Chapter 2 Measures to Reinforce the Fundamental Capability for Science, Technology and Innovation

As explained in Chapter 1, there is a need to reinforce the "fundamental capability" for science, technology, and innovation (STI), given the significance of its role in the development of Japan and the world and the changes in the situation surrounding STI. Chapter 1 also gave an overview of international trends in STI and the current situation of STI in Japan and analyzed the current status and identified challenges regarding the three important elements referred to in the Science and Technology Basic Plan: high-quality human resources, intellectual infrastructure, and research funds.

Chapter 2 summarizes topics that are being discussed by government organizations with an eye to reinforcing the fundamental STI capability. It then explains the direction of efforts required of the government, universities, national R&D agencies, and the private sector, bearing in mind the current situation and challenged identified in Chapter 1.

1 Major Topics Being Discussed by Government Organizations

Efforts to reinforce the fundamental STI capability are being discussed by various government organizations, including the Council for Science, Technology and Innovation (CSTI), the Council on Investments for the Future, and the Council for Science and Technology. This section summarizes major topics that are being discussed by these government organizations with an aim to reinforce Japan's fundamental STI capability (high-quality human resources, intellectual infrastructure, and research funds).

(1) Council for Science, Technology and Innovation (CSTI)

CSTI, chaired by Chief Cabinet Secretary, holds Innovation Strategy Coordination Meetings with relevant cabinet members. With a mission to establish Japan as the leader of global innovation, CSTI develops comprehensive innovation strategies, which cover the entire innovation process starting from basic research and ending with putting research outcomes into practical use.

(2) Council on Investments for the Future

The Council on Investments for the Future is a subsidiary organization of the Headquarters for Japan's Economic Revitalization. It holds meetings to develop growth strategies and measures to accelerate structural reforms with a view to increasing investments for the future. To bring about a productivity revolution, the Council has discussed reform measures to drastically enhance universities' management capability, such as reform plans for university compensation management systems to empower young researchers, and a plan to establish universities as innovation centers.

(3) Council on Economic and Fiscal Policy

The Council on Economic and Fiscal Policy revises Japan's innovation policies and discusses measures to fundamentally strengthen the country's innovation capability in order to promote innovation that contributes to the productivity revolution. The Council has discussed measures to improve the working environment for young researchers, such as the expansion of research funds and human resources budgets,

as well as innovation-driven university merger plans, private-sector investment stimulation measures, and measures to promote R&D projects that contribute to the resolution of social issues.

(4) Council for Designing 100-year Life Society

The Council for Designing 100-Year Life Society was established to develop a grand design for the economic and social systems that fit the 100-year life society. The Council has also discussed university reform. It has pointed out that universities should invite external experts into their curriculum development process in order to create flexible curricula which are capable of fulfilling new social needs. It has also advocated the need for a framework to facilitate inter-university collaboration and mergers.

(5) Council for Science and Technology (CST)/Central Council for Education (CSTP)

The Council for Science and Technology (CST), an ad-hoc council of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), has discussed measures to foster and empower STI professionals. In order to specifically study and discuss university personnel systems and career paths for STI professionals, a joint council was established under the Committee on Human Resources, Council for Science and Technology, and the University Working Group, University Subcommittee, Central Council for Education. This joint council discusses measures to address the current challenges and issues, which are identified based on the statistics of students proceeding to doctoral programs and investigations on the career paths of researchers, on the research and employment environment for young researchers, and on the diversity and mobility of research human resources.

(6) Others

The Comprehensive Strategy for Communities, People, and Job Creation (2017 edition) approved by the Cabinet in December 2017 aims to increase the number of industry-academia joint research projects and the quantity of budget allocated to such research projects. It also aims to establish innovation incubation centers for industry-academia-government collaboration, with a view to create a domestic innovation ecosystem that contributes to regional revitalization. Moreover, the Cabinet Office, the Ministry of Internal Affairs and Communications (MIC), MEXT, the Ministry of Health, Labour and Welfare (MHLW), the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of Economy, Trade and Industry (METI), the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), and other relevant government agencies are working together under the direction of the Strategic Council for AI Technology to promote the R&D of AI technology and to accelerate the process to put AI technology into use.

Topics in other areas are also being discussed by various government organizations, including the Strategic Headquarters for Space Policy, the Headquarters for Healthcare Policy, the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society (IT Strategic Headquarters), the Intellectual Property Strategy Headquarters, the Headquarters for Ocean Policy, and the Global Warming Prevention Headquarters.

2 Direction of Future Measures for the Reinforcement of the Fundamental STI Capability

This section explains the direction of possible future measures to reinforce fundamental STI capability, bearing in mind what has been discussed by government organizations, which were explained in the previous section, as well as the current challenges and issues concerning the elements that support STI, which were specified in Chapter 1, namely human resources, intellectual infrastructure, and research funds.

(1) Efforts Required of the Government

In terms of human resources, the government needs to take a strategic approach to the cultivation of young researchers that can take leadership position in the world. It is also necessary to create an environment that allows young researchers to fully exercise their talent, while supporting them in establishing good career paths. More specifically, there is a need to create opportunities for young researchers to build their career while engaging in their research activities in a highly competitive environment. It is also necessary to develop a research environment that allows young researchers to take on creative and innovative research projects.

As for intellectual infrastructure, there is an urgent need to fundamentally reform the basic systems of universities, national R&D agencies, etc. in order to equip them with the capability to achieve their goals, by such means as establishing a personnel system that allows gifted young researchers to fully exercise their talent, securing substantial research funds and time, and promoting organization-to-organization industry-academia collaboration. In addition, from the viewpoint of promoting open science, it is also important to develop and utilize research infrastructure that supports research activities in Japan, such as large-scale high technology research facilities and IT infrastructure, while also improving the current data infrastructure.

In terms of research funds, it is important to secure governmental investment in research and development projects that will contribute to the realization of the Fifth Science and Technology Basic Plan. It is also necessary to promote the reform of basic research funds and publicly solicited research funds for young researchers to carry out creative and innovative research projects. It is also important to use these two types of funds in the most optimal combination. To create a virtuous cycle of knowledge and funds, it is also effective to strengthen the capability to create and develop ventures, while also realizing flexible budget execution and diversification of funds.

The government needs to develop effective measures to support the resolution of the above challenges, bearing in mind the current situation of universities, national R&D agencies, etc., and that of industries surrounding them. To realize Society 5.0, it is necessary to enhance activities of national R&D agencies and other research institutions capable of conducting leading-edge research. Moreover, systemic obstacles need to be addressed by the agencies responsible for the system and other relevant government organizations. Countermeasures for such obstacles should be implemented in a steady manner. Furthermore, it is also necessary to build a platform to discuss issues for which consensus among industry, academia, and government is required.

(2) Efforts Required for Universities, National Research and Development Agencies, and Other Research Institutions

There are high expectations for universities, national R&D agencies, and other research institutions that will lead STI. The diversification of research funds, through securing joint research funds and industry-academia collaboration funds and expanding the scope of accepted contributions, is a necessary measure in order to effectively promote the creation of STIs. Moreover, it has been pointed out that experience in research in overseas countries and international joint research projects contributes to obtaining more significant research outcomes and improving the quality of research papers. Securing international mobility of human resources and maintaining presence in the international brain circulation are very important from the viewpoint of fostering perspectives that contribute to the resolution of social challenges. Collaboration with industry is also effective in equipping researchers with multifaceted perspectives.

In addition, it is important for the abovementioned organizations to reform the personnel and compensation management systems by such means as introducing an annual salary system, while also significantly enhancing their management capability through such efforts as dividing responsibilities for management and those for teaching and research. In order to increase time that can be spent for research, the fostering and strategic utilization of human resources to support research activities, abolition of local rules, reduction of redundant meetings, and improvement of efficiency of administrative work are necessary. Each organization needs to accelerate the reform process for the strategic enhancement of their management capability, including the expansion of external funds through diversification of funding sources, the reform of its personnel management system, and enhancing the mobility and diversity of human resources.

To implement the concept of Society 5.0, it is necessary to actively promote comprehensive efforts beyond the border of the human and social science and natural science, while also fostering high-quality human resources.

(3) Efforts Required of the Private Sector

The private sector plays an important role in enhancing the country's research capability through providing opportunities for doctoral graduates to exercise their talent. It is hoped that this sector will employ and utilize doctoral human resources that meet their needs in a more active manner. Active industry-academia collaboration is an effective way to ensure that such human resources are fostered at universities, etc.

Promoting open innovation and securing R&D investments from companies through deeper organization-to-organization industry-academia collaboration projects will contribute to the creation of a virtuous cycle of knowledge, funds, and human resources and are very important for the constant creation of STI.

(4) Others

While there are roles that the government, universities, national R&D agencies, etc., and the private sector are expected to play respectively, there are also many roles that individual researchers are expected

to play towards the reinforcement of fundamental STI capability. For example, the statistics of doctoral graduates' careers show that the majority is strongly oriented toward academic posts such as teaching positions. It is hoped that they will choose their career paths from more diverse options, including working for private companies. In addition, it is also hoped that individual researchers will take on innovative and creative research projects, while also actively networking with overseas researchers and participating in the international brain circulation.

Meanwhile, the role that the Science Council of Japan needs to play as a leading institution of the community of Japan's scientists is carrying out discussions that contribute to the further enhancement of fundamental STI capability.

Conclusion

More than twenty years have passed since the announcement of the first Science and Technology Basic Plan in 1996. The relevant government organizations have worked together in promoting science and technology policies according to the Basic Plan. As a result, scientific and technological achievements that contribute not only domestically but also globally have been made. Examples of such achievements include the invention of the blue light-emitting diode, which is used for LED lighting, and establishment of human IPS cell lines, which are used in regenerative medicine. Japan has also contributed to the resolution of global challenges, including infectious disease. Japan boasts the second largest number of Nobel prize winners in natural sciences in the twenty-first century. This reflects the world's appreciation of our contribution to the search for truth and the development of human society with our unique ideas. This is achievement that Japanese people should be proud of.

While Japan has made such great achievements, we cannot deny there are various challenges and issues. In March 2017, Nature pointed out that Japan's scientific research has lost its momentum in recent years, referring to the fact that Japan's share in global scientific research papers has dropped. This Nature article, which covered the stagnation of the Japanese scientific research scene that many university and research institution workers must have been aware of, came as a shock not only to researchers, but also to the public.

This year's White Paper examined international trends concerning "fundamental STI capability," analyzed the current status and challenges concerning Japan's research capability in terms of human resources, intellectual infrastructure, and research funds, and presented the direction of efforts that need to be made into the future.

As for the quantity and quality of research papers, Japan is losing its relative superiority to other countries, experiencing a drop in its rank in all research categories. In particular, the number of quotations (top 10% correction applied), which serves as an index of the quality of research papers, has significantly dropped. In the field of patents as well, Japan lost its long-held high position to China in the ranking of the number of PCT applications, descending to the third position. In terms of these aspects, it cannot be denied that Japan's international competitiveness has deteriorated.

In terms of human resources, it has been pointed out that the recent decrease in the number of doctoral students could be attributed to the unreliability of researchers' career path and economic burdens that students must endure while attending the program. It has also been pointed out that limited international mobility of human resources and isolation from the international brain circulation have affected the quality of research papers. To embrace more diverse human resources, including female and foreign researchers, is also another challenge that needs to be addressed. Japan needs to secure high-quality human resources and strongly promote measures to ensure that they can fully exercise their talent.

As for intellectual infrastructure, there are few creative and innovative research projects to pioneer new research fields. Japan has also significantly lagged behind other countries in terms of the diversity of research projects. At universities, the proportion of time spent on research in the total number of working hours has been pressed down by the increase in the load of work other than research in recent years.

While the quantity of research support staff has been increasing, it is still remarkably small when compared to other countries.

In terms of research funds, the amount of basic research funds for universities, national R&D agencies, etc. has been decreasing or flat in recent years. Even though universities are striving to strategically use various funds, the proportion of private investments in university research funds is extremely low compared to their peers in other countries. Since the establishment of the Science and Technology Basic Law, Japan has strived to increase governmental R&D investment toward the goal set in the Science and Technology Basic Plan. As a result, the government's budget allocated to science and technology research has steadily grown. Meanwhile, China's governmental R&D investment budget has increased thirteen-fold in sixteen years. The United States has maintained a high level national budget, while other major countries, including South Korea, Germany, and the U.K., are increasing their budget concerning R&D at a faster pace than Japan.

Our economy and society are going through rapid changes with the diversification and acceleration of innovation processes. In order to effectively address new challenges for which conventional methods and approaches do not work, we need to promote academic and basic research in order to yield excellent knowledge across various fields, which serves as the source of innovations, while also reinforcing "fundamental capabilities," including research funds, to support all research activities. At the same time, we also need to promote the reform and strengthen the function of universities and national R&D agencies, etc. as the leading implementers of STI activities. Moreover, in order to swiftly put STI into use in society, comprehensive measures beyond the border between human and social sciences and natural sciences are needed.

Meanwhile, we are seeing concrete results of the efforts that have been made so far. For example, career path development and diversification for doctoral graduates have been promoted through various JSPS programs, including the Research Fellowship for Young Scientists, the Overseas Research Fellowships, and the Program for Leading Graduate Schools. We should also note that large-scale high technology research facilities, such as SPring-8 and supercomputer Kei, and inter-university research institutes, such as Super-Kamiokande, have achieved globally praised research outcomes as platforms for international joint research and industry-academia collaboration for knowledge creation. In terms of full-fledged organization-to-organization industry-academia collaboration, we are starting to see some large-scale collaboration projects, in such forms as comprehensive collaboration contracts among universities and pharmaceutical companies, in which the parties jointly use human resources, technology, knowhow, funds, and other resources. Moreover, against the background of intensifying global competition, we have seen the rise of open innovation. It is hoped that companies, universities and R&D agencies, etc. will further strengthen their collaborative relationships by tapping into their own strengths.

It is also necessary to develop an environment in which ambitious researchers can take on new research projects. To this end, it is required to build an understanding among researchers, universities, R&D agencies, the government, industry, and the public to the effect that it is important to pioneer new research fields without fearing failure, that projects that were unsuccessful in yielding expected outcomes should be fairly evaluated, and that all failures contribute to research projects carried out later.

In order for Japan to survive this era of great change and to envision a growth strategy toward the goal

of a 600 trillion yen GDP, it needs to establish an ecosystem for the accelerated creation and sustainable circulation of STI.

If Japan is to maintain its international presence as the front runner of science and technology and keep creating research outcomes that are worth Nobel Prizes or international attention, we need to be aware of the urgent need for various reforms and gain concrete results from such reforms in a speedy manner. In order to strongly promote STI, which is the core element for the country's economic growth and well-being, it is necessary to reinforce the fundamental STI capability, including high-quality human resources, intellectual infrastructure, and research funds.