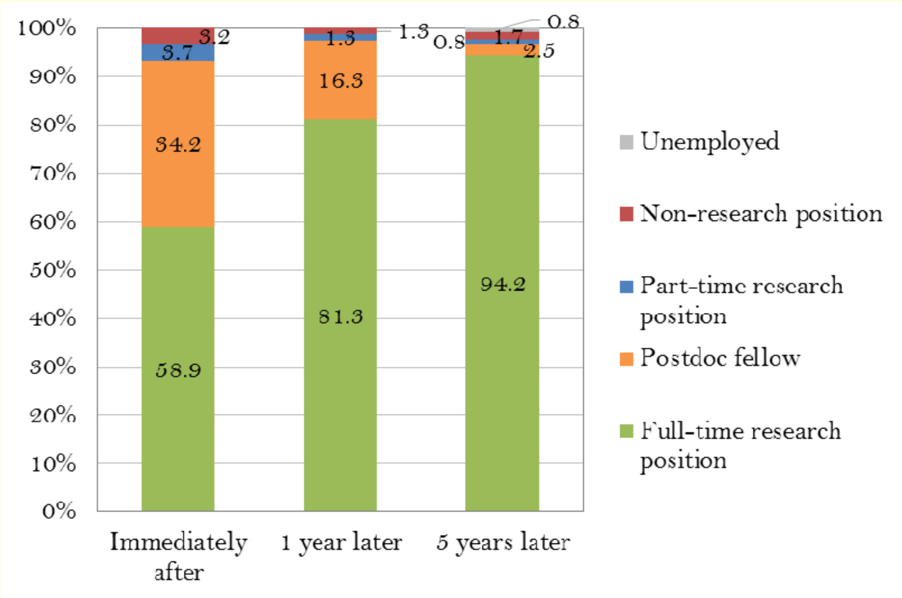
C. Typical program

A typical program concerning the diversity and mobility of human resources is mentioned here. It is the "Overseas Research Fellowships" system[1] which has been implemented for more than 30 years. The system was created in 1982 to dispatch young researchers overseas and enable them to devote themselves to long-term studies at specific universities, research institutions, etc. for the sake of nurturing and securing young, competent researchers with broad international perspectives who will lead the future of Japan's academia. It is run by the Japan Society for the Promotion of Science, which adopted 164 people in FY2017.

As achievements to date, 94.2% of overseas research fellows landed full-time research positions five years after adoption for the system, which has been playing important roles to nurture and secure researchers in Japan (Figure 1-1-84).

1 The period of adoption (dispatch) is two years from the day of dispatch.

Figure 1-1-84 Follow-up survey on the employment, etc. of overseas research fellows



Note: "Immediately after" applies to fellow adopted in FY2013, "1 year later' to those in FY2012 and "5 years later" to those in FY2008.

Source: Prepared by the Japan Society for the Promotion of Science, based on the society's "Follow-up Survey on the Employment, etc. of Overseas Research Fellows (FY2016)"

To promote the empowerment of female researchers, the state, universities, R&D corporations, private enterprises, etc. have introduced various programs to help them achieve a balance between childbirth, child-rearing, nursing-care, etc. and research activities. MEXT has introduced the "Initiative for Realizing Diversity in the Research Environment" to support universities, etc. implementing advanced programs systematically and structurally under goals and plans for achieving the diversity of research environments through the promotion of female researchers' active roles by such means as nurturing leaders through the integrated promotion of efforts to achieve a balance between research and childbirth, child-rearing, nursing-care, etc. and to improve the research ability of female researchers. As of FY2017, the initiative was supporting 69 institutions. Iwate University, for example, has the "One-Up Open Recruitment System" to support the open recruitment of female faculty members for high positions if such a recruitment is considered effective in recruiting female faculty members. The university also has the "Positive Action System" to provide expenses for three years to create work environments friendly to female researchers when they are hired through open recruitment targeting female researchers of natural science. For researchers faced with the difficulty of continuing research due to child-rearing and nursing-care, the university makes research supporters and assistants available. Through such efforts to improve research environments, the ratio of female faculty members rose to 29.4% in 2012 from 6.7% in 2009. Among other improvements, no female researchers have come to quit the university while more female researchers now receive grants-in-aid for scientific research.

For young and competent researchers' smooth return to work after suspending research for childbirth and child-rearing, the Japan Society for the Promotion of Science started the Restart Postdoctoral Fellowship (RPD) system in 2006 to support their research activities by providing monetary research incentives to them for a set period of time. Some 50 to 70 researchers become eligible per year under the system.

2-2 Knowledge Infrastructure

(1) Academic and Basic Research

In order to continuously create innovations, it is essential to strengthen the infrastructure that generates a diversity of excellent knowledge and a wellspring of innovations. In doing so, it is particularly important to conduct research based on flexible thinking that is not constrained by traditional customs and conventional concepts but instead utilizes innovative ideas. However, in Japan, neither the number of research papers nor the number of frequently cited papers is growing sufficiently, and the growth in the number of internationally co-authored papers is also relatively low. As a result, there are concerns over a decline in Japan's academic study and basic research capabilities. In this section, we provide an overview of the current status of academic and basic research in Japan, common infrastructure technologies and advanced research facilities and equipment that play an important role in supporting research activities, and the share of hours which researchers can devote entirely to research. In addition, it provides an overview of institutional systems related to universities and national research and development agencies, for which expectations are growing due to the central role that they are expected to play in supporting knowledge infrastructure by creating excellent knowledge, technology and human resources.

A. Analysis of the Current Status

Regarding the production of papers, which can be identified as output of academic and basic research, the number of papers produced in Japan has been trending downward compared with 10 years ago, as was mentioned earlier. In particular, as a result of an increase in the number of papers produced in other countries, Japan's global ranking has fallen (Table 1-1-22). In addition, it has been pointed out that the range of research areas in Japan is narrow and that Japan's participation in interdisciplinary and multidisciplinary areas is insufficient.

The Science Map,[1] which is compiled by NISTEP, clarifies the relationships between research areas attracting international attention that have been selected through the analysis of the global top 1% of papers in terms of citation frequency based on a database of papers (Figure 1-1-85). When one or more papers produced in a country are related to a paper among the global top 1% of papers in terms of citation frequency (hereinafter referred to as the "core papers") in a research area indicated in the Science Map, it is assumed that the country is participating in that field. It may be said that the status of participation by individual countries is an indicator of their research diversity.

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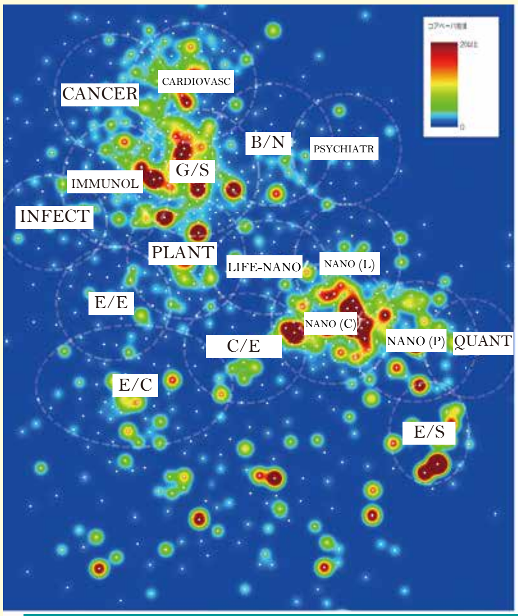
1 Until now, seven Science Maps, from Science Map 2002 to Science Map 2014, have been compiled every other year, covering seven points in time. Each Science Map analyzed the top 1% papers published over a six-year period. For example, Science Map 2002 analyzed the top 1% papers published between 1997and 2002, Science Map 2008 analyzed the top 1% papers published between 2003 and 2008 and Science Map 2014 analyzed the top 1% papers published between 2009 and 2014

Figure 1-1-85 Science Map 2014



White circles indicate the locations of research areas.

Groups of research areas	Abbreviated
Cancer research	CANCER
Research on cardiovascular disease	CARDIOVASC
Research on infectious diseases and public hygiene	INFECT
Research on immunology (incl. gene expression control)	IMMUNOL
Research on gene expression control and stem cells	G/S
Research on brain and neurological	B/N
Research on psychiatric diseases	PSYCHIATR
Research on plant and micro-organisms (including gene expression control)	PLANT
Research on the environment and ecology	E/E
Research on the environment and climate change (observation, modeling)	E/C
Intersection of biological mechanism and nano-scale phenomena (Life-nano bridge)	LIFE-NANO
Research on chemical synthesis and energy generation	C/E
Nanoscience research (life sciences)	NANO (L)
Nanoscience research (chemicals)	NANO (C)
Nanoscience research (physics)	NANO (P)
Quantum materials science	QUANT
Research on elementary particles and outer space theories	E/S

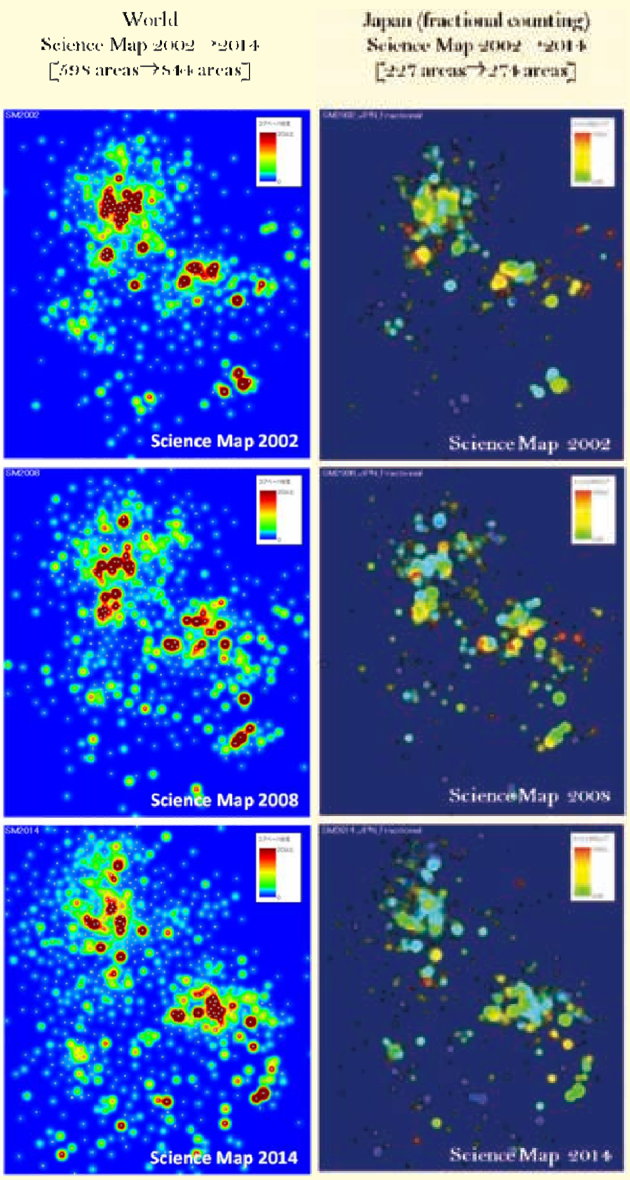
Note 1: Since the map is created by a force-directed placement method, relative location of research areas is important, but there is an arbitrariness in the direction of the X and Y axes. In this report, we present maps in which life sciences are located in the upper left, while particle physics and cosmology are located in the bottom right.

Note 2: White circles indicate the locations of research areas. White dotted lines indicate the rough locations of groups of research areas. Research areas outside groups of research areas are not included in any group only because the number of research areas based on similar concepts falls short of a prescribed threshold number, and they are not necessarily unimportant.

Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.) (Science Map 2014 (September 2016))

On the Science Map, white circles indicate the locations of research areas. The stronger the shade of red of a research area is, the greater the number of core papers is in the area and the more international attention the area is attracting. Concerning research areas in which Japan is participating as shown in Figure 1-1-86, areas represented by the light blue color are those in which Japanese papers have a share of 5% or more in the total number of papers and areas represented by the red color are those in which Japanese papers have a share of 20% or more. Looking at time-sequential changes as indicated by the Science Maps 2002, 2008 and 2014, we see that compared with the increase in the global number of research areas, the increase in the number of research areas in Japan is small.

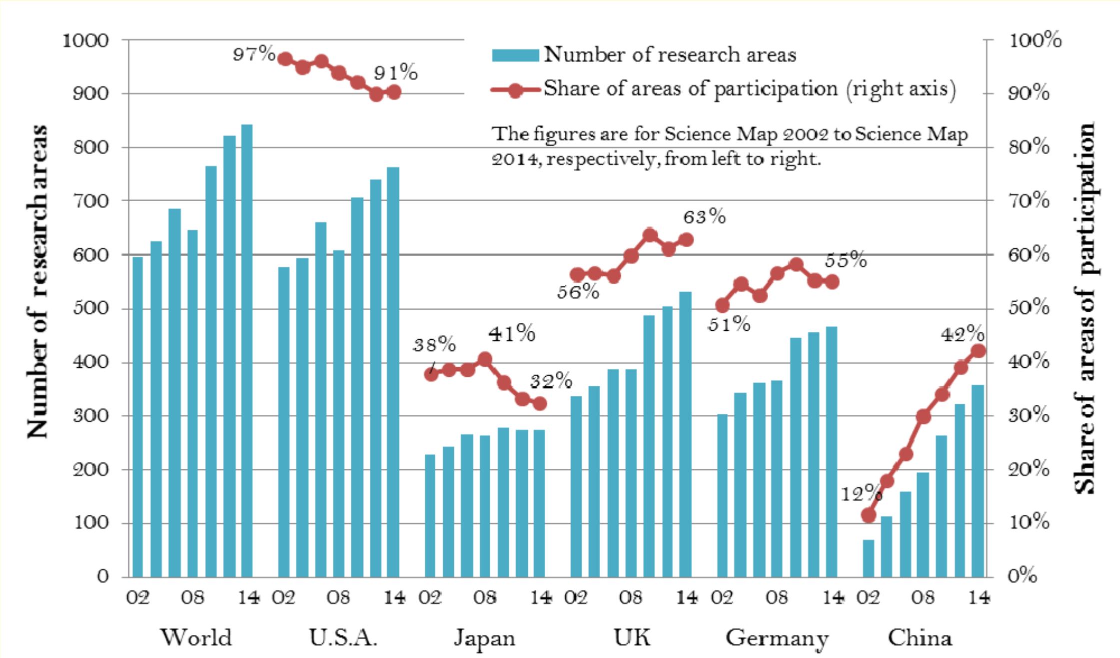
Figure 1-1-86 Time-sequential changes from Science Map 2002 to Science Map 2014



(Note): Regarding Japan, the pale blue color indicates the areas in which the Japanese share in the total number of papers is 5% or higher, while the red color indicates the areas where the Japanese share is 20% or higher.
Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.)(Science Map 2014 (September 2016)).

As indicated in Figure 1-1-87, the total number of research areas in which countries around the world are participating (hereinafter referred to as "areas of participation") increased from 598 (Science Map 2002) to 844 (Science Map 2014). The number of areas of participation is high among major countries: particularly the United States, which was participating in more than 90% of the global total number of research areas, and the number of areas of participation also rose for the United Kingdom and Germany, both of which continued to participate in between 50% and 60% of the global total number of research areas. On the other hand, the number of areas of participation for Japan has remained stagnant since the Science Map 2008. The share of areas of participation by Japan in the global total number of research areas fell from 41% (Science Map 2008) to 32% (Science Map 2014). In the case of China, both the number of areas of participation and its share in the global total number of research areas increased.

Figure 1-1-87 Major countries' number of areas of participation and share of the number in the global total number of research areas

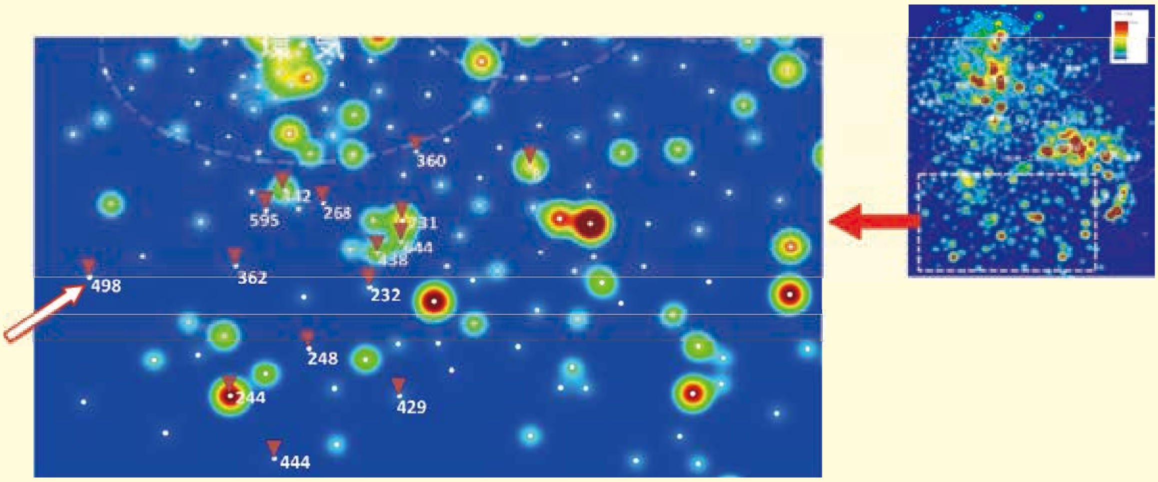


Note: When the core papers constituting a research area include one or more papers produced in a relevant country, the country is assumed to be participating in the area.

Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.)(Science Map 2014 (September 2016)).

If we select research areas attracting international attention based on papers published in 2009 to 2014 as indicated by Science Map 2014, we see that many research areas considered to be related to artificial intelligence (AI), which has been attracting attention in recent years, emerged during that period. Looking at the specifics of 15 research areas considered to be related to AI, only one co-authored Japanese paper (Research area ID 498) appeared as a core paper on the Science Maps over the six years to 2014. This indicates that during that period, Japan was lagging in research in those areas in terms of the quality of papers (Figures 1-1-88 and 1-1-89).

Figure 1-1-88 **Examples of research areas considered to be related to AI on Science Map 2014 (locations of research areas)**



Note: White and yellow circles indicate the locations of research areas. The yellow color indicates the areas in which the number of core papers is 20 or higher. The red marker (inverted triangle) indicates areas considered to be related to artificial intelligence.

Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.)(Science Map 2014 (September 2016)).

Figure 1-1-89 **Examples of research areas considered to be related to artificial intelligence in Science Map 2014**

Research area ID	keywords	Area	No. of core papers
244	Group decision-making; group decision-making problems; aggregation operator; intuitive fuzzy sets; ordered weighted averaging aggregation operator	Computer science	115
○731	Artificial bee colony algorithm; artificial bee colony; particle swarm optimization (PSO); gravitational search algorithm; optimization problems	Interdesciplinary/ mutidisplinary areas	59
○8	Neural networks; Takagi-Sugano fuzzy model; fuzzy logic control; control system; based on the fuzzy theory	Engineering	53
442	Test results; proposed methods; dimensionality reduction; facial recognition; situation	Engineering	30
438	Teaching-learning-based optimization; optimization algorithm; test system; multi-purpose optimization; optimization problems	Engineering	25
○644	Differential evolution; optimization problems; evolutionary algorithm; differential evolutionary algorithm; particle swarm optimization (PSO)	Computer science	20
○232	Type-2 fuzzy; Interval Type-2 fuzzy logic controller; Type-2 fuzzy sets; Type-2 fuzzy mechanism; Type2 fuzzy logic mechanism	Computer science	8
○429	Least squares support vector machine (LSSVM); artificial neural network (ANN); optimized least squares support vector machine (LSSVM); enhanced oil recovery (EOR); least squares support vector machine (LSSVM) model	Engineering	7
○498	Automated voice recognition; deep neural network (DNN); large vocabulary continuous speech recognition (LVCSR); Gaussian mixture model (GMM); hidden Markov model	Engineering	5
362	Fuzzy rule base; evolutionary algorithm; machine learning; non-parametric statistical examination, dataset	Interdesciplinary/ mutidisplinary areas	5
○360	ELM (extreme learning machine); single hidden layer feed-forward neural network; generalization capability; neural network; test results	Interdesciplinary/ mutidisplinary areas	5
○595	Sparse expression; facial recognition; classification based on sparse expressions; training samples; test results	Engineering	4
○444	Artificial neural network (ANN); artificial neural network (ANN) model; wavelet transform; time sequential; root mean square error (RMSE)	Engineering	4
○268	Hyperspectral imaging; hyperspectral imaging classification; spectral space; spatial information; classic support vector machine (SVM)	Geoscience	4
○248	Optimization mode; effectiveness of proposed models; genetic algorithm; fuzzy optimization approach; fuzzy variables	Interdesciplinary/ mutidisplinary areas	4

Note: The research areas whose research area ID is preceded by the circle mark are those which appeared for the first time in Science Map 2014

Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.)(Science Map 2014 (September 2016)).

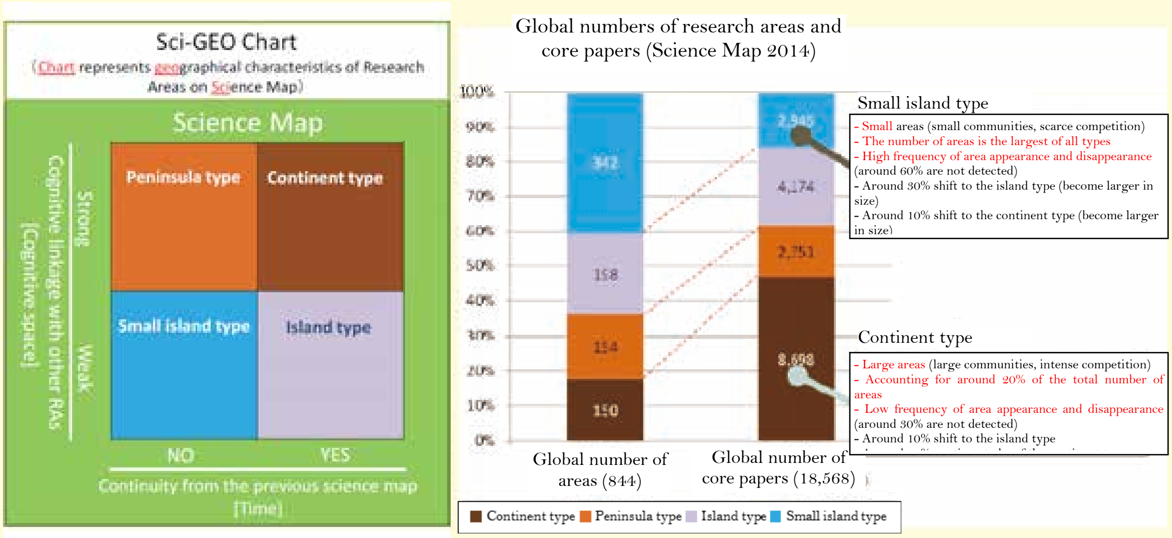
Regarding social implementation of science and technology, there is an increasing number of cases in which social decision-making is necessary with respect to ethical and legal system challenges in such areas as genetic diagnosis, regenerative medicine and AI. Therefore, it is necessary to promote research activities involving various areas related to humanities and social sciences as well as natural sciences with respect to ethical, legal system and social challenges.

B. Identification of Challenges

Continuous observation of the Science Maps shows that some research areas continued to exist throughout the period covered by the maps, while others did not. It also shows that some research areas are strongly related to other areas, while others are not. To quantitatively examine those findings, we will use the Sci-GEO Chart (the Chart represents the geographical characteristics of the Research Area on Science Map), which classifies research areas on the Science Maps into four area types based on continuity (time axis) and the strength of relationship to other research areas (spatial axis). Research areas which have continuity with past Science Maps are classified either as the "continent type," whose relationship with other areas is strong, or as the "island type," whose relationship with other areas is weak. Research areas which do not have continuity with past Science Maps are classified either as the "peninsula type," whose relationship with other areas is strong, or as the "small island type," whose relationship with other areas is weak (Figure 1-1-90). Looking at the global total number of research areas and the share of areas of participation by individual countries on the Science Map 2014, we see that the share of continent-type areas of participation by Japan is larger compared with the global average, while the share of small island-type areas of participation by Japan is smaller compared with the global average. On the Science Map 2004, the share of areas of participation by Japan was similar to the figures for the United Kingdom and Germany. However, while the share of small island-type areas of participation by the United Kingdom and Germany increased in the following 10 years, the figure for Japan did not change much (Figure 1-1-91).

In continent-type research areas, research communities are large and international competition is intense. Continent-type research areas account for around 20% of the global total number of research areas, but core papers in those areas account for more than 40% of the global total number of core papers. From the viewpoint of continuity, continent-type research areas are more reliable as research targets than other types of research areas.

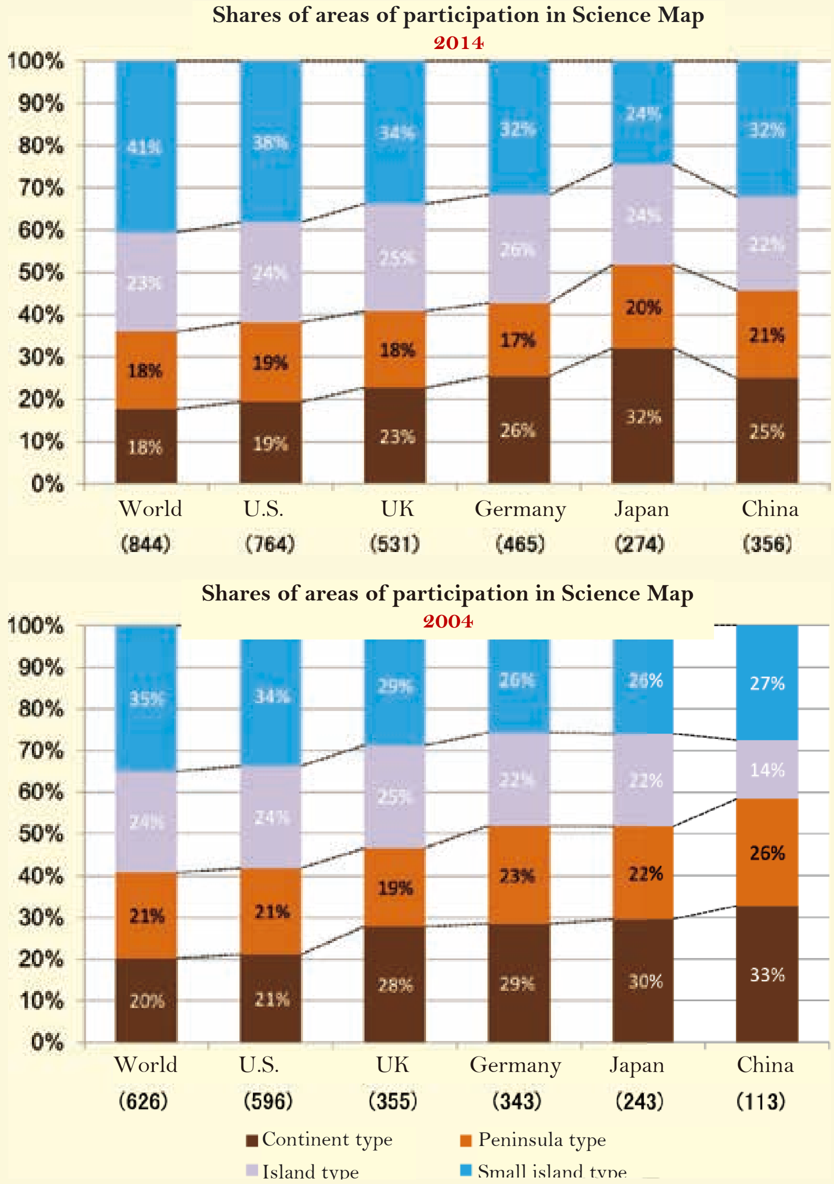
Figure 1-1-90　Research area types and the global numbers of research areas and core papers as shown by the Sci-GEO Chart



Note: Core papers refers to the top 1% papers in terms of citation frequency that constitute research areas indicated in the science map.
Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.) (Science Map 2014 (September 2016)).

On the Science Maps, small island-type areas account for around 40% of the global total number of research areas, and the large number is presumed to indicate research diversity. Individual areas are small, and the emergence of new areas and the disappearance of old ones occur frequently, and emerging areas include ones with the potential to develop into major research areas in the future. The fact that the number of core papers in small island-type research areas in Japan is small indicates the possibility that research programs in Japan are not necessarily exploring unique or challenging areas. In order to increase Japan's presence in small island-type research areas, it is necessary to develop an environment conducive to brisk research activity in unique and challenging areas and to strengthen systems that support striving researchers.

Figure 1-1-91 Shares of areas of participation by major countries in the science map

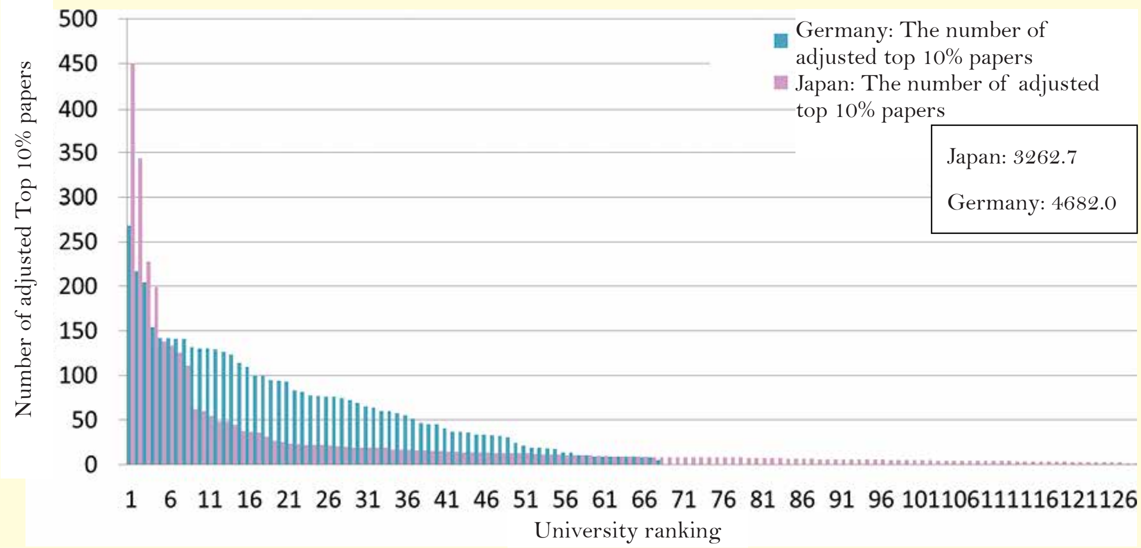


Source: Prepared by NISTEP based on Clarivate Analytics' Essential Science Indicators (NISTEP ver.) and Web of Science XML (SCIE, end of 2015 ver.) (Science Map 2014 (September 2016)).

Here, we look at research diversity in light of the status of production of papers at Japanese universities. Paper production at universities accounts for more than 70% of all papers produced in Japan. Here, we compare Japan and Germany in terms of the number of adjusted top 10% papers by university ranking. As most universities in Germany are state universities, it must be kept in mind that a simple comparison with Japan is difficult because of differences between the university structures in the two countries. In Japan, a small group of top-ranking universities are leading paper production, while in Germany, middle-ranking universities are also producing many papers included among the adjusted top 10% papers, indicating the depth of university research activities (Figure 1-1-92).

In Japan, in order to secure research diversity, it is important not only to enhance the capabilities of top-ranking universities but also to pay attention to research activities at middle-ranking universities and increase the research department activities across universities as a whole.

Figure 1-1-92 Comparison between Japan and Germany in terms of the distribution of the number of adjusted top 10% papers produced by individual universities

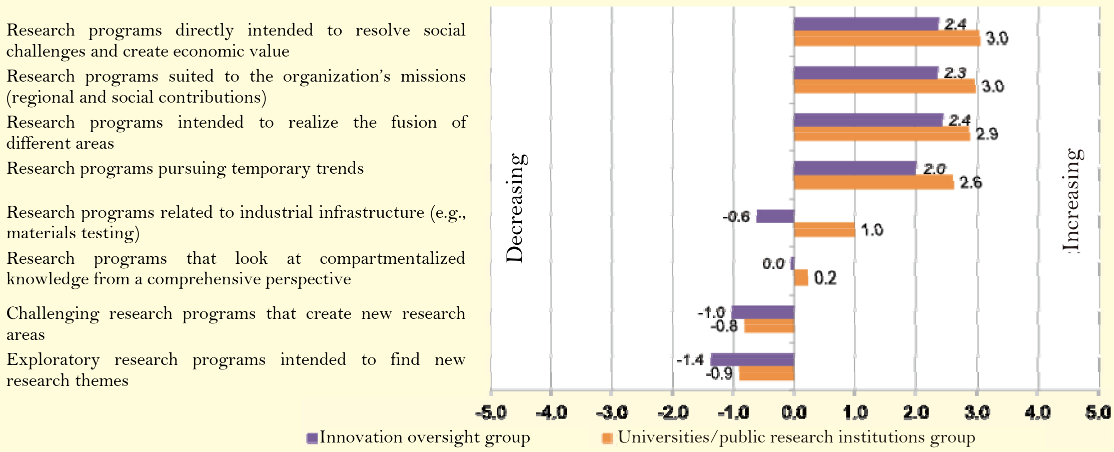


Note: Tabulated through the factional counting method. The above figures represent the annual average numbers of papers in 2007 to 2011.

Source: Prepared by NISTEP based on Clarivate Analytics' Web of Science (SCIE, CPCI-S) (*Quantitative and Comparative Analysis on National University Systems in Japan and Germany based on Scientific Publications* (December 2014)).

The low level of diversity in Japanese research activities indicated by the analysis data concerning papers has also been pointed out by people on the frontlines of research. In the 2015 NISTEP Teiten Survey, a questionnaire survey was conducted with top-level researchers and experts in industry, academia and government. From the results of the questionnaire concerning changes in the specifics of research at universities and public research institutions over the past 10 years, it is clear that "challenging research programs that create new research areas" and "exploratory research programs intended to find new research themes" are decreasing, and this change is unfavorable from the viewpoint of securing research diversity (Figure 1-1-93).

Figure 1-1-93 **Changes in the specifics of research activities at universities and public research institutions over the past 10 years**



Note: The innovation oversight group comprises around 500 people, including industrial experts, while the universities/public research institutions group comprises around 1,000 people, including heads of institutions and frontline researchers. The questionnaire asked the respondents to select replies from among the options "steeply decreasing" "decreasing," "no change," "increasing," and steeply increasing" with respect to numerical changes compared to periods around 2005. The above data show the results obtained through the following indexation of the replies: steeply decreasing=minus 10 points; "decreasing=minus 5 points; no change=zero; increasing (plus 5 points); steeply increasing (plus 10 points).

Source: *Analytical Report for NISTEP Expert Survey on Japanese S&T and Innovation System (2015 NISTEP TEITEN survey* (March 2016), NISTEP

In the same survey, questions were asked as to whether there was sufficient collaboration between humanities/social sciences and natural sciences to resolve ethical, legal system and social challenges when implementing science and technology, and the results show that the general consensus in both academia, including universities and public research institutions, and industry was that collaboration was insufficient (Figure 1-1-94). Of the respondents, 9% gave a better assessment of collaboration compared with the previous survey, while 11% gave a worse assessment. Among the reasons cited for a better assessment were that a center intended to promote interdisciplinary research has been opened and that activities aiming for the fusion of natural sciences areas and humanities/social sciences areas increased. Among the reasons cited for a worse assessment were that it is necessary for both the government and research institutions to develop human resources that cover gaps between areas and that the opportunity for exchange between researchers in humanities/social sciences areas and natural sciences areas is limited. In order to realize "Society 5.0," it is more necessary than ever to promote comprehensive activities extending across the boundaries between humanities/social sciences and natural sciences and to develop human resources.

Figure 1-1-94 Results of a survey on the perception of collaboration between humanities/social sciences and natural sciences

Question	Highly insufficient 2	Strong perception of insufficiency 3	Index figure insufficient 4	Almost no problem 5	No problem 6
Do you think that there is sufficient collaboration between humanities/social sciences and natural sciences in social implementation of science and technology in order to resolve ethical, legal system and social challenges?		▲ (3.0)	▲ (3.7)		

Note: The orange triangle indicates the index figure for the innovation oversight group as a whole, while the blue triangle indicates the index figure for the universities/public research institutions group as a whole. The innovation oversight group comprises around 700 people, including industrial experts, and the universities/public research institutions group comprises around 2,100 people, including heads of institutions and frontline researchers.

Source: *Analytical Report for NISTEP Expert Survey on Japanese S&T and Innovation System* (2017 NISTEP TEITEN survey) (April 2018), NISTEP

C. Examples of Major Initiatives

The government is conducting various initiatives in order to promote academic and basic research activities that create and accumulate new knowledge and serve as a wellspring of social and economic development based on continuous innovations. Here, we explain examples of major initiatives concerning academic and basic research.

MEXT's Grants-in-Aid for Scientific Research program (hereinafter referred to as "scientific research grants-in-aid") is promoting the review and revision of the screening system and research items and frameworks and the use of flexible and appropriate use of research funds. At the same time, MEXT is promoting international joint research and strengthening support measures that enable researchers to explore and tackle new challenges. Specifically, it is promoting the reform of the scientific research grants-in-aid program that aims to achieve knowledge breakthrough, for example by establishing the "challenging research" category, which places emphasis on the novelty of ideas, rather than past achievements, such as paper production, while aiming for a new adoption rate of 30%, and also by implementing the "scientific research grants-in-aid support plan for young researchers," which includes support for the independence of young researchers.

In addition, MEXT has been implementing the World Premier International Research Center Initiative (WPI) since 2007 in order to promote international joint research in a strategic manner and establish research bases that form the core of international brain circulation in Japan. This program aims to establish "visible research bases" with an excellent research environment and a high level of research that attract top-level researchers from across the world by encouraging voluntary initiatives, such as introduction of system reforms, through intensive governmental support for plans intended to develop world-leading research bases comprised of high-level researchers as the core. Research bases are required to meet four conditions: world-leading level of research, creation of multidisciplinary areas, realization of an international research environment, and reform of research organization. As a result of support provided under the WPI program, research bases with a level of research capability and internationalization comparable to that of world-leading institutions are starting to emerge and research

Chapter 1

papers of world-leading quality (adjusted top 1% papers) have already been produced. System reforms are also proceeding, as exemplified by the fact that the proportion of foreign researchers at research bases established under this program is higher than 40% on average and by the acquisition of large-scale donations and financial assistance funds from private-sector companies and other sources.

In the life sciences areas, the Human Frontier Science Program (HFSP), an international project proposed by Japan at the G7 Summit in Venice in June in 1987 is being implemented with support from 15 countries and organizations, including Japan. This is an international research support program that promotes cutting-edge research programs intended to examine the complex mechanisms of living organisms. With the International Human Frontier Science Program Organization, located in Strasbourg (France), as the main implementing organization, the program is promoting activities to support unique and ambitious interdisciplinary international research involving scientists from across the world and to provide young researchers with international research opportunities. Since the start of the program in 1990, 3,902 researchers (including 483 Japanese researchers) received research grants by 2017, of whom 27 won Nobel prizes. Japan is contributing to the promotion of the program through the Japan Agency for Medical Research and Development. The Japan Agency for Medical Research and Development is supporting the use of this program by Japanese researchers, for example by raising awareness about it and providing easy-to-understand explanations concerning the application method and other related matters.

(2) Research Facilities and Equipment and Information Infrastructure

A. Analysis of the Current Status

The Act on the Promotion of Public Utilization of the Specific Advanced Large Research Facilities (Act No. 78 of 1994) has been enacted with the aim of strengthening research infrastructure and integrating a diversity of knowledge possessed by research institutions and researchers by promoting sharing of large-scale research infrastructure facilities which are established by the government and research institutions and which are used widely in cutting-edge science and technology fields. Under this act, the government designates advanced large research facilities with incomparable performance which can maximize their value through their use in research in a wide range of fields as specific advanced large research facilities and promotes their sharing by researchers in industry, academia and government through budgetary measures necessary for the development and sharing of facilities. Among existing facilities designated as specific advanced large research facilities are a specific synchrotron radiation facility (a large synchrotron radiation facility (SPring-8), an X-ray free electron laser facility (SACLA)), a specific high-speed computer facility (the K supercomputer), and a specific neutron facility (a large high-intensity proton accelerator (J-PARC)). All these facilities are playing a significant role as knowledge infrastructure that lead to the enhancement of international competitiveness (Reference: Part II, Chapter 4, Section 2.2 (2) A(A) Specific advanced large research facilities).

Large synchrotron radiation facility
SPring-8
X-ray free electron laser facility SACLA
(RIKEN: Sayo Town, Hyogo Prefecture)
Courtesy of RIKEN

Specific high-speed computer
K supercomputer
(RIKEN: Kobe City, Hyogo Prefecture)
Courtesy of RIKEN

High-intensity proton accelerator
J-PARC
(Japan Atomic Energy Agency/High Energy Accelerator Research Organization: Tokai Village, Ibaraki Prefecture)
Courtesy of Japan Atomic Energy Agency/High Energy Accelerator Research Organization

In order to enhance knowledge infrastructure, it is necessary to develop advanced research facilities and equipment and information infrastructure supporting research and also to pay attention to the open science approach, activities related to which have accelerated in recent years. Open science refers to a new approach to promoting science that aims to make it possible to give not only academia but also a wider society, including industry and the general public, easy access to research results (papers, research data, etc.), thereby opening new paths to knowledge creation, and to ensure that research results lead to innovation creation by promoting science and technology research in an effective manner. Open science, a concept that includes open access and open data, is expected to make it possible for all users to access research results, accelerate knowledge creation through cooperation across the boundaries of fields of specialty and national borders, and create new value.

Measuring and analysis technologies and a set of scientific technologies supporting the development, utilization and management of oceans and outer space are common infrastructure technologies that support research in a broad and diverse range of research areas and application fields, so they are important technologies that support not only research but also Japan's main industries. The technologies not only enhance industrial competitiveness and help to deal with economic and social challenges but also consolidate Japan's foundation as a country. At the same time, they help Japan gain high regard and respect in the international community and enlighten the Japanese people about science. These scientific technologies need to be continuously enhanced from a long-term perspective.

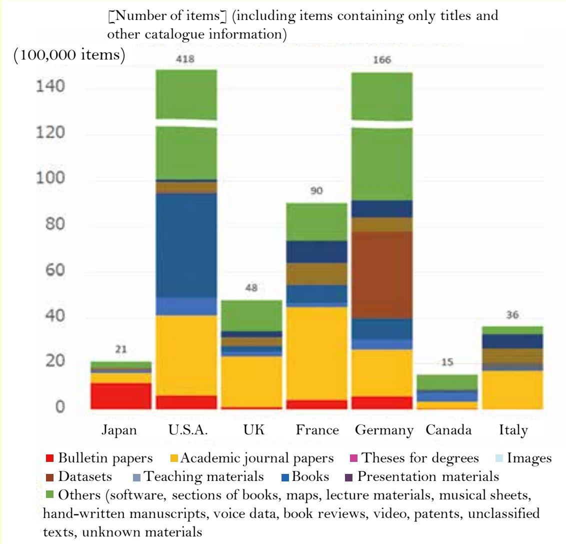
B. Identification of Challenges

Until now, vigorous efforts have been made to make large research facilities and equipment publicly available for use by researchers in a diverse range of fields and open them to academia, industry and government and to develop the facilities into platforms. For example, in the case of Spring-8, 20% of all usages are industrial usages, and the share of industrial usages is around 30% for the K supercomputer and slightly less than 30% for J-PARC. The share of industrial usages of these facilities is higher than the share of facilities of comparable size in other countries. In order to maximize the achievements of these large research facilities and their equipment, it is important to make maximum possible use of them. Therefore, it is essential to ensure sufficient sharing of facilities by researchers by securing the maximum possible amount of operating hours, raising the research theme adoption rate, and enhancing convenience. Not only do those research facilities, that are the most advanced in the world, and research facilities publicly available for use by industry, academia and government contribute to advances in research and development but also the mingling of diverse personnel at the facilities is expected to accelerate the sustainable creation of science and technology innovations. Therefore, in order for Japan to compete with foreign countries on an equal footing, it is important to increase facilities and equipment available for sharing across the whole of Japan.

With respect to small and medium-size appliances (worth several hundred million yen to hundreds of millions of yen) that have been mainly managed on a research team-by-research team basis, it has been pointed out that sufficient efforts toward sharing have not necessarily been made. From the individual researcher's viewpoint, problems arise after the expiry of the period of research implementation, which typically lasts for three to five years, with respect to continuous usage of devices procured with competitive research funds in terms of procuring supplies, securing technical staff and maintaining and managing machinery. From the organization's viewpoint, shifting the management of small and medium-size appliances to a department-by-department basis, for example, enables efficient sharing of the devices by multiple researchers, and it is also expected to make it possible to efficiently allocate human resources and enhance the professional expertise of technical staff because it enables the allocation of technical staff on a department-wide basis. In order to enable researchers to continue to make effective use of devices, exercise their research capabilities to the maximum possible extent, and use research and development investment as efficiently as possible, it is essential to reform the management system concerning research facilities and equipment at universities and national research and development agencies and it is also necessary to shift management from a research team-by-research team basis (researcher-by-researcher basis) to a research institution-by-research institution basis.

From the viewpoint of promoting open access, Japan is making steady progress in the development of institutional repositories, which are online archive systems intended to store and disseminate electronic intellectual output produced by universities and other organizations, in line with the global standard. While Japan is leading the world in terms of the number of institutional repositories developed, the United States and Germany are far ahead of other countries in terms of the volume of contents stored in institutional repositories, so Japan must also expand and enhance the contents of the repositories (Figure 1-1-95). In order to promote open science, it is necessary to develop infrastructure for utilization of research data that enables integrated search covering research data and paper information and field-by-field data search. There are expectations for further enhancement of the functions of existing institutional repositories and for further collaboration between, and utilization of, field-by-field databases. Moreover, Japan is lagging behind other countries in formulating a policy concerning utilization of research data (data policy) on a research area-by-research area basis and a research institution-by-research institution basis. It is necessary to formulate a data policy and a data management plan in order to prevent a situation in which Japan would make progress in public disclosure of research data without considering an open-and-close strategy and would lose opportunities for preferential utilization of research data for the purpose of promoting Japanese industries, thereby allowing foreign countries to use Japanese research data for commercialization earlier than Japanese companies.

Figure 1-1-95　Status of contents stored by major countries' institutional repositories



Source: Prepared by the National Institute of Informatics based on data compiled by the Bielefeld Academic Search Engine

C. Examples of Major Initiatives

Specific advanced large research facilities are producing various research results, and as an example, we cite the contribution to the development of a high-performance, high-quality, low fuel consumption tire. This tire has been developed by Sumitomo Rubber Industries, Ltd. based on a new materials development technology (Advanced 4D Nano Design) involving the structural analysis of the rubber molecule conducted through the use of synchrotron radiation created by Spring-8 and kinematic analysis using neutrons created by J-PARC and large-molecule simulation using the K supercomputer. Sumitomo Rubber succeeded in developing a tire material that makes it possible to drastically improve abrasion resistance in addition to simultaneously enhancing tires' mutually conflicting performances, namely, low fuel cost and grip performance, based on the combination of the analysis results produced by those advanced large facilities. The abrasion resistance of the product adopting this material is remarkably superior: 51% higher than the resistance of existing products. Advanced 4D Nano Design has gained a high reputation internationally, as exemplified by the winning of the Tire Technology of the Year prize in the Tire

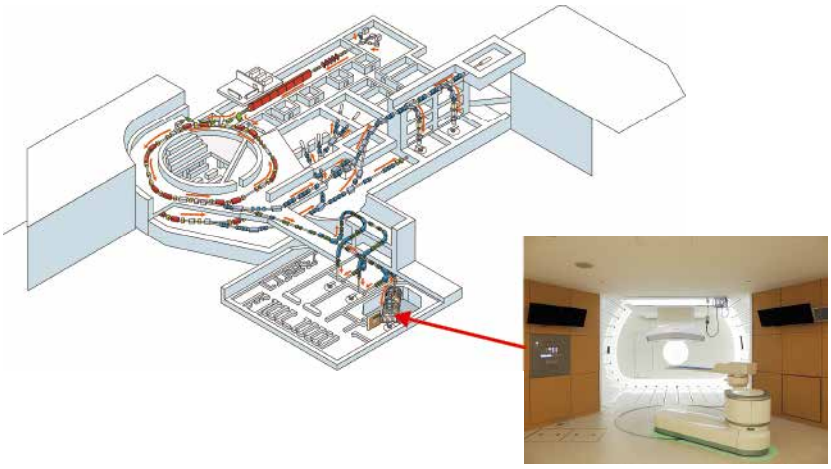
Technology Expo 2017, which was held in Germany in February 2017.

Below, we explain major initiatives related to research facilities and equipment and information infrastructure. With respect to large research facilities and equipment, until now, Japan has gradually proceeded with technology development in order to maximize the results made through the use of the facilities. Initiatives to promote further use of large research facilities and equipment are under way. For example, SACLA started operating three beam lines simultaneously in September 2017 for the first time in the world, contributing to an increase in the number of hours used by researchers.

As for large-scale academic research projects, at the Super-Kamiokande, an astroparticle observatory installed 1,000 meters underground at the Kamioka mine in Gifu Prefecture, world-leading neutrino research is being conducted with the participation of seven countries and 22 organizations. In 1998, the observatory found that neutrinos coming from the other side of the earth transform themselves into a different type of neutrinos and proved that neutrinos have mass. In recognition of this discovery, which rewrote the existing standard theory concerning elementary particles (which maintained that neutrinos have no mass), the Nobel Prize in Physics in 2015 was awarded to Takaaki Kajita, Director of the Institute for Cosmic Ray Research at the University of Tokyo. The technology developed for the purpose of high-sensitivity observation of neutrinos is contributing to the resolution of social challenges, as it is used in photomultiplier tubes utilized for medical devices, analysis and measurement appliances, and security systems.

With respect to advanced research facilities and equipment available for sharing by industry, academia and government, the Project for the Introduction of New Systems for Advanced Research Infrastructure Sharing (Project to Support the Development of Platforms for Sharing) is being implemented. Regarding research facilities and equipment covered by the program, platforms have been developed in order to create innovations related mainly to advanced measurement and analysis appliances through the networking of facilities, including in terms of maintenance and operation. Six platforms have been developed across Japan, including the NMR Platform, the Photon Beam Platform, and the Clinical Mass Spectrometer Platform, and various organizations, including universities and national research and development agencies, are participating in the platforms. In the future, it will be necessary to achieve more results by establishing a one-stop service centered around a coordinating organization as the core, strengthening the function of developing human resources, including expert staff, and accumulating knowhow and data. Regarding small and medium-sized devices, which are managed mainly on a research team-by-research team basis, problems have been pointed out with respect to their effective use, as was mentioned earlier. However, in fiscal year 2016, MEXT started a new program to support the introduction of a sharing system under which groups of research facilities and equipment managed individually by research teams can be centrally managed. As of fiscal year 2017, the number of implementing organizations was 29. Shared management systems are being developed and devices are being reallocated.

In the life sciences field, cancer therapy research using a heavy particle accelerator for medical use is being promoted. The National Institute of Radiological Sciences (NIRS) under the National Institutes for Quantum and Radiological Science and Technology developed HIMAC, the world's first heavy particle accelerator for medical use, and since 1994, it has been engaging in clinical research concerning cancer therapy using heavy particle beams. In recent years, technological improvements have been made based on the NIRS's research results and the size of the accelerator has been reduced. In Japan, five heavy particle beam accelerators are in operation, while one is operating on a trial basis and another is under construction. Currently, expectations for cancer therapy using heavy particle beams are growing in and outside Japan and efforts to spread the Japanese technology abroad are being made. In this situation, the NIRS is providing technical assistance to spread the accumulated technologies in Japan and abroad and develop human resources. The NIRS has established a rotary gantry technology that enables the radiation of heavy particle beams from multiple directions and is also developing smaller, lower-cost high-performance cancer therapy equipment using heavy particle beams.



HIMAC, a heavy particle accelerator for medical use (upper left), and a rotary gantry therapy room (lower right) (National Institute of Radiological Sciences: Chiba City, Chiba Prefecture)
Courtesy of the National Institute of Radiological Sciences

For Japan's space development, possessing domestically made rockets as a means of stable access to outer space is very important. Therefore, in order to go beyond introducing foreign technology and acquire world-class rocket technology, Japan has engaged in the development of the H-I and H-II rockets over the past half century. Following the development of these rockets, Japan's main rockets (e.g., H-IIA) have recorded 41 consecutive successful launches, with the successful launch rate reaching the world's highest level of 98% (as of the end of 2017). As in the case of rockets, Japan has until now launched many artificial satellites. Earth observation satellites, including the "DAICHI-2", the Advanced Land Observing Satellite-2 (ALOS-2), and communication satellites are contributing to the observation of natural disasters and comprehensive national security. The "KOUNOTORI" (HTV) Space Transfer Vehicle, which has the world's largest supply capacity among the supply vehicles now in operation, is contributing to the supply of goods to the International Space Station. Because of the technology cultivated through the development of these rockets and satellites, Japan has received a number of orders for the launch of foreign satellites. In addition, in the space sciences field, including X-ray astronomy, Japanese scientific satellites have come to play an essential role internationally. Each of the main rockets and satellites is a system comprised of more than one million parts, so their development and production require a comprehensive integration technology, which is supported by excellent Japanese manufacturers:

including small and medium-size enterprises, and by their technologies.

Regarding ocean development, “Chikyu,” the world’s largest deep-earth research drilling vessel, that is owned by the Japan Agency for Marine-Earth Science and Technology, serves as basic research infrastructure in the marine research field. “Chikyu” has a deep-sea drilling capability that enables drilling to the depth of 7,000 meters under the seabed. In 2013, its drilling depth reached 3,058.5 meters under the seabed. This is the deepest oceanic scientific drilling in the world. This unprecedented deep-sea drilling capability has made it possible to retrieve and analyze core samples from the epicenter areas of potential huge earthquakes. Moreover, as a result of the installation of observation equipment in the drilling hole, research results contributing to the examination of the occurrence mechanism of huge earthquakes have been produced. In addition, “Chikyu” is contributing to the examination of micro-organisms living in an extreme environment under the seabed, and research results that shed light on the origin of life are expected to be produced. “Chikyu” is positioned as a major research platform under the International Ocean Discovery Program. The International Ocean Discovery Program is a large-scale international joint project in the field of marine science which is led by Japan, the United States and Europe and which involves 25 countries around the world (as of April 2018). As described above, in addition to functioning as Japan’s important research infrastructure that produces excellent research results, “Chikyu is making significant contributions to international joint research programs.

The National Institute of Informatics (NII), as the main information infrastructure that supports academic research by universities and educational activities in general, has continued to maintain and improve an academic information network (SINET) that links national, public and private universities across Japan since 1992. In order to support the development of a community comprised of numerous people involved in education and research and promote the smooth distribution of a variety of academic information, SINET has installed nodes (network connection bases) across Japan and provides an advanced network for universities, research institutions and other organizations. In addition, in order to facilitate smooth international distribution of research information necessary for advanced international research projects, SINET is linked with many foreign research networks. The fifth-generation SINET5, which started operation in April 2016, seamlessly connects universities and other organizations across Japan at a data transmission speed of 100 Gbps and it features various improvements, including efficient maintenance due to the rental of unused circuits from private business operators (Figure 1-1-96). SINET is used for various purposes, including sharing of large testing facilities, cooperation with countries around the world, enhancement of cooperation in various research fields, international cooperation with countries around the world, dissemination of academic information, sharing of big data, development of infrastructure to improve the quality of university education. Regarding the promotion of open science, Japan is developing a system to create platforms for sharing of research results and data using Japanese institutional repositories, whose total number is the largest of all countries around the world.

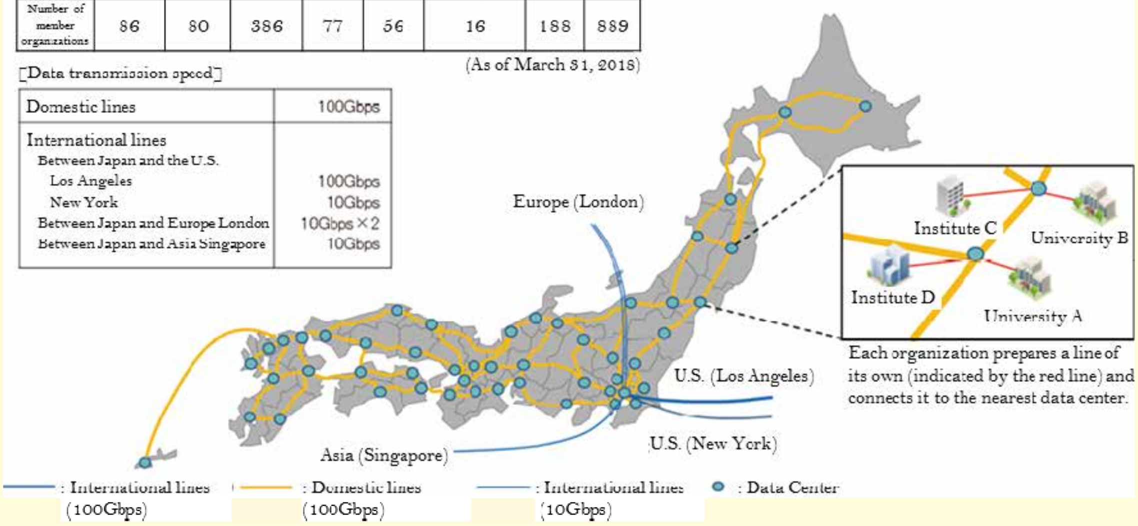
Figure 1-1-96 Data transmission speed and the number of member organizations of the academic information network (SINET5)

	National universities	Public universities	Private universities	Junior colleges	Technical colleges	Inter-University Research Institutes	Others	Total
Number of member organizations	86	80	386	77	56	16	188	889

(As of March 31, 2018)

[Data transmission speed]

Domestic lines	100Gbps
International lines	
Between Japan and the U.S.	
Los Angeles	100Gbps
New York	10Gbps
Between Japan and Europe London	10Gbps × 2
Between Japan and Asia Singapore	10Gbps



Source: Prepared by MEXT

(3) Research hours

A. Analysis of the current status

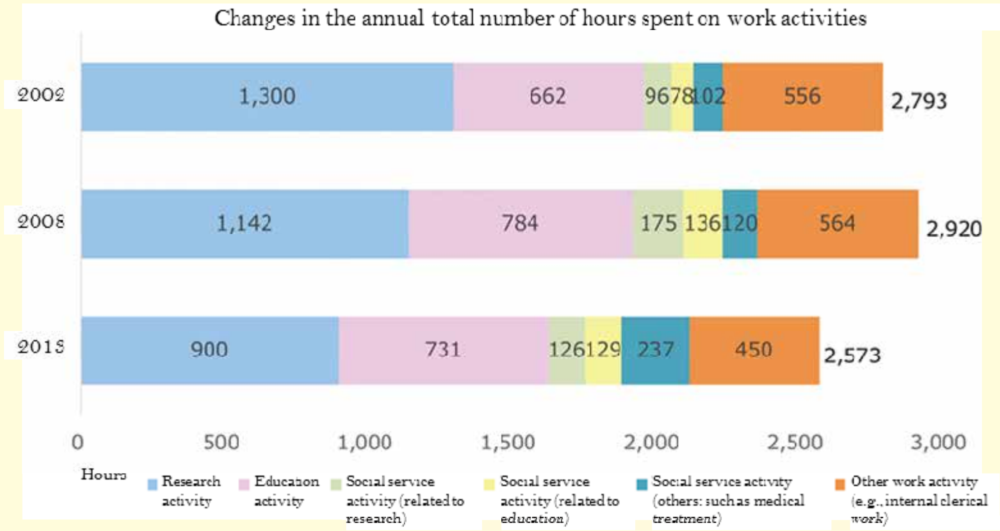
(A) Current status of research hours

Up until the present time, MEXT has conducted the "Survey of Full-time Equivalency Data at Universities and Colleges three times, in 2002, 2008 and 2013.

Looking at changes in the total number of hours spent on work activities by university and college faculty members based on the results of the survey, the average annual total number was 2,793 hours in 2002, 2,920 hours in 2008 and 2,573 hours in 2013. Meanwhile, the average annual total number of research hours[1] continuously declined, from 1,300 hours in 2002 to 1,142 hours in 2008 and 900 hours in 2013 (Figure 1-1-97).

1 Research hours include hours spent on research-related meetings and preparation of application forms concerning competitive funds in addition to hours spent on research activities such as collecting research-related information and reference materials, document research, data input and processing, prototyping, testing, data tabulation, and analysis.

Figure 1-1-97 **Changes in the total number of hours spent on work activities by university and college faculty members**



Source: Prepared by MEXT based on *"Survey of Full-time Equivalency Data at Universities and College"*

As university and college faculty members engage in a variety of activities, including education, research and social contribution, it is necessary to look at those activities from a comprehensive perspective. To do so, it is appropriate to examine the share of hours spent on each category of activity in the overall number of hours spent on work activities. While each and every category of work activity conducted by faculty members is important, it is difficult to increase the number of hours spent on all those activities because faculty members are already spending a large number of hours on their work activities. Moreover, from the perspective of management of universities and colleges, it is appropriate to pay attention to how to allocate the number of hours spent on work activities.[1]

There is a positive correlation between the number of researchers adjusted for the number of research hours and the number of papers as output.[2] As increasing the share of research hours as input is expected to lead to a rise in the efficiency of paper production, it is important to grasp the current status of research hours.

Therefore, this white paper conducts an analysis concerning the number of research hours in terms of its share in the overall number of hours spent on work activities by faculty members.

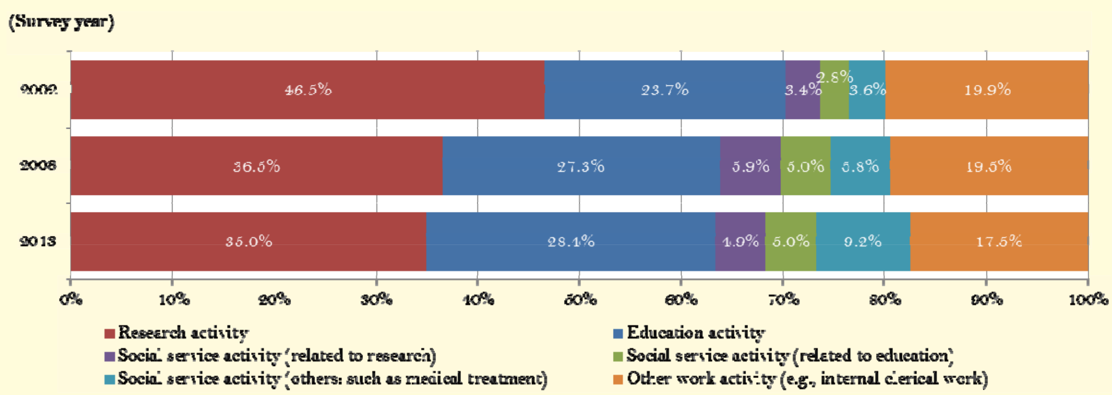
Looking at changes in the number of research hours spent by university and college faculty members, the average annual number of research hours in all areas of research fell from 46.5% in 2002 over the following six years to 36.5% in 2008, and it declined slightly over the following five years, to 35.0% in 2013. On the other hand, the share of hours spent on education activity increased from 23.7% in 2002 over

1 According to *Changes in the Ratio of Time Spent on Work Activities by University & College Faculty Members — A Comparison of results of the 'Survey of Full-time Equivalency Data at Universities and College' of 2002, 2008 and 2013.* (Research Material-236 (April, 2015), NISTEP

2 Regarding paper production activity in natural sciences fields at Japanese universities, *An analysis on the relationship between input and output in the production of articles in universities - An approach using Web of Science and Survey of R&D* [Discussion Paper No.89] by NISTEP conducted a regression analysis based on research paper data available from Web of Science and panel data on the number of researchers and research expenditures tabulated on a university-by-university basis in the *Survey of R&D* and showed the presence of positive correlation between the number of researchers adjusted for the number of hours spent on research and the number of papers produced.

the following 11 years to 28.4% in 2013. In addition, regarding the number of hours spent on social service activity as a social contribution, the number of hours spent on all categories of social service activity—including research-related activity, such as providing technical consultations concerning the use of research results; education-related activity, such as giving lectures open to the general public; and other activity, such as medical treatment—increased steeply between 2002 and 2008. Between 2008 and 2013, in particular, the number of hours spent on other social service activity, such as medical treatment, increased steeply. The number of hours spent on other work activity (e.g., internal clerical work) declined slightly (Figure 1-1-98). As indicated above, the number of research hours spent by university and college faculty members in general is on a downtrend.

Figure 1-1-98 **Changes in the share of hours spent by university and college faculty members on work activities**



Source: Prepared by MEXT based on *Changes in the Ratio of Time Spent on Work Activities by University & College Faculty Members — A Comparison of results of the 'Survey of Full-time Equivalency Data at Universities and College' of 2002, 2008 and 2013* (Research Material-236) (April 2015), NISTEP.

(B) University and college faculty members' perceptions

As causes of the decline in the number of research hours, various factors were cited, including: an increase in activity related to university and college management and reform, an increase in the burden related to the acquisition and management of external funds, an increase in the number of hours spent on activity related to education and student guidance, an increase in the number of hours spent on social activity service, an increase in the number of hours spent on evaluation-related clerical work, an increase in the burden of maintaining and managing facilities and equipment, and an increase in the burden of clerical work due to redundant procedures and an increase in accountability. Universities and colleges are expected to make efforts to secure research hours spent by faculty members (Figure 1-1-99).

(C) Analysis of the share of research hours

In this section, we conduct a more detailed analysis of the decline in the share of research hours in light of the circumstances that were described in (A) and (B).

Figure 1-1-99 Examples of university and college faculty members' perceptions of the decline in the number of research hours

<Activity related to the management and reform of the university>

- The number of faculty members has gradually been reduced, increasing the burden related to university management per faculty member, so it is becoming more and more difficult to secure sufficient time for research. (A university, agriculture, department head/professor-class, male)

<Activity related to the acquisition and management of external funds>

- A very large amount of time is spent on the process of filling in application forms for research funds. I strongly hope that the university will secure a necessary minimum amount of budget funds for basic sciences fields while developing a system to curb expenditures regarding equipment through sharing so that researchers can steadily engage in basic sciences research. (A university, sciences, researcher/research assistant-class, female)

<Activity related to education and student guidance>

- At local universities, the number of students per department faculty member is higher than four students/year, and in addition, young researchers must also take assignments for laboratory lessons. As a result, the research environment is insufficient. (A university, department head/professor-class, male)

<Activity related to social service>

- There are many work duties other than pure research, including regional and international contributions, so the number of hours that can be allocated to research continues to decline. (A university, agriculture, senior researcher/associate professor-class, male)

<Activity related to evaluation-related clerical work>

- The periods of education and research projects are short, and much time has to be spent on budget application, interim evaluation, ex-post evaluation and organizing of various events intended to produce results for evaluation, including symposiums and workshops. As a result, it cannot be said that there is sufficient time for research. (A university, engineering, researcher/assistant researcher-class, male)

<Activity related to redundant procedures and accountability>

- It seems wasteful that the time for research is reduced due to various rules (e.g., rules concerning goods procurement) that we must observe as a public research institution required to be followed by public. We need a system (including a budget) that makes it possible to secure and utilize personnel who support research. (A public research institution, department head/professor-class, male)

Source: Prepared by MEXT based on *Analytical Report for NISTEP Expert Survey on Japanese S&T and Innovation System* (2016 NISTEP TEITEN survey) (May 2017), NISTEP

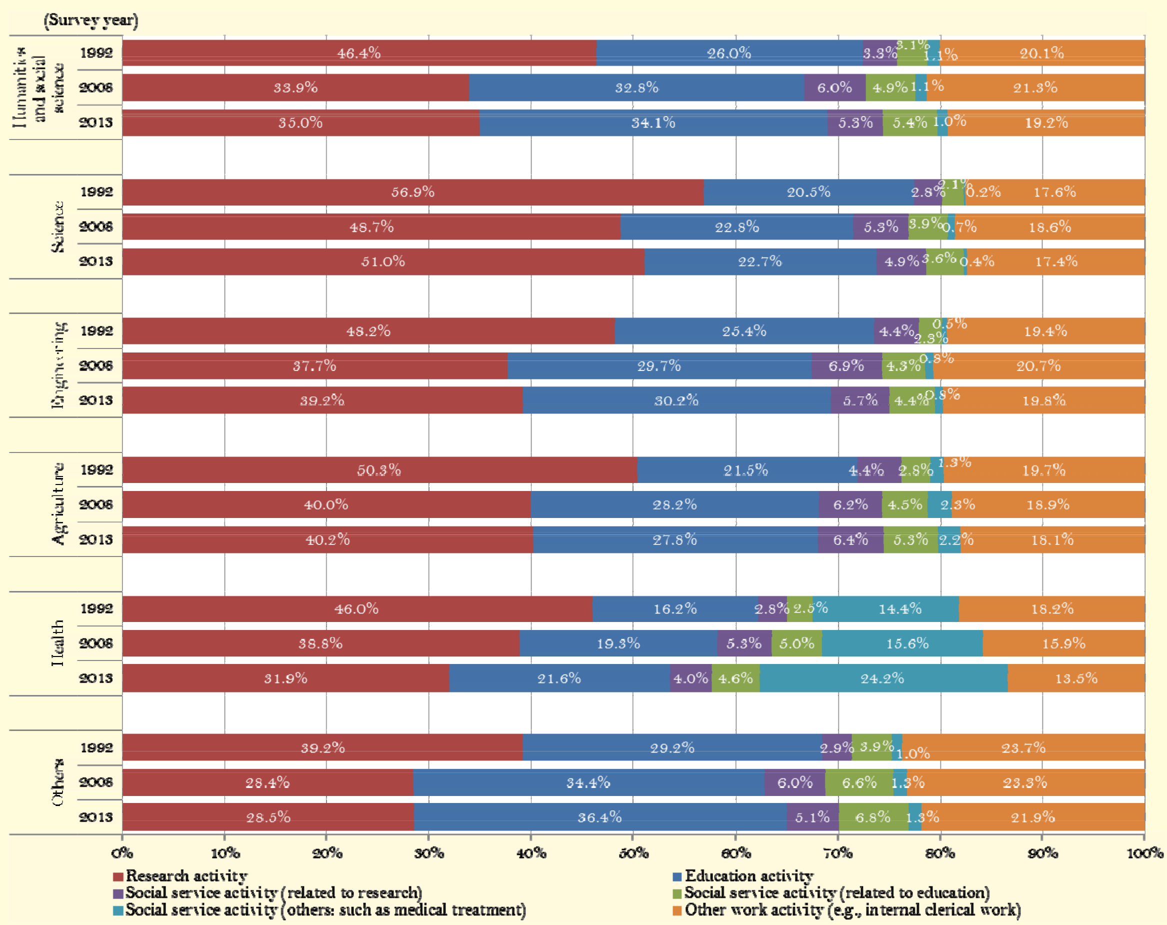
(i) Share of research hours by academic field

The change in the share of hours spent on work activities differs across academic fields.[1] Between 2002 and 2008, the number of research hours declined in all academic fields. This is considered to be due to

1 This is a classification of organizations of universities and other institutions by academic research field based on the *Report on the Survey of Research and Development*, which is prepared every year by the Statistics Bureau of the MIC.

increases in the number of hours spent on education and social service activities by university and college faculty members. Between 2008 and 2013, in the field of healthcare, the share of research hours declined from 38.8% to 31.9%, while the share of hours spent on social service activity (other activity, such as medical treatment) increased significantly. In fields other than healthcare, between 2008 and 2013, the share of research hours increased slightly in all fields, indicating a marginal improvement in the situation (Figure 1-1-100). As the number of faculty members in the field of healthcare accounts for around 30% of the total number of faculty members, the change in the share of research hours in this field has a large impact on the share of the overall number of research hours spent by faculty members.

Figure 1-1-100 Changes in the share of hours spent on work activities by university and college faculty members by academic field



Source: Prepared by MEXT based on "Analytical Report for 2016 NISTEP Expert Survey on Japanese S&T and Innovation System (2016 NISTEP TEITEN survey)" (May 2017), NISTEP

(ii) The share of research hours by employment position

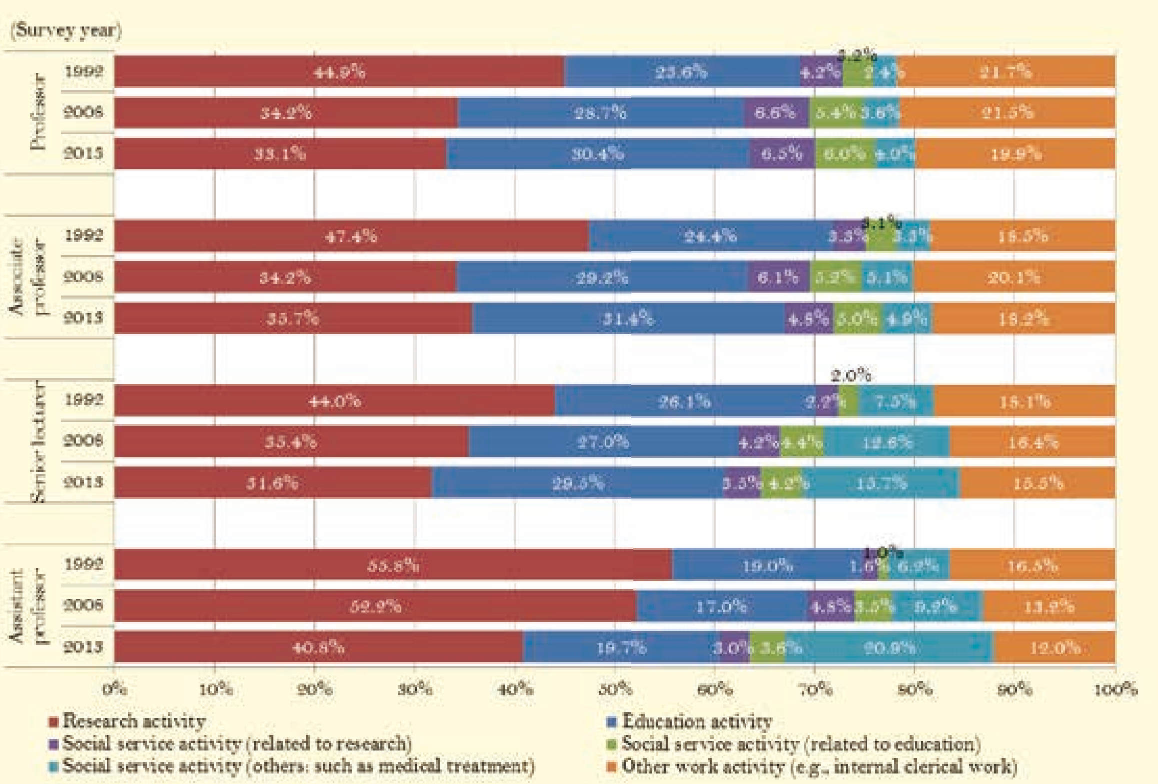
Next, we look at faculty members' work activities by employment position.[1] Regarding all employment

1 The definitions of faculty members' employment positions are different between the survey in 2002 and the surveys in 2008 and later. In addition, the revision of the university faculty organization in 2007 caused some changes in the classification of employment positions and the specific job duties of employment positions.

positions, the share of research hours declined between 2002 and 2008, just as the share declined in all fields on a field-by-field basis. In particular, the margin of decline was large for professors and associate professors (assistant professors), while the margin of decline was small for assistant researchers.

However, between 2008 and 2013, the share of research hours declined most, from 52.2% to 40.8%, for assistant researchers. This is largely due to an increase in the share of hours spent on social service activity (other activity, such as medical treatment) from 9.2% to 20.9%. On the other hand, with respect to other employment positions, the share of research hours decreased slightly for professors and lecturers and increased slightly for associate professors (assistant professors) (Figure 1-1-101).

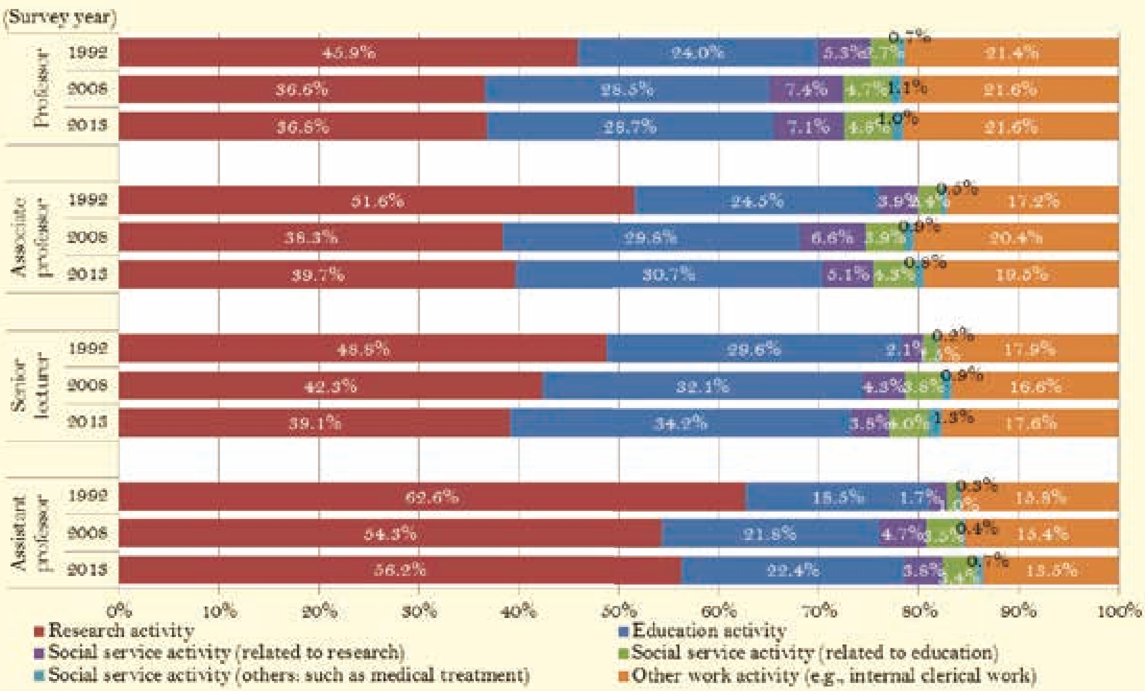
Figure 1-1-101 Changes in the share of hours spent on work activities by university and college faculty members by employment position



Source: *Changes in the Ratio of Time Spent on Work Activities by University & College Faculty Members — A Comparison of results of the 'Survey of Full-time Equivalency Data at Universities and College' of 2002, 2008 and 2013* (Research Material-236) (April 2015), NISTEP

Looking at the decline in the share of research hours spent by assistant researchers by field, we see that the impact of the change in the healthcare field is large, as was the case with the overall trend across fields. If we look at the share of hours spent on work activities in the fields of sciences and agriculture, excluding healthcare, the share of research hours was higher than 50% for assistant researchers in all of 2002, 2008 and 2013. For lecturers, the share of research hours declined slightly between 2008 and 2013, while the shares of hours spent on education activity and hours spent on other work activities (e.g. internal clerical work) increased (Figure 1-1-102).

Figure 1-1-102 **The share of hours spent on work activities by university and college faculty members by employment position in sciences and agriculture fields**



Source: *Changes in the Ratio of Time Spent on Work Activities by University & College Faculty Members — A Comparison of results of the 'Survey of Full-time Equivalency Data at Universities and College' of 2002, 2008 and 2013* (Research Material-236) (April 2015), NISTEP

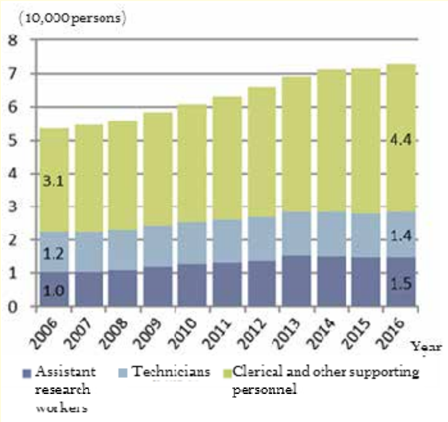
(D) Allocation of research assistants

Allocation of research assistants who assist university and college faculty members' research activity and research-related clerical work is also important for securing research hours. According to the Report on the Survey of Research and Development, compiled annually by the Statistics Bureau of the MIC, research assistants can be classified into assistant research workers, technicians, and clerical and other supporting personnel. Assistant research workers are persons who assist researchers and who are engaged in research activities under their direction and supervision. Technicians are persons who provide research-related technical services under the supervision and direction of researchers and assistant research workers. Clerical and other supporting personnel are those who engage in research-related work concerning general affairs and accounting.

Regarding research assistants at universities and colleges, clerical and other supporting personnel accounted for the largest number, 43,000 personnel, in 2016, followed by assistant research workers, totaling 15,000, and technicians, 14,000. While the numbers of clerical and other supporting personnel and assistant research workers are increasing, the number of technicians has remained almost flat (Figure 1-1-103).

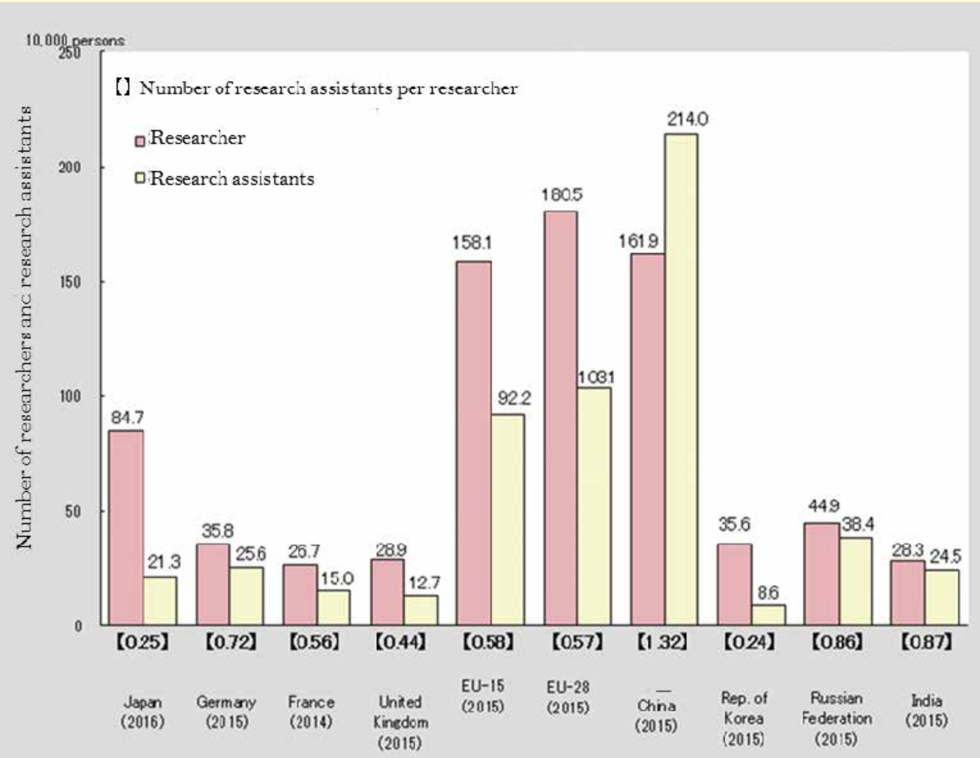
On the whole, the number of research assistants at universities and colleges is trending upward. However, as the number of research assistants per researcher in Japan is very small compared with the numbers in other countries (Figure 1-1-104), it is necessary to continue efforts to secure research assistants.

Figure 1-1-103 Changes in the number of research assistants in Japan



Source: *Inputs structure of the university system in Japan – In-depth analyses of the survey of research and development (2002～2015)* –Research Material -257 (February 2017), NISTEP (Prepared by MEXT based on the *Report on the Survey of Research and Development* by the Statistic Bureau of the MIC)

Figure 1-1-104 The number of research assistants per researcher in major countries



Notes: 1. The number of research assistants per researcher was calculated by MEXT based on the numbers of researchers and research assistants.
2. The figures for all countries include the numbers in humanities/social sciences fields.
3. Research assistants include personnel supporting research activity, personnel providing research-related technical services and personnel engaging in research-related clerical work. In Japan research assistants are classified into assistant research workers, technicians, and clerical and other supporting personnel.
4. The figures for Germany are estimated and provisional ones.
5. The number of researchers in the United Kingdom is an estimated, provisional figure, and the number of research assistants is underrepresented.
6. The figures for the EU are those estimated by the OECD.

Source Japan: *Report on the Survey of Research and Development*, the Statistics Bureau of the MIC; India: UNESCO Institute for Statistics S&T database; other countries: Prepared by MEXT based on *Main Science and Technology Indicators* (2017/1), OECD (Indicators of science and technology, 2017 ver.)

Research administrators (URA[1]), who engage in work activities that help to advance researchers' research activity and enhance research and development management by working with researchers in implementing planning and management of research activity and in promoting the utilization of research results, are required to play a role in research management at universities and colleges. They are expected to engage in work activities that facilitate research activity. In fiscal year 2016, a total of 916 URAs were in place at 102 institutions,[2] and their number is trending upward.

B. Identification of Challenges

As described in A., the share of research hours spent by university and college faculty members is trending downward on the whole. However, as the situation differs across academic fields and employment positions, we cannot generalize the situation by pointing out the decline in the share of research hours. On the other hand, there is no doubt that researchers working on the frontlines of research are feeling the squeeze from the decline in research time.

As a means to increase the number of research hours, many faculty members cited improving the efficiency of university/college management work and internal clerical procedures. The next most frequently cited means to increase the number of research hours is reducing the burden of education activity by securing faculty members dedicated to education and personnel dedicated to clerical work.[3] The university/college management work as referred to here include attendance at meetings of professors and senior faculty members and related work, and work related to self-check and evaluation by universities and colleges. The internal clerical procedures include procedures for supply procurement and application for the use of facilities,[4] and there are expectations for improvement in the efficiency of such work.

In addition, a great majority of faculty members cited "reducing the frequency of and the burden associated with internal meetings" as an initiative that they considered to have actually produced positive effects at their institutions (Figure 1-1-105). The next most frequently cited effective initiative is appointing staff responsible for supporting education activity and technical staff responsible for supporting research activity. Moreover, using common equipment shared by many research assistants and reducing the frequency of outside visits and the associated burden by introducing a tele-conference system, for example, were cited as effective initiatives, indicating that it is also important to improve the research environment.

A survey respondent at a university/college which appointed an URA made the following comment: "I can obtain the URA's cooperation in relation to the organizing of seminars, and as a result, it has become possible to increase the time that I can spend on my own research."[5] There are expectations for further promotion of the appointment of URAs.

As described above, many faculty members believe that improving the efficiency of work activities

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1 University Research Administrator

2 MEXT, *FY2016 Status of Industry-Academia Collaboration at Universities, etc.* (February 2018).

3 NISTEP, *Changes in the Ratio of Time Spent on Work Activities by University & College Faculty Members — A Comparison of results of the 'Survey of Full-time Equivalency Data at Universities and Colleges' of 2002, 2008 and 2013"* (Research Material-236) (April 2015).

4 As defined in the *'Survey of Full-time Equivalency Data at Universities and Colleges.*

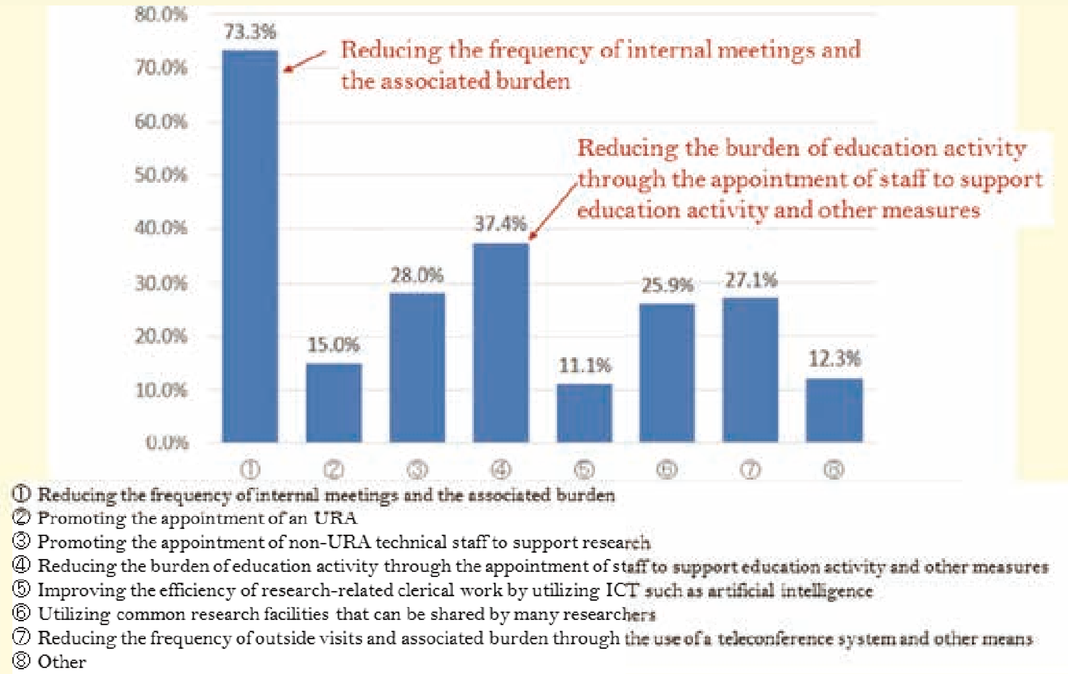
5 From a free comment given in response to MEXT/NISEP, *Survey on the Actual Situation of Researchers who Contribute to the Improvement of Japan's Research Capacity: From a Survey with a Network of Science and Technology Experts,* STI Horizon 2018 Vol. 4 No. 2, http://doi.org/10.15108/stih.00132.

related to internal meetings and internal clerical work is effective in securing research hours. On the other hand, as indicated in A (A), the share of hours spent on other work activities (e.g., internal clerical work) is decreasing, so it is necessary for both the government and universities to further examine the fundamental causes of the changes in the actual status of research hours and implement countermeasures.

C. Examples of Major Initiatives

In fiscal year 2011, in order to introduce and establish the URA as a category of job with a high level of professional expertise at universities, MEXT started the Program to Foster and Secure Research Administrators with a view to improving the environment to invigorate researchers' research activity, strengthening the system to promote research through the enhancement of research and development management and diversifying the career paths for workers in science and technology fields. In fiscal year 2013, MEXT started the Program for Promoting the Enhancement of Research Universities, under which selected organizations are promoting the employment, training and utilization of URAs.

Figure 1-1-105 Initiatives considered to have been effective in increasing the number of research hours at the organization of affiliation



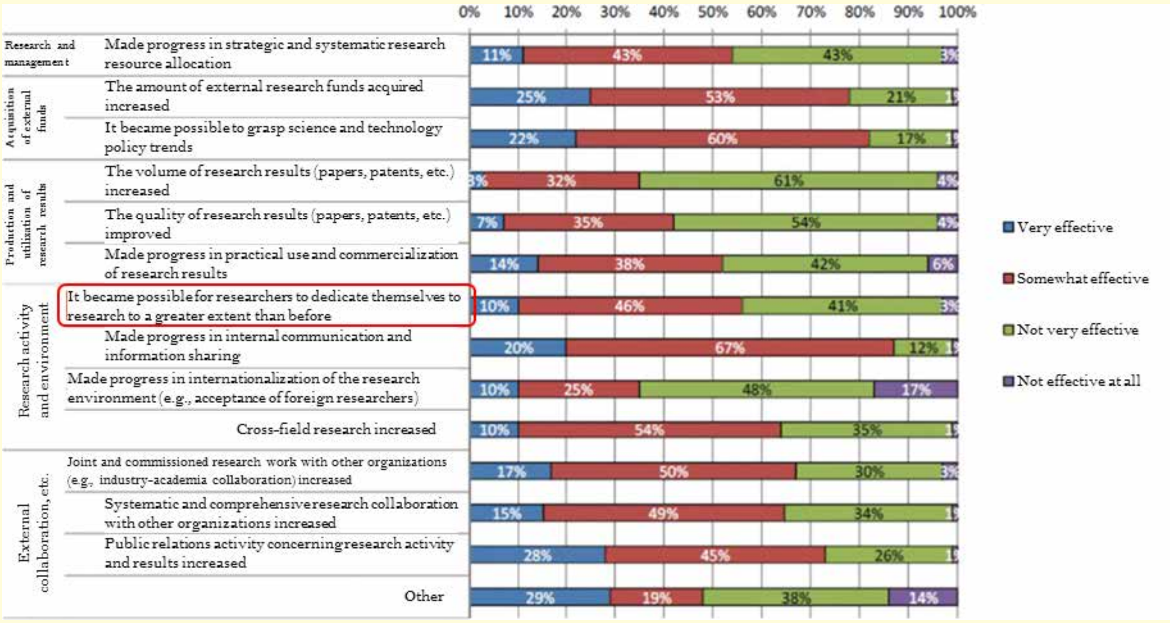
Source: MEXT/NISTEP, *STI Horizon 2018* Summer Edition[1]

As mentioned earlier, as a result of those initiatives, a total of 916 URAs were in place at 102 organizations in fiscal year 2016, and the number of URAs is trending upward. In addition, regarding how effective the appointment of URAs is in enabling researchers to dedicate themselves to research to a greater extent than before, 56% replied that the appointment was "very effective" or "somewhat effective" (Figure 1-1-106). This indicates that the appointment of URAs is producing some effects in securing

1 MEXT/NISTEP, *Survey on the Actual Situation of Researchers who Contribute to the Improvement of Japan's Research Capacity: From a Survey with a Network of Science and Technology Experts*, STI Horizon 2018 Vol. 4 No. 2, http://doi.org/10.15108/stih.00132

research hours spent by faculty members. Many organizations believe that the appointment of URAs is highly effective in making it possible to grasp science and technology trends and in making progress in internal communication and information sharing, indicating that URAs play various roles at universities and other organizations. On the other hand, as some organizations have not yet appointed an URA, it is necessary to continue efforts to promote such appointment.

Figure 1-1-106 Effects of the appointment of URAs



Source: MEXT, *Survey and Analysis for Autonomous Management of Research Administrator Operation* (March 2016)

In order to secure research hours spent by faculty members, it is important for individual universities and colleges to conduct their own initiatives. Individual universities and colleges are engaging in various initiatives to secure research hours spent by faculty members, such as revising the frequency of internal meetings and simplifying internal clerical procedures

For example, a certain university has introduced an internal system which exempts faculty members who have continued to work for a prescribed number of years from work duties related to lectures, attendance at meetings of professors and committee meetings so that they can concentrate on research. Another university has introduced a system of office hours during which questions and requests for consultations from students are received in a concentrated manner, thereby securing the time for student guidance and enabling faculty members to focus on research outside those hours.

In addition, as improving clerical staff members' professional skills is expected to help to secure research hours spent by faculty members, some universities are implementing systematic training and research (staff development (SD[1])) focusing on employees' management and administration skills and education and research support skills. Moreover, many universities have adopted institutional research (IR[2]) and are

1 Staff Development: Systematic efforts to improve the skills of staff members, including clerical and technical staff, with respect to activities including management and administration, and education and research support.

2 Institutional Research: Activities to support internal decision-making and improvement activity and fulfill accountability to the outside

gathering and analyzing information related to research hours spent by faculty members.

Individual universities and colleges are expected to continue to conduct initiatives that are considered to be effective in securing research hours spent by faculty members.

(4) Institutional systems related to Research and Development

A. Analysis of the Current Status

With respect to national research and development agencies, various institutional system reforms have until now been implemented. Regarding national universities, three frameworks of intensive support under the management expense grant program for national university corporations have been established in order to provide meticulous support for individual universities' initiatives to strengthen their functions. In addition, the reorganization initiative intended to realize education and research activities that take advantage of universities' own strengths and unique features has accelerated further, and self-reform and renewal efforts are being promoted. The details of institutional system reforms concerning national universities will be described in "C. Examples of Major Initiatives."

With respect to national research and development agencies, the National Institute for Materials Science (NIMS), RIKEN and the National Institute of Advanced Industrial Science and Technology (AIST) have been designated as specific national research and development agencies, which are core organizations responsible for leading innovation. Under a new national research and development agency system, these agencies are conducting research and development activities that lead to the production of world-leading research results. The details of institutional system reforms concerning national research and development agencies will be described in "C. Examples of Major Initiatives."

B. Identification of Challenges

If Japan is to overcome global competition and maintain sustainable growth through innovation, it is an urgent challenge to encourage universities and national research and development agencies, which are responsible for creating science and technology innovations, to improve research productivity and tackle the challenge of exploring new research areas.

Regarding universities, challenges include the aging of faculty members due to the curb on employment and the extension of the mandatory retirement age and the narrowing of the career path for researchers to become regular teachers immediately after acquiring a doctorate due to a decrease in untenured posts for young researchers. Therefore, promoting a generational change through a systematic personnel management reform is also a challenge.

Other challenges include stagnant participation in new research areas due to a decline in the number of research hours spent by researchers, problems related to the return of Japanese researchers staying abroad,

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through the collection and analysis of information related to university organization, education, research, etc.

and the presence of factors obstructing the promotion of internationalization.

Many of those challenges can be resolved if universities strengthen their management capability, so it is said that participation of management professionals in university management and reform of the mindset of faculty members are essential.

With respect to industry-academia collaborative activity, companies' investments in programs of universities and national research and development agencies and utilization of patents are increasing in terms of volume and value, indicating a steady expansion of industry-academia collaboration. On the other hand, compared with the situations in other countries, it cannot necessarily be said that industry-academia collaboration on an institution-to-institution basis is sufficient.

Regarding national research and development agencies, amid the decline in management expense grant revenue, the agencies must shift from management dependent on public funds to strategic management using private funds as well. The agencies are also expected to serve as the engine that invigorates the creation of science and technology innovation in Japan. In particular, it is important to strengthen the capabilities to create and develop ventures spun out of the agencies that play an important role in quickly recycling the agencies' research results to society and creating a virtuous cycle between knowledge and funds. It is also important for national research and development agencies to diversify their fund sources to include private funds. For example, it is necessary to implement institutional system reforms that invigorate the creation of science and technology innovation, such as expanding the scope of national research and development agencies allowed to invest in ventures spun out of the agencies—currently, only some agencies are allowed to do so—and allowing national research and development agencies to acquire and hold shares in such ventures when they provide support to the ventures, such as permitting the use of intellectual property and lending facilities.

C. Examples of Major Initiatives

Described below are examples of major initiatives concerning institutional systems related to research and development.

(A) Institutional system reforms related to universities that have already been implemented

(Incorporation of national universities)

In April 2004, national universities were incorporated, and 89 national university corporations were established. The incorporation of national universities was implemented in order to grant the corporation status to those universities, which had been positioned as the government's internal organizations since the Meiji Period, and significantly increase the room for discretion under an autonomous and independent environment, thereby further invigorating universities and encouraging them to actively provide excellent education and engage in unique research and realize attractive universities full of individuality.

(Changes in the environment surrounding universities)

As Japan is confronted with rapid social changes, including the rapid aging of society with a low birth rate and the intensifying competition due to globalization and the rise of emerging countries, it has become necessary to implement reforms with the aim of realizing a vigorous society that develops in a sustainable manner. In response to these changes in the environment surrounding universities, the government reviewed the role of national universities in light of the changing social situation and started to implement reforms in earnest.

In November 2013, MEXT announced the National University Reform Plan and decided to create an environment that promotes constant review of education and research organizations and internal resource allocations through such measure as redefining individual universities' strengths, characteristics and social roles (missions) in order to establish a system that encourages voluntary, autonomous improvement and development.

In addition, in order to improve the international compatibility and competitiveness of Japan's higher education, MEXT started the Top Global University Project in fiscal year 2014 and it is providing intensive support to universities making thorough efforts to promote internationalization, such as collaborating with world-leading universities and strengthening systems to develop students' capability to adapt to globalization.

(Toward universities with sustainable competitiveness that create high value added)

In order to enable individual universities to further take advantage of their strengths and unique features during the third medium-term goal period in light of the National University Reform Plan, MEXT formulated the National University Management Strategy in 2015, and under the budget for fiscal year 2016, the first year of the strategy, it introduced a system to intensively allocate management expense grants for national university corporations to national universities making active efforts to strengthen their functions in accordance with the directions of those efforts. Under this system, three new frameworks for intensive support have been established in order to provide meticulous support for efforts to strengthen individual national universities' functions, thereby making prioritized allocations based on the evaluation of efforts.

Intensive support (i)

Mainly support national universities concentrating on efforts to contribute to local communities and efforts to promote global and nationwide education and research in fields where they have strengths and unique features while giving consideration to the nature of fields of specialty.

Intensive support (ii)

Mainly support national universities concentrating on efforts to promote global and nationwide: rather than local, education and research in fields where they have strengths and unique features while giving consideration to the nature of fields of specialty.

Intensive support (iii)

Mainly support national universities concentrating on university-wide efforts to promote outstanding education and research and social implementation in competition with foreign universities producing outstanding results.

In addition, in May 2016, the National University Corporation Act (Act No. 112 of 2003) was amended and the Designated National University Corporation System was established in order to ensure that national university corporations designated by Minister of Education, Culture, Sports, Science and Technology conduct university management based on high-level goals so that world-leading education and research activities can be conducted. In addition, as a measure to promote effective use of national university corporations' assets, the legal amendment eased the regulation of lending of land to third-party persons and somewhat expanded the scope of investments using donation and other own revenues that do not correspond to public funds to include financial products with higher returns. Through these initiatives, MEXT is encouraging national universities to further take advantage of their strengths and unique features and accelerate the national university reform.

Regarding private universities as well, MEXT is securing recurring expense subsidies for private universities, which are basic funds that support their research activity, and is implementing the Private University Research Branding Project in order to promote the enhancement of the functions of private universities advocating individuality on a university-wide basis based on unique research activity under the presidents' leadership. As intensive support for initiatives related to the fostering of young researchers, MEXT intensively supports universities engaging in initiatives to foster young researchers who constitute the core of science and innovation activity and enable them to make successful achievements.

Moreover, regarding graduate school education, in order to strengthen graduate schools' international competitiveness and establish bases for the training of doctorate-level researchers, MEXT compiled the "Basic Concept concerning Doctoral Program for World-leading Innovative & Smart Education (tentative name)" in April 2016. Based on this, in fiscal year 2018, MEXT started the Doctoral Program for World-leading Innovative & Smart Education, under which individual universities take advantage of their strengths to engage in systematic collaboration with external organizations such as top-level foreign universities and private companies and develop five-year doctoral programs that bring together world-leading educational and research capabilities. This program is expected to lead to the establishment of outstanding institutions where training and mingling of personnel and joint research will continuously occur.

(B) Institutional system reforms concerning national research and development agencies that have already been implemented

(Establishment of the independent administrative agency system and the enactment of the Research and Development Capacity Improvement Act)

The independent administrative agency system was introduced as part of the reform of central government ministries and agencies in January 2001 with the aim of improving the results of policy implementation by separating the planning and implementing divisions of administrative organizations and giving corporation status and management discretion to implementing divisions. Former national research institutions, such as NIMS and the National Research Institute for Earth Science and Disaster Resilience, were transformed into independent administrative agencies in 2001, and former government-affiliated corporations, such as RIKEN and the Japan Science & Technology Agency were transformed into independent administrative agencies in 2003-2004.

Later, against the backdrop of the sense of crisis about the intensifying international competition and Japan's declining competitiveness due to the advance of globalization and the rise of emerging countries, the Act on Improving the Capacity, and the Efficient Promotion of Research and Development through Promotion of Research and Development System Reform (Act No. 63 of 2008; hereinafter referred to as the "Research and Development Capacity Improvement") was enacted in June 2008 in order to create innovations by strengthening the research and development capacity of public research institutions, universities and other organizations in Japan.

(Amendment of the Research and Development Capacity Improvement Act and the establishment of the national research and development agency system)

From the viewpoint of further strengthening the research and development capacity, the Research and Development Capacity Improvement Act was amended in 2013 in order to designate the Japan Science & Technology Agency, AIST, and the New Energy and Industrial Technology Development Organization as corporations that can make equity investment.

In 2014, the Act on General Rules for Incorporated Administrative Agencies was amended in order to designate corporations mainly engaging in research and development activity contributing to public interests as national research and development agencies. In order to secure the maximum research and development results, institutional system reforms were implemented, including the introduction of the requirement that opinions should be solicited from a newly established research and development council in order to manage multiyear (medium-to-long term, or five to seven year) goals and to ensure that the evaluation of national research and development agencies and the setting of goals, which require a high level of professional expertise, are consistent with scientific evidence and international standards.

(Establishment of the specific national research and development agency system)

In May 2016, the Act on Special Measures Concerning Promotion of Research and Development, etc. by Specific National Research and Development Agencies (Act No. 43 of 2016) was enacted. Of national research and development agencies, NIMS, RIKEN and AIST were selected as "specific national research and development agencies" that serve as the core organizations that promote the creation, dissemination and utilization of world-leading research and development results and lead innovation. Thus, a legal basis was provided for measures to secure researchers with high international competitiveness and for the provision of consideration to the nature of research and development activity in order to quickly and aptly adapt to significant changes in the domestic and overseas situations and produce world-leading research and development results in an effective manner.

(Major results produced by specific national research and development agencies)

Unlike companies, which conduct research and development based on market principles, and universities, which conduct research based on researchers' free ideas and spirit of inquiry, specific national research and development agencies are expected to continuously produce new concepts that serve as seeds for innovations by producing innovative basic research results based on national strategy even while pursuing the fundamental principles. These agencies as a whole are also strongly expected to conduct research and development activity intended to resolve challenges in an effective manner, produce world-leading research and development results, and act as leaders on the frontlines of science and technology innovation in Japan. Here, we describe major research and development results so far produced by NIMS, RIKEN and AIST, which have been selected as specific national research and development agencies.

1) The National Institute for Materials Science (NIMS): (a) SiAlONs (based on the elements silicon (Si), aluminum (Al), oxygen (O), and nitrogen (N)) had initially been used as heat-resistant ceramics. However, NIMS discovered that SiAlONs doped with a rare-earth element become fluorescent, and succeeded in developing energy-saving, long-lasting, small, and lightweight phosphors with high color-rendering properties, contributing to the global diffusion of light-emitting diode (LED) lighting. (b) For the first time in the world, NIMS developed an odor sensor that is greater than 100 times more sensitive compared to conventional sensors as well as being ultracompact, demonstrated the possibility of diagnosis through breath analysis, and built an international industry-government-academia alliance toward establishing a *de facto* standard for odor analysis and sensor systems.
2) RIKEN: (a) For the first time in the world, RIKEN conducted a clinical study to transplant retinal pigment epithelial (RPE) cells differentiated from induced pluripotent stem cells (iPSCs) into a patient with age-related macular degeneration. This was also the world's first-ever clinical study using iPSCs, and an achievement that will greatly contribute to development of the healthcare field, which constitutes one of the pillars of Japan's economic revitalization strategy. (b) RIKEN acquired the right to name element 113, which it discovered in an experiment to synthesize a superheavy element using a heavy ion linear accelerator and other equipment, and made an achievement of adding the Japan-originated element name "nihonium" and chemical symbol "Nh" to the periodic table.
3) The National Institute of Advanced Industrial Science and Technology (AIST): (a) AIST developed power devices/inverters using a new semiconductor material, silicon carbide (SiC), which can reduce power loss to about 1/200 of the conventional semiconductor material (with an effect of saving energy by 70–90% of the conventional level). (b) AIST jointly conducted research and development of technology to use ammonia through direct combustion with Tohoku University. They succeeded in generating 41.8 kW of power through bifuel combustion of a methane-ammonia gas mixture in a (50 kW-rated) micro gas turbine, and, for the first time in the world, also succeeded in generating power by using only ammonia as fuel.

2-3 Research Funds

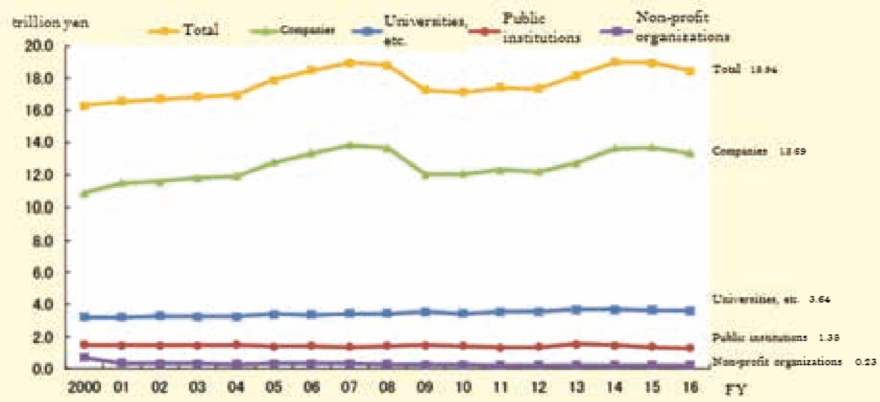
The promotion of science, technology, and innovation (STI) and establishment of Society 5.0 are the keys to Japan’s growth strategy, which aims to achieve a 6 trillion yen economy around 2020. In addition to promoting efforts toward the establishment of Society 5.0, it is also important to expand government R&D investment and thereby induce the expansion private R&D investment, while also increasing joint R&D investment between the two sectors. This section will give figures regarding the total R&D expenditure in Japan and an overview of research funds of private companies that lead innovation activities and those of universities, R&D agencies, etc. that serve as the sources of innovation.

(1) Total R&D Expenditure in Japan

A. Analysis of the Current Situation

As shown in Figure 1-1-26, Japan’s total R&D expenditure has been generally increasing despite some small fluctuations. Among major countries, Japan ranks third after the United States and China in the ranking of national R&D spending. Looking at the breakdown of Japan's R&D expenditure by sector, companies account for approximately 70% and universities account for approximately 20% (Figure 1-1-107).

Figure 1-1-107 Changes in R&D Expenditures in Japan by Sector

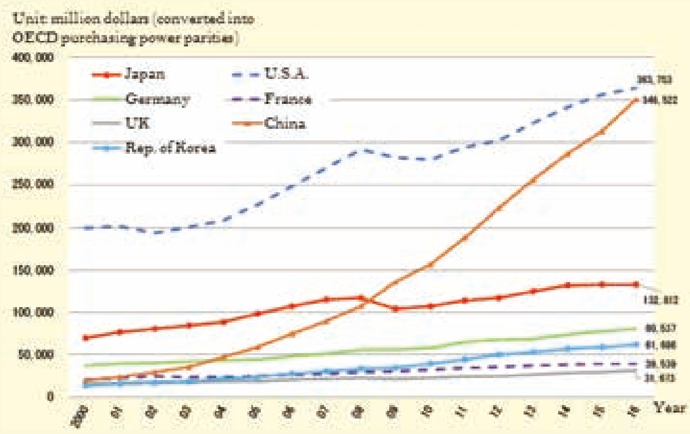


Source: Prepared by MEXT based on the Report on the Survey of Research and Development (MIC)

Looking at companies' R&D expenditures, which account for the majority of national R&D expenditures, Japan ranks third after the United States and China. We can say that R&D activities of Japanese private companies are relatively active compared to other countries. The chart of the changes of R&D expenditures of Japanese companies shows an obvious fall around 2009 following the collapse of Lehman Brothers in 2008. After 2009, however, the figure has been on a recovery trend (Figure 1-1-108). As demonstrated here, private R&D expenditures are greatly influenced by the economic climate. A report has pointed out that R&D expenditures of Japanese companies are heavily focused on R&D projects where commercialization is expected in a short term.[1]

1 According to the report by the Research and Development Group, Industrial Technology Subcommittee, Industrial Structure Council (issued in April 2012), the majority of companies' R&D expenditures are spent on short-term projects which expect commercialization within three years, although there is some disparity among industries. Meanwhile, mid- to long-term R&D projects, which take up to five years until commercialization, account for only 10% of the companies' R&D expenditures.

Figure 1-1-108 Companies' R&D Expenditure in Major Countries



Source: Prepared by MEXT based on Main Science and Technology Indicators 2017/2 (OECD)

B. Identified Issues

Japan has clearly set target amounts of government R&D investment since the issuance of the First Science and Technology Basic Plan. As a result, government R&D investment has increased over the following ten years, supporting the improvement of Japan's research capability, such as the increased number of researchers and the enhancement of intellectual infrastructure. The 5th Science and Technology Basic Plan sets a goal that an amount equivalent to or more than 4% of GDP should be spent on R&D (the private and public sectors combined). It also sets the target government R&D investment amount at 1% of GDP. If the average nominal GDP growth rate during the Plan Period was 3.3%, the total amount of government R&D investment required during this period would be approximately 26 trillion yen.

Since the majority of R&D investment is made by the private sector, it is crucial that the private and public sectors cooperate with each other in promoting STI. Government R&D investment that not only supports the development of intellectual infrastructure as the source of innovation, but also stimulates investment from the private sector that supports innovation under public-private collaboration. Therefore, it is important for Japan to secure adequate government R&D investment toward the goals set forth in the 5th Science and Technology Basic Plan.

C. Measures

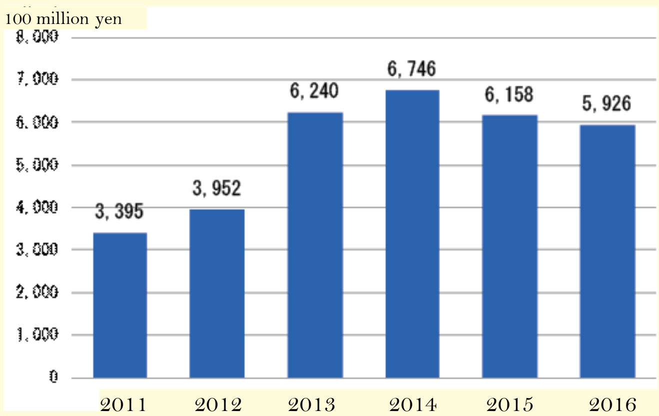
Below are case studies related to research funds.

The Council for Science, Technology and Innovation (CSTI) adopted a strategy titled "Towards Achieving Government R&D Investment Target and Promoting Society 5.0" in April 2017. Based on this strategy, the CSTI has promoted a measure called "STI conversion." This measure aims to "convert" existing government projects into STI-oriented ones through the introduction of advanced technologies and the procurement of goods incorporating advanced technologies. It promotes the social introduction of advanced technologies, while also improving the efficiency and effectiveness of these projects. The ultimate goal is to contribute to economic and social development through full utilization of STI. As part of this effort, for example, the government has conducted demonstration experiments of advanced technologies under some public projects with an eye to their social use. The government has also revised some subsidy programs into STI promotion programs. Of the FY2018 government budget, a total of 191.5 billion yen was allocated to the STI conversion efforts.

In addition, the CSTI also worked toward the launching of the Public/Private R&D Investment Strategic Expansion Program (PRISM) in FY2018. This program aims to encourage government agencies to carry out more projects in the areas that have a high potential of stimulating private R&D investment (target areas). By promoting such projects and providing additional budgets thereto when necessary, this program promotes and drives R&D activities in those areas toward a unified direction.

Moreover, in order to promote R&D investment by private companies, the government has introduced tax credits for experiment and research expenditures (the R&D Promotion Tax System). This system started in 1967 to provide tax credits based on increases in corporate R&D expenditures (increase-based credits) and has been revised constantly since then. Figure 1-1-109 shows the changes in the value of R&D tax credits in recent years. Today, the R&D Promotion Tax System grants three types of tax credits: [1] total amount-based credits, which are granted based on the total amount of R&D expenditures; [2] open innovation credits, which are tax credits for special experiments and research; and [3] ratio-based credits, which are granted when the experiment and research expenditure is equal to or greater than a certain portion of the average sales. Tax credits are granted up to the amount equivalent to 40% of the corporate tax in total (Figure 2-5-2).

Figure 1-1-109 Changes in in the Value of R&D Tax Credits



Note: The breakdown of the figure for FY2016 is as follows: total amount-based tax credits - 511.9 billion yen; open innovation tax credits - 4.2 billion yen; ratio-based tax credits -4.5 billion yen; and increase-based credits (abolished at the end of FY2016) - 64 billion yen.
Source: Prepared by MEXT based on Special Tax Measures Survey Report (MOF).

The total amount-based credits are tax credits granted according to the total amount of experiment and research expenditure. The amount calculated by multiplying the experiment and research expenditure by a rate between 6% and 14%[1] in the case of large companies or between 12% and 17%[2] in the case of SMEs (the ratio is decided based on the increase/decrease in the experiment and research expenditure) can be

1 Rates more than 10% are only applicable until the end of FY2018.
2 Rates more than 12% are only applicable until the end of FY2018.

subducted from the tax amount, to the extent that it does not exceed the amount equivalent to 25% of the corporate tax. However, if the experiment and research expenditure exceeds 10% of the average sales, the upper limit on the amount of tax credits can be raised by up to 10%. Moreover, the upper limit on the amount of tax credits is also raised by up to 10% when an SME's experiment and research expenditure has increased by 5% or more.[1]

Open innovation credits are granted based on the amount of experiment and research expenditure of joint studies carried out in collaboration with universities, national research institutions (including national R&D agencies), etc. and studies outsourced to these institutions. The amount calculated by multiplying the special experiment and research expenditure by 20% or 30%[2] (up to the amount equivalent to 5% of the corporate tax) is subducted from the tax amount (these credits are not granted for experiment and research expenditures to which total amount-based credits have already been granted).

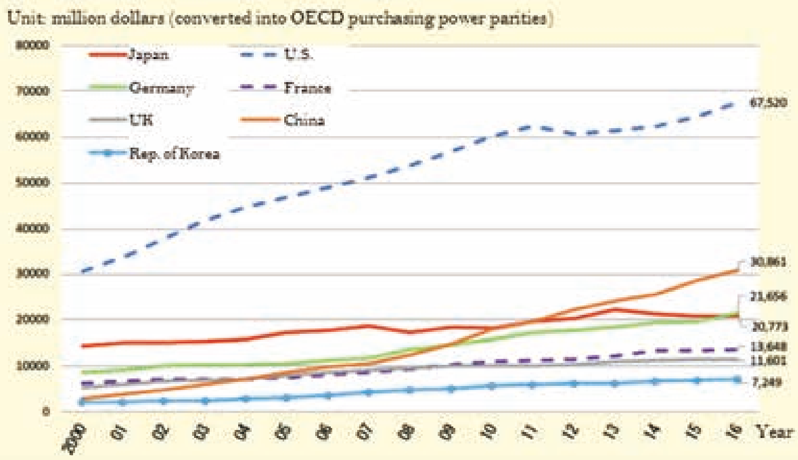
Ratio-based credits are granted when the experiment and research expenditure exceeds the amount equivalent to 10% of the average sales. The amount calculated by multiplying the excess amount by a certain rate is subtracted from the tax amount to the extent that it does not exceed the amount equivalent to 10% of the corporate tax (this is a temporary measure expiring at the end of FY2018).

(2) R&D Expenditure of Universities, National R&D Agencies, etc.

A. Analysis of the Current Situation

Looking at university R&D expenditures in major countries, the United States has maintained a far higher level compared to other countries, as shown in Figure 1-1-110. China overtook the position of Japan in 2011, becoming a country with the second greatest university R&D expenditure. Japan ranked fourth after Germany in 2016.

Figure 1-1-110 Changes in University R&D Expenditures in Major Countries



Source: Prepared by MEXT based on Main Science and Technology Indicators 2017/2 (OECD)

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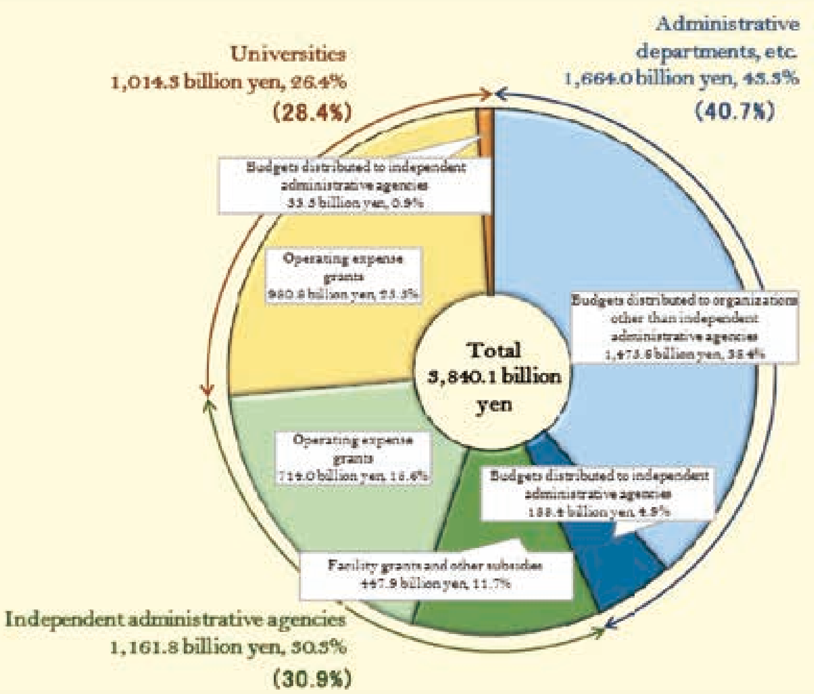
1 This measure to grant the raise of the tax credit limit is only applicable until the end of FY2018. Moreover, this measure cannot be applied when ratio-based credits are granted.

2 If the partner is a university, national research institution, etc., 30%; in other cases, 20%.

Of the science and technology-related national budget in FY2018, approximately 1,014.3 billion yen[1] was spent as subsidies and grants for universities, and 1,161.8 billion yen was spent as subsidies and grants for national R&D agencies and other independent administrative agencies. Some of the operating expense grants for independent administrative agencies and budgets of some departments are distributed to universities and national R&D agencies in the form of public funding (Figure 1-1-111).

Figure 1-1-111 Science and Technology-Related Budget in FY2018 (Breakdown by Institution)



Note: Figures in brackets are the proportions of initial budgets as of FY2017. The amounts are as of April 2018.
Source: Cabinet Office (April 2018)

(A) Basic Research Funds

The mission of national university corporations is to meet the public need for university education and research and to raise the standards and achieve the balanced development of higher education and academic research. They are managed and operated in an independent and autonomous manner. Private universities also contribute to the development of education and research in Japan through unique activities that are conducted in accordance with their individual philosophy. On the other hand, the purpose of national R&D agencies is to raise the standards for science and technology and achieve best possible R&D outcomes, which contribute to public interests. They are defined as the implementing bodies of the government's mission.

Funds that support these corporations' stable and sustainable operation are called basic research funds. Operating expense grants, facility grants, and private university grants are included in this category. Basic

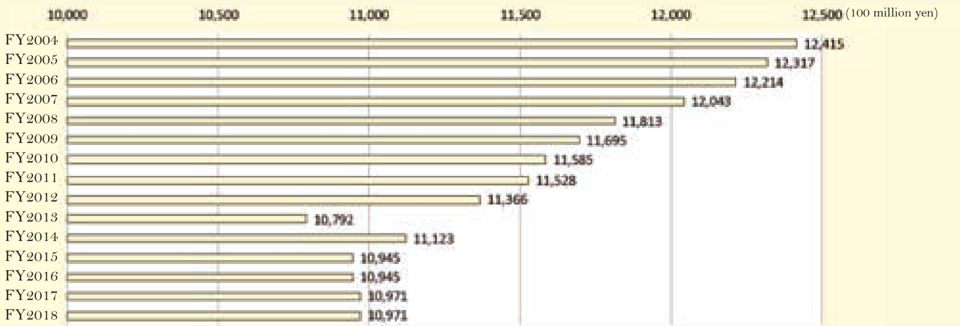
1 University budgets for undergraduate education are not included in this figure. The scope of STI policies toward the establishment of Society 5.0 regarding such budgets is to be discussed.

research funds are spent on labor and maintenance of facilities, which are crucial for the full-fledged implementation of research and education activities.

Looking at the changes in basic research funds by category, operating expense grants for national university corporations have stayed at almost the same level in the past few years, although they had decreased significantly before that since FY2004 (Figure 1-1-112). Current expenditure grants for private universities have also been hovering at the same level in recent years albeit at a lower level compared to FY2004 (Figure 1-1-113). Operating expense grants for national R&D agencies have been on a decreasing trend from the mid- to long-term perspective, but they have slightly recovered since FY2017 (Figure 1-1-114).

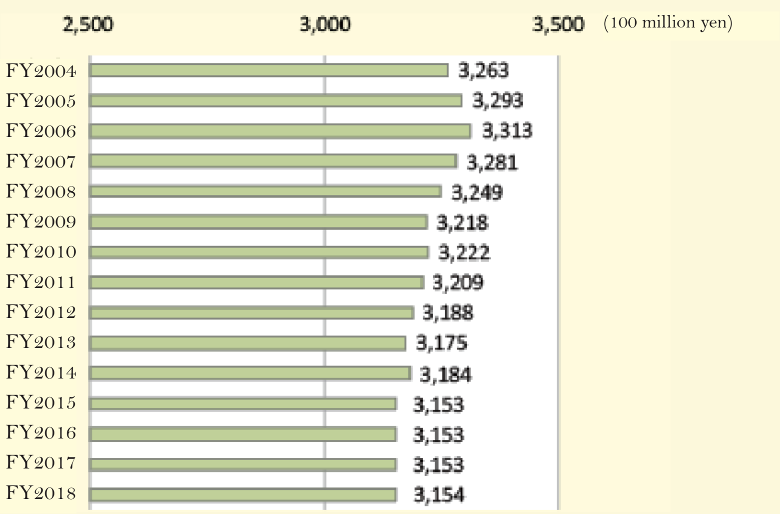
Basic research funds are crucial to the operation of individual corporations and are the core of Japan's fundamental STI capability.

Figure 1-1-112 **Changes in the Budget of National University Corporations, Including Operating Expense Grants**



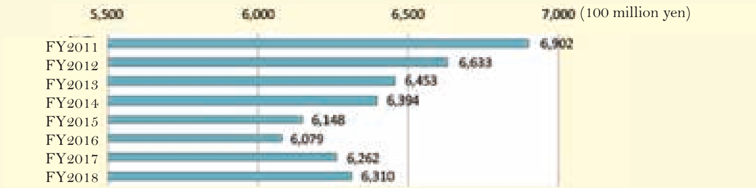
Note: The figures are the initial budget amounts of the general account of individual fiscal years. The budget for FY2017 includes funds to enhance the function of national university corporations (4.5 billion yen). The budget for FY2018 includes funds to enhance the function of national university corporations (8.9 billion yen).
Source: MEXT

Figure 1-1-113 **Changes in the Budget of Private Universities, Including Current Expenditure Grants**



Note: The figures are the initial budget amounts of the general account of individual fiscal years.
Source: MEXT

Figure 1-1-114 Changes in the Budget of National R&D Agencies, Including Operating Expense Grants



Note: The figures are the initial budget amounts of the general account of individual fiscal years. Corporations that have been merged into other corporations were also tabulated.
Source: Prepared by MEXT based on "Explanation of the Budget and the Fiscal Investment and Loan Program" (MOF).

(B) Public Funding for Universities, National R&D Agencies, Etc.

In addition to basic research funds, public funds are also important resources to support STI activities of universities, national R&D agencies, etc. Competitive funds are distributed to outstanding research projects and project with special purposes. Competitive funds, which are a type of public funds, are important in securing the diversity of R&D projects and creating a competitive R&D environment in Japan. Each competitive research fund accepts applications of R&D plans from a wide variety of entities. Projects that passed screening by multiple people including specialists are qualified to receive the funds. The competitive fund system has gone through various enhancement measures, including the securing of funds and systemic improvements and upgrades. Competitive funds are distributed through various programs covering different R&D phases, topics, areas, and policy purposes, from bottom-up type programs to foster the source of innovation to top-down type programs directly promoting contribution of R&D outcomes to the society (Table 1-1-115).

Table 1-1-115 Competitive Fund System

As of April 2018

Ministry	Implemented by	Program	FY 2018 Budget (million yen)
Cabinet Office	Food Safety Commission	Research Program for Risk Assessment Study on Food Safety	183
		Subtotal	183
MIC	MIC	Strategic Information and Communications R&D Promotion Programme (SCOPE)	2,106
		ICT innovation (the "I-Challenge!" program)	255
		R&D of Technologies for Resolving the Digital Divide	50
	Fire and Disaster Management Agency (FDMA)	Promotion Program for Fire- and Disaster-Prevent on Technologies	126
		Subtotal	2,537
MEXT	MEXT/AMED	R&D Promotion for National Issues	23,571
	JSPS	Grants-in-Aid for Scientific Research (KAKENHI)	228,550
	JST	Future Society Creation Program	5,500
	JST	Strategic Basic Research Programs	49,703
	AMED		9,181
	JST	Industry-Academia Collaborative R&D Programs	22,236
	AMED		4,266
	JST	International Collaborative Research Program	2,677
	AMED		844
		Subtotal	346,528
MHLW	MHLW	Health and Labour Sciences Research Grants	4,999
	AMED	Grant Programs of AMED	35,874
	AMED	Grants for promoting hygiene and medical care surveys	7,349
		Subtotal	48,222
MAFF	National Agriculture and Food Research Organization (NARO)	Innovative Research Projects Promotion Program	4,132
		Subtotal	4,132
METI	METI	Project for Strategic Promotion of Advanced Basic Technologies and Collaboration	10,532
		Subtotal	10,532
MLIT	MLIT	Construction Technology Research and Development Subsidy Program	190
		Program to Promote the Technological Development of Transportation	102
		Subtotal	292
Ministry of the Environment (MOE)	MOE/Environmental Restoration and Conservation Agency (ERCA)	Environment Research and Technology Development Fund	5,107
	Nuclear Regulatory Agency	Grants for strategic promotion of research on regulation for radiation safety	344
		Subtotal	5,451
Ministry of Defense (MOD)	Acquisition, Technology & Logistics Agency	Innovative Science & Technology Initiative for Security *The figure is the total value of contracts (total of the spending of the relevant year and the maximum amount of sovereign bonds that can be taken from the following fiscal year onward).	9,820
		Subtotal	9,820
Total (21 projects)			427,697

*Note: Subtotals and totals may not match due to rounding.

Source: Cabinet Office (April 2018)

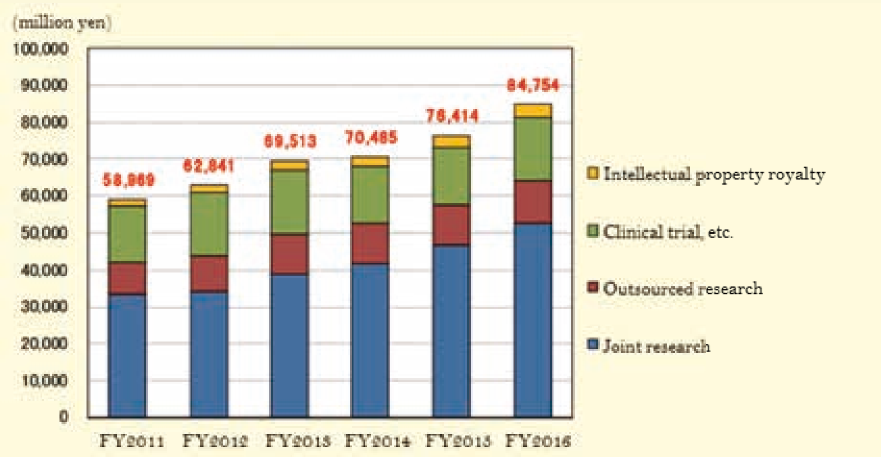
(C) Diversification of Funding Sources for Universities, National R&D Agencies, etc.

In order to reinforce its efforts to encourage universities, national R&D agencies, etc. to obtain external funds, the government announced in Japan Revitalization Strategy 2016 (approved by the Cabinet on June 2, 2016) that it aimed to triple corporate investments in universities, national R&D agencies, etc. from 2014 to 2025. It is important for these entities to procure funds from more diverse sources, such as research projects jointly conducted with or outsourced from private companies, intellectual property royalties, and donations, in order to utilize research outcomes of universities, national R&D agencies, etc. to create innovation as well as to secure enough resources, which will allow these entities to actively take on new R&D projects. In order for these entities to pursue organizational management that is in line with their own vision and strategies with limited operating expense grants, it is important for them to obtain more external funds and donations.

(i) Joint Research

The amount of research funds provided by private companies and received by universities, etc. (income from joint research projects, outsourced research projects, clinical trials, etc. and intellectual property royalties, etc.) has steadily grown in recent years and reached 80 billion yen in FY2016 (Figure 1-1-116). Especially, income from joint research projects with private companies has shown a remarkable growth. While the average income per university-private company joint research project is 2.28 million yen, large-scale projects in which the amount received by universities, etc. exceeds 10 million yen have increased in recent years. The number of projects of that scale implemented in FY2016 was 918 (14.3% increase from the previous year), which totaled to 23.2 billion yen of research funds received (12.2% increase from the previous year). Income from royalties of patent and other intellectual property rights has been also growing in recent years, reaching 3.5 billion yen in FY2016.

Figure 1-1-116 **Changes in Research Funds Provided by Private Companies and Received by Universities, etc.**



Source: Industry-Academia Collaboration Projects Implemented by Universities, Etc. in FY2016 (MEXT) (February 2018)[1]

1 A document reporting the FY2016 results of MEXT's annual survey on industry-academia collaboration projects conducted by universities, etc. across Japan.

The steady growth in research funds provided by private companies and received by universities suggests that universities are now more actively engaged in industry-academia collaboration projects. There have also been some large-scale organization-to-organization industry-academia collaboration projects carried out by companies, universities, and national R&D agencies. The momentum for open innovation is becoming stronger.

Below are examples of leading practices of organization-to-organization industry-academia collaboration.

<Takeda Pharmaceutical Company provides CiRA[1] with 20 billion yen over ten years>

Kyoto University CiRA and Takeda Pharmaceutical Company concluded a joint research contract in April 2015. Under this contract, the company will provide CiRA with 20 billion yen over the following ten years as well as facilities, equipment, the company's researchers, knowhow on R&D of pharmaceuticals, and various other forms of support. This project, which is led by Director of CiRA Shinya Nakayama, is not only supported by Takeda in the form of research funds, which is to be provided over a long term; the company will also advise on the management of the project. Research will be carried out by about a hundred people from Takeda and CiRA using the company's special research assets, including the compound library and research equipment optimized for pharmaceutical development. This collaborative project is expected to strongly promote the research and clinical application of the iPS cell technology, which requires enormous investment of time and labor over an extensive area, working toward the early development of new drugs, cell therapy, and other innovative treatments.

<Chugai Pharmaceutical provides Osaka University IFReC[2] 10 billion yen over ten years>

Osaka University and Chugai Pharmaceutical entered into a comprehensive partnership agreement in May 2016. In exchange for providing a billion yen fund each year over ten years, the company will have access to research outcomes held by IFReC as well as the pre-option for joint research projects between the two parties. They have also jointly established the Collaborative Promotion Laboratory in IFReC as a platform for promoting research activities and interaction of researchers from both sides with a view to building a foundation for successive creation of innovative pharmaceuticals. IFReC also concluded a similar partnership agreement with Otsuka Pharmaceutical in February 2017 to promote open innovation. These contracts allow IFReC to maintain a quality research environment in which individual researchers can engage in basic research planned on their own, while also promoting social use of the outcomes of advanced immunology research. Such industry-academia collaboration, which enables companies to carry out R&D projects in a new way, will reduce barriers between basic research and clinical application research and lead to the creation of innovative drugs in the immunology area.

<Hitachi and Hokkaido launches the Hitachi Hokkaido University Laboratory>

Following the success of the COI[3] Program, Hitachi and Hokkaido University established the

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1　Center for iPS Cell Research and Application

2　Immunology Frontier Research Center

3　Center of Innovation

Hitach-Hokudai Lab in June 2016 to promote further interorganizational industry-academia collaboration. The Hitachi-Hokudai Lab carries out joint research programs that address social issues, such as the low birth rate and aging population, the deterioration of regional economy, and global warming. Specifically, it works on the development of new concept computing technology, which outputs optimal solutions for social challenges based on mathematical models, as well as the analysis of the impact of global warming and environmental changes on economy.

MEXT and JST launched the COI Program in FY2013 aiming to promote full-fledged industry-academia collaboration among companies and universities, etc. to create innovation with great impact that can change society. This Program envisions three goals for Japan after ten years and provides for R&D topics that need to be addressed using the backcasting method. The total amount of financial resources provided by private companies under the COI Program from FY2013 to FY2016 was approximately 18.4 billion yen.

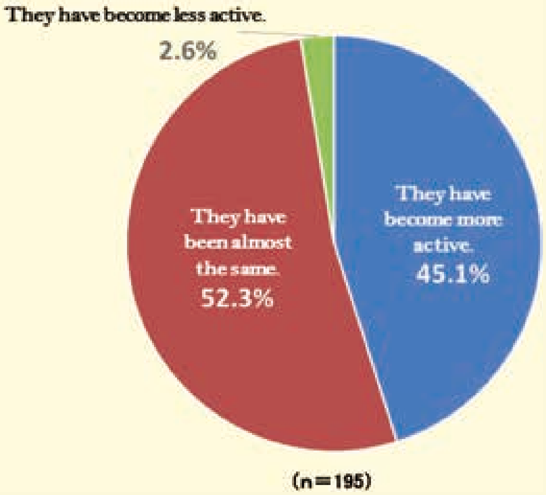
Open innovation is becoming a more important agenda for private companies, as it is becoming more and more difficult for them to create innovation with their resources alone amid intensifying competition and the prevalence of shorter production cycles. METI conducted a questionnaire survey with domestic listed companies on their decision making process and awareness regarding open innovation. To the question asking how their open innovation activities have changed in these ten years, the most common response was "almost the same" (52.3%), followed by "more active" (45.1%) (Figure 1-1-117).

R&D expenditures of private companies in Japan have been on an increasing trend over a long term; however, with their reserve funds reaching a record high, it is hoped that they will further increase their investment in R&D activities to create innovation. It is considered that open innovation will be more common and active into the future, as we see more evidence such as the increase of M&A[1] and companies' heightened awareness.

1 M&A refers to the transfer of control over the management of a company or business for the purpose of optimizing the use of existing management resources. While M&A includes share acquisition, which allows participation in corporate management, mere partnership that does not involve the transfer of assets or liabilities is excluded from the scope of this term. M&A is achieved mainly in the following five ways: [1] merger: two parties combine into one entity based on a merger contract; [2] acquisition: acquisition of more than 50% of shares; [3] transfer of business: transfer of a business consisting of assets, employees, and brands; [4] capital acquisition: acquisition of less than 50% of shares; and [5] expanded investment: the party having a stake in the other party additionally acquires less than 50% of shares.

Figure 1-1-117 Changes in Large Companies' Awareness Toward Open Innovation

How have your open innovation activities changed in the past ten years?



Source: Questionnaire Survey on Corporate Decision Making Process and Awareness Regarding Open Innovation (METI)

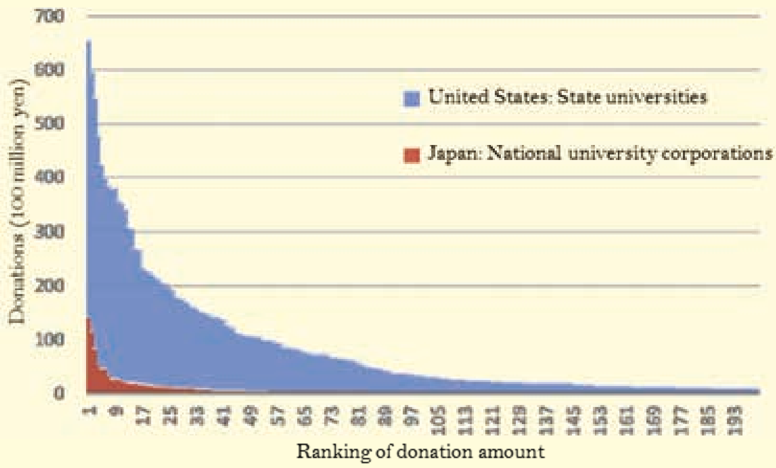
(ii) Acceptance of Donations

According to "Giving Japan 2017[1]," despite the recent growth of the donation market in Japan, the amount of individual donations is still far lower compared to the United States, the United Kingdom, and South Korea. The scarcity of donators and the low donation amount per capita are the factors behind this situation.

While state universities in the United States rely heavily on donations, the proportion of such funds in Japanese national corporations' income is extremely small (Figure 1-1-118). National R&D corporations also receive few donations.

1 Giving Japan 2017 (December 2017) written by the Giving Japan Editorial Team and edited by the Japan Fundraising Association (editing)

Figure 1-1-118 **Amount of Donations Received by Japanese National University Corporations and US State Universities**



Note: Calculated with the exchange rate of 110 yen to the dollar. For the United States, the top 200 state universities are listed. For Japan, all national university corporations (86 corporations) are listed. The figures are based on the financial statements of individual national university corporations in Japan and the FY2016 data provided by the Council for Aid to Education, Voluntary Support of Education in the United States.
Source: Prepared by Fumitake Fukui (Associate Professor at Kamakura Women's University) as a material for the project at the SciREX Center, National Graduate Institute for Policy Studies, titled "Identification of Systemic Issues of Public Research Institutions Promoting the Innovation System and Improvement Measures."

B. Identified Issues

NISTEP conducted a survey on ordinary research funds distributed to researchers in Japan who had been main authors of research papers (external funds acquired by individual researchers and labor costs are excluded; hereinafter referred to as "foundational research funds"). As a result, it was discovered that foundational research funds had decreased from 2000 to 2013 across a wide range of job ranks and positions. At national universities, the median value of such funds had changed from 1.5 million yen to 1 million yen for professors, 0.9 million yen to 0.6 million yen for associate professors, 0.5 million yen to 0.54 million yen for lecturers, and 0.5 million yen to 0.42 million yen for assistant professors (Figure 1-1-119). Many university researchers argue that more foundational research funds are needed.

Table 1-1-119 **Changes in Foundational Research Funds by Job Rank and Position**

Amount of Annual Foundational Research Funds (National Universities, Etc.)

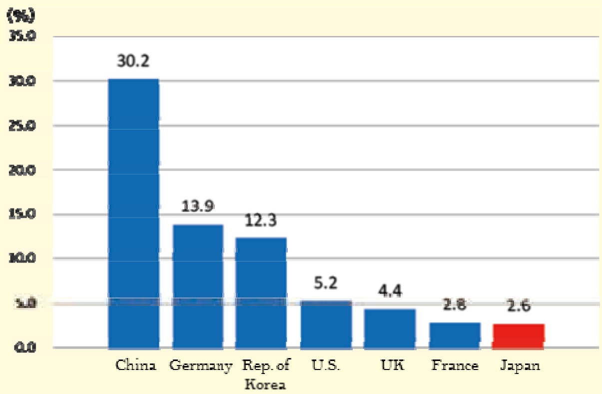
	Median Value (10,000 yen)		
	2000	2005	2013
Professors	150	120	100
Associate professors	90	80	60
Lecturers	50	50	54
Assistant professors	50	540	42
Overall	100	90	80

Note: The respondents are researchers who have been main authors of Japanese research papers published between 2003 and 2012 and belonged to a university or public research institution in 2000, 2005, and 2013. The respondents were first asked their job ranks and positions and whether they had ever received foundational research funds and then asked the amount of such funds.
Source: Funds and Human Resources of Research Activities That Produced Research Papers: Analysis of the Large-Scale Questionnaire Survey on the Main Authors of Research Papers Published from 2004 to 2012 (Survey on Research Papers)" (June 2017)

Meanwhile, for competitive funds, which plays a core role in the diversification of R&D projects and the formation of a competitive research environment in Japan, efforts to achieve the maximum research capability and outcomes and more effective and efficient fund management are required. At the same time, both basic research funds and public funds need to be reformed and used in an optimal combination.

The input of research funds from private companies has been steadily growing in recent years. Today, the situation surrounding innovation is drastically changing with the change of the industrial structure and globalization. Industry's expectations toward universities, etc. are becoming high. On the other hand, the ratio of private funding is still low among Japanese universities, etc. compared to their peers in other countries (Figure 1-1-120), while the average funds for joint research projects among universities and private companies remains as low as 2.28 million yen per project. It has been also pointed out that funding agreements made by Japanese companies with domestic universities are generally lower than the amounts agreed to with overseas universities (Table 1-1-121). There is a need to further promote open innovation through large-scale organization-to-organization joint research projects.

Figure 1-1-120 Ratio of Private Funding in University Research Funds



Source: Prepared by MEXT based on Main Science and Technology Indicators 2017/2 (OECD)

Table 1-1-121 Disparity in Investment Amounts of a Domestic Company between Domestic and Overseas Universities (ratios of contract amounts to the typical amount agreed under a one-off contract with a domestic university)

	Comprehensive partnership	One-off contract
Overseas universities	50-300	10-20
Domestic universities	10-50	1

Source: Prepared by Kazuhito Hashimoto based on the material provided at the second meeting of the Council for the Diversification of Funding Sources for Innovation (material for the Dialogue on Future Creation through Industry-Academia-Government Collaboration 2016).

As explained above, the number of industry-academia collaboration projects and the amount of joint research funds received by universities, etc. have been steadily increasing (Figure 1-1-116). However, the scale of such trend is still far small compared to other countries. There is a need for further efforts to secure more diverse funding sources.

In terms of diversification of funding sources, it is also important to secure donations, etc. as funds to support the foundation of university management. In order to increase donations to R&D activities, it is important to create a donation culture while taking advantage of tax benefits. Efforts of the recipients of donations themselves, i.e. universities, national R&D agencies, etc., are essential in creating a donation culture.

C. Measures

Below are case studies regarding the enhancement of research funds.

The Grants-in-Aid for Scientific Research (Kakenhi) is the only competitive fund for academic research covering all types of research from basic research to application research across all fields from humanities and social science to natural science (research projects planned based on researchers' own ideas). The needs for Kakenhi are becoming stronger due to the deterioration of the university management environment and decrease of foundational research funds distributed to individual researchers. In response to this situation, MEXT has worked on the fundamental reform of the Kakenhi system since FY2015.

In accordance with the principles and processes outlined in the Guidelines for the Implementation of the Kakenhi Reform Plan (issued by MEXT in September 2015; revised in January 2017), MEXT has systemically and comprehensively promoted reform through three measures: [1] the revision of the screening system; [2] the revision of covered research categories and frameworks; and [3] the promotion of more flexible and proper execution of research funds. These measures are also included in the Science and Technology Basic Plan along with the quantitative goal of bringing the proportion of new research projects to 30%.

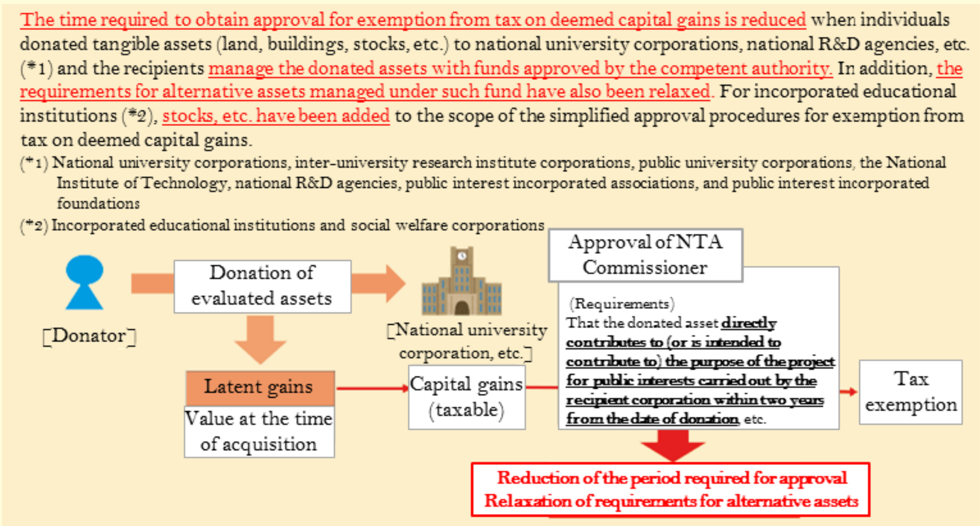
Moreover, the Japan Revitalization Strategy 2016 set a goal to triple companies' investment in universities and national R&D agencies, etc. from 2014 to 2025, with a view to enhancing efforts of these entities to acquire external funds. To promote innovation through industry-academia-government collaboration, MEXT and METI jointly published the Guidelines for the Enhancement of Joint Research through Industry-Academia-Government Collaboration (November 2016) (hereinafter referred to as the "Guidelines"), which described measures to deepen organization-to-organization industry-academia collaboration and specific steps that need to be taken to implement these measures. By identifying issues from the industry's perspective in strengthening the capability of university and national R&D agencies, etc. for industry-academia collaboration and describing measures that can be taken against such issues, the Guidelines showed the direction that these entities should follow in promoting industry-academia-government collaboration projects at their own initiative. The Guidelines also referred to the need for industry's efforts, as this is important in implementing full-fledged joint research to promote reforms on the industry's side concurrently with the reform of universities, national R&D agencies, etc.

As measures to encourage donations, the government has introduced tax benefits for donations to universities, national R&D agencies, etc. Individuals who made donations to such entities are qualified for a tax break, which allows them to deduct the amount calculated by subtracting 2,000 yen from the annual total amount of specified donations (specified donations as provided in Article 78, paragraph (2) of the

Income Tax Act) (up to the amount equivalent to 40% of the annual total income) from the income amount. In addition, individuals who made donations to universities, etc. can also choose to receive another type of tax break, which allows them to deduct the amount equivalent to 40% of the amount calculated by subtracting 2,000 yen from the total amount of specified donations meeting certain criteria (up to 40% of the annual total income) from the income tax amount (up to 25% of the annual income tax). Donations from companies to national university corporations, etc. can be all registered as deductible expenses. Donations to incorporated educational institutions or national R&D agencies can be registered as deductible expenses separately from the general donations, up to the amount calculated by the following formula: 6.25% of the income amount + Capital amount × 0.375% × 1/2.

Furthermore, the donation of tangible assets is eligible for exemption from tax on deemed capital gains if approval of the Commissioner of the National Tax Agency is obtained. The special tax exemption measure was further enhanced with the tax reform in FY2018. Specifically, the time required to obtain tax exemption approval is reduced when it is an individual that donated tangible assets to a national university corporation, etc. and the recipient manages the donated assets with a fund approved by the competent authority. In addition, the requirements for alternative assets managed under such fund have also been relaxed (Figure 1-1-122).

Figure 1-1-122 Relaxation of the Requirements for the Approval of Exemption from Tax on Deemed Capital Gains Regarding Donations of Evaluated Assets to National University Agencies, Etc.



2-4 A Bird's Eye View on the Current Situation and Issues Surrounding Japan's Fundamental STI Capability

So far, the current situation and issues were analyzed with a focus on human resources, intellectual infrastructure, and research funds. This section gives a bird's eye view on the current status and challenges regarding Japan's fundamental STI capability.

The number of research papers in Japan has been decreasing. The country's position in the international ranking of country outputs of research papers has become lower. Japan has also descended in the ranking of the number of cited papers (top 10% correction applied), which is an indicator of the quality of research papers, due to a dramatic increase in the number of research papers from other countries. Moreover, while research projects in highly anticipated areas have been increasing around the world, there is a concern that the number of pioneering projects is rather small in Japan.

On the other hand, looking at the situation concerning intellectual property rights and technology transfer, the number of patent applications has been high, while the number of licenses of universities' patents has been also growing. Moreover, the number of university ventures has shifted to an increasing trend in recent years. Some university ventures have been listed on the market and valued at more than 1 trillion yen. In the case of the COI Program, the total value of the resources provided by private companies, such as research funds and human resources, has reached 18.4 billion yen (from FY2013 to FY2016). Although we fall far behind compared to other countries, full-fledged industry-academia collaboration among universities and companies are making steady progress.

In terms of human resources, there are such issues as the low growth rate of the number of young researchers, poor international mobility, lack of diversity (e.g. female researchers, excellent foreign researchers, etc.), and poor inter-sectoral mobility among the industry, academic, and government sectors. There is a need for the fostering of next-generation researchers, support for career path development for young researchers, and resolution of economic concerns for researchers.

In terms of intellectual infrastructure, the joint use of specified large-scale high technology research facilities and inter-university research institutes has been promoted, which contributed to the achievement of remarkable research outcomes. However, the proportion of faculty staff working hours spent on research has been decreasing. While the number of research support staff has been increasing, it is still remarkably small when compared to other countries. Moreover, comprehensive efforts beyond the boundaries among humanities, social sciences, and natural sciences are also needed in order to promote the social use of science and technology.

In terms of research funds, basic research funds of universities and national R&D agencies, which support the stable and constant implementation of their research activities, have been on a decreasing trend over a long term and have stayed at almost the same level in recent years. On the other hand, companies' awareness regarding open innovation is becoming stronger. It is necessary to secure diverse funding sources, such as joint research expenses, donations, and external funds, while also promoting large-scale organization-to-organization joint research projects through open innovation into the future.

Many of the above challenges can be solved by strengthening organizational management capability. Universities are required to enhance their strategic management capability to address such issues as the inflexible personnel system, aging human resources, and shortage of research funds and time. National R&D agencies, etc. are also required to tackle their systemic issues to enhance their capability to create and foster new ventures.