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Science, Technology and Innovation Policy Utilizing Industry-Academia Collaboration in Japan.

日本の産学連携を活用した科学技術・イノベーション政策.

2020/06

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目次

概要
科学研究は新たな知識を生み出すプロセスであり、産業に展開してイノベーションを創出することで経済成長のエンジンとなる。日本では 1995 年に科学技術基本法が成立し、大学での研究から産業化までを視野に入れたイノベーション政策を打ち出す体制へと変わった。
本稿では、1995 年の科学技術基本法から、第 5 期科学技術基本計画までのイノベーション創出に向けた政策を概観し、NISTEP 科学技術指標 2019(NISTEP, 2019)や科学技術白書(MEXT, 2019)のデータから日本のイノベーションを取り巻く環境の分析を行った。大学と企業の共同研究予算や大学発ベンチャーの創業数には増加傾向が見られる一方で、高被引用論文数の世界シェアは低下傾向にある。大学における研究環境・資源の改善が課題であることが明らかとなった。
実用化・商品化を意識して直近の課題解決に役立つ研究だけを推奨する産学連携では、長期的に多様な知識が蓄積されなくなり、イノベーション創出を妨げる要因にもなりうる。第 5 期科学技術基本計画において Society 5.0 の概念が示されたことは、直近の課題ではなく未来のビジョンと研究開発の方向性を示すことで、イノベーションに対する政策のスタンスを変える取組みと考えられる。

Abstract

Scientific research is a process that generates new knowledge, which can be deployed in the industry to create innovation and become an engine of economic growth. In Japan, the Basic Law on Science and Technology was enacted in 1995, and the system was transformed to create an innovation policy with a view to everything from university research to industrialization.

This paper outlines the policies for innovation creation from the 1995 Basic Law on Science and Technology to the 5th Science and Technology Basic Plan, and analyzes the environment surrounding innovation in Japan from data from the NISTEP Science and Technology Indicators 2019 (NISTEP, 2019) and the White Paper on Science and Technology (MEXT, 2019). While there is an upward trend in the joint research budgets of universities and companies and also the number of university-launched ventures, the global share of the number of highly cited papers is on the decline. Improving the research environment and resources in universities was identified as a challenge.

If industry-academia collaboration encourages only research that is useful for solving immediate problems with an awareness of practical application and commercialization, a variety of knowledge will not be accumulated in the long term, and this may be a factor that hinders the creation of innovation. The presentation of the Society 5.0 concept in the 5th Science and Technology Basic Plan can be seen as an effort to change the policy stance on innovation by presenting a vision of the future and the direction of research and development rather than the immediate issues.

1. Introduction

Scientific research is a process of generating new knowledge, and it functions as an engine of economic growth by expanding into industries and creating innovation. Japan has been the world's second-largest recipient of the Nobel Prize in natural sciences since 2001 (MEXT, 2018), and has a significant global presence in science and technology. On the other hand, looking at the trend of papers as a result of scientific research, Japan's ranking in the number of papers and citations started declining 10 years ago (NISTEP, 2019), thus it can be said that Japan is currently in a critical situation where its fundamental ability to lead innovation is weakening.

In Japan, the birthrate has been decreasing along with the aging of the population, and according to a basic school survey by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the 18-year-old population who was supposed to receive higher education peaked at 2.05 million in 1992 and decreased to 1.17 million in 2019. At the same time, the aging of society has been remarkable, and the burden of social security costs such as medical care and pensions is increasing rapidly. In order to maintain social security and grow the economy while the working-age population is decreasing, it is essential to create innovation and increase productivity.

The Science, Technology and Innovation Policy has been providing incentives to create innovation by deregulating universities and public research institutes so that they can cooperate with companies, and by incorporating public support mechanisms. Competitive funding[1] for solving specific problems, which has been heavily used in recent years, has less duplication of themes compared to free researcher-initiated studies and leads to more efficient budget allocation. In addition, setting specific targets will increase the motivation of the industry and increase corporate commitment. However, although such a policy can be expected to contribute to the economy in the short-term, it also has the aspect that only the knowledge of specific fields that can be easily applied to industries may be given preferential treatment. If the types of knowledge output by universities continue to be largely biased, there is a concern that the diversity of knowledge accumulated at universities will be lost, and that research capability will decline over time. Therefore, in a situation where the basic costs of universities have been reduced and their reliance on competitive funding has increased, a policy that balances long-term perspectives is needed. The concept of Society 5.0, which is taken up in the 5th Science and Technology Basic Plan, is considered to be an effort to change the policy on innovation by setting a theme that has a future vision rather than focusing on the latest issues.

This paper summarizes the changes in the environment and policies surrounding universities in recent years, as well as policy-related efforts to create innovation since the enactment of the Science and Technology Basic Plan. It then reviews and

[1] For example, the Cabinet Office's Innovative Research and Development Promotion Program (ImPACT), Japan Science and Technology Agency (JST) CREST, PRESTO, etc.

discusses the current achievements of science, technology and innovation in Japan, and the efforts of the 5th Science and Technology Basic Plan.

2. The role of universities in creating scientific and technological innovation

Universities are expected to have an educational function to train highly specialized human resources as institutions of higher education, as well as a research function to create cutting-edge knowledge. If universities can create more cutting-edge, original knowledge and use that knowledge to innovate industries, it would lead to economic growth (Mansfield, 1991; 1998). Therefore, it is an important mission from a long-term economic viewpoint to foster excellent human resources who have acquired specialized knowledge and education, and send them out into society.

If a company's proprietary technology can provide products that meet customer needs, that technology can be a source of competitive advantage (Barney, 1991). However, even if a company has the technology to continue to provide innovative products, if it becomes short-sighted to only recognize the needs of existing customers and fails to search for new technologies in time, existing technology will be driven out by new technologies that have newly entered the market (Christensen, 1997). In addition, advanced science and technology are becoming more fragmented (Adams, 2005; Wuchty, 2007), and it is not realistic for companies to create new knowledge and technology only in-house. For this reason, open innovation, in which companies exchange knowledge with the outside to create innovation, has become important (Chesbrough, 2003; Chesbrough and Appleyard, 2007). For companies, it is also effective to use the advanced knowledge generated at universities to develop unique technologies that lead to innovation (Agrawal and Henderson, 2002; Cohen, Nelson and Walsh, 2002). Among others, star scientists with outstanding academic achievements have contributed to improving corporate performance not only through their own research, but also by undertaking collaborative research with start-up companies (Zucker, Darby and Brewer, 1994; Zucker and Darby, 2001; Zucker, Darby and Armstrong, 2002). Moreover, there is a virtuous cycle in which the improvement of corporate performance has given good feedback to star scientists and increasing their number of papers (Zucker and Darby, 2007). Hence, it is very important for companies to make effective use of the knowledge created at universities and to create innovation.

While it is important to create cutting-edge knowledge at universities, scientifically discovered, invented, and created knowledge itself is a non-exclusive, non-competitive public asset. Leaving investments in science and technology to market decisions results in under-investment due to the emergence of free riders (Nelson, 1959; Arrow, 1962). Therefore, past science and technology policies have focused on creating technological innovations through public investments and avoiding market failures, while also implementing measures to foster domestic industries that contribute to economic growth. However, there may not always be a clear division of roles, such as with a linear model, in which universities do basic research, and companies do applied research and developmental research. Universities and companies need to work together to make innovations while interacting in a chain model (Leonard-Barton, 1988). Therefore, in recent years, science, technology and innovation policy have been formulated to cover the entire process from the creation of new knowledge, its transfer to industries and its social application. Consequently, the government should promote a comprehensive policy to make public investments that create scientific knowledge, give appropriate incentives to universities and companies to utilize the results, and encourage the creation of large numbers of innovations in society as a whole. In this paper, to answer the question of how Japan's science, technology and innovation policy should address the above issues in the future, we review how it attempted to make innovations in the past, look at past and present measures, and then review the current science, technology and innovation policy.

The most common way to create innovation by using knowledge from universities is to transfer that knowledge to companies and implement it in society. Knowledge transfer pathways may be classified into three types according to the degree to which researchers are committed to innovation. The first pathway is where companies gain knowledge from papers and patents filed by researchers. Researchers publish the scientific knowledge they have created in papers and the technology they have invented in the form of patents. Companies have voluntary access to the published literature to acquire this scientific and technological knowledge, and create innovation. Since the number of articles authored is a major indicator for the promotion of university researchers, they often publish their results as a paper. The papers and patents written by these researchers are important sources of knowledge for company researchers (Agrawal and Henderson, 2002; Cohen, Nelson and Walsh, 2002). The second pathway is where researchers transfer their knowledge directly to companies through collaborative research with those companies. Among the new knowledge created by research, there is tacit knowledge such as work know-how that cannot be translated into language. This knowledge is "sticky" and cannot be easily communicated to others (von Hippel, 1994). Long-term, close communication with researchers increases the possibility that tacit knowledge which is difficult to verbalize will be transferred to companies (Zucker and Darby, 2001; Zucker, Darby and Armstrong, 2002). Companies can also enter into contracts that monopolize the innovations that emerge from collaborative research. The third pathway is where researchers themselves start-up companies as entrepreneurs, and use the knowledge gained through their research to create innovation.

To realize innovation stemming from cutting-edge knowledge created by universities and public research institutions in this manner, in addition to enriching university research and creating new knowledge, there is a need to expand the routes for transferring this knowledge to industries.

Looking back on Japan's Science, Technology and Innovation Policy, the turning point was in 1995. That year, the Basic Law for Science and Technology was enacted and the Council for Science, Technology and Innovation, chaired by the Prime Minister, was launched. It stipulated that a basic policy for science and technology, which is the general national policy for innovation, be formulated every 5 years. Unlike the previous era when the ministries and agencies in charge issued its policies, Japan changed to a new system in which there is a unified, national plan for innovation. The proposal for the Basic Law for Science and Technology stated: "Innovative, advanced science and technology will be developed in order to create new industries". The Science and Technology Basic Plan stipulated not only that basic research in universities is promoted, but also that products and services that applied that knowledge obtained through research be released. Thus, in 1995, Japan made the move to put together a consistent policy of innovation from R&D to market development.

In 1998, the Law on the Promotion of Technology Transfer and Universities was enacted to eliminate barriers in the system to transfer the knowledge and technology created at universities to companies, and to promote its transfer and application to industries. This made it possible to patent the achievements of university researchers and establish a Technology Licensing Organization (TLO), which is a corporation that transfers technology to companies. By matching the technology "seeds" created by universities with the business needs of companies, the specialist staff of TLO encourages the use of patents, as well as collaborative and contractual research. This legislation allowed universities to procure external funding other than the national budget, and companies also to be connected to innovation, so it was hoped that each would benefit the other economically.

Subsequently, in 1999, the Japanese version of the Bayh-Dole system was implemented under Article 30 of the Special Measures for Industrial Revitalization (Koide et al, 2018). Even if researchers make inventions in a government program, if they do not gain the right to the invention, they will lose incentive and this will not be conducive to innovation. Thus, as with the Bayh-Dole Act, which had been introduced in the United States in 1980, it was now possible to attribute intellectual property rights arising from government-funded research and development to the trustee. However, at that time, national universities did not have corporate status, and the rights to inventions created at national universities were attributed to the state or an individual. In order for universities to hold and manage patents, it was necessary to wait for the incorporation of the universities in 2004 (Takahashi et al., 2018), which will be described later. This legislation provided incentives for university researchers and companies to actively use government-sponsored research themes. Then, in 2007, the Japanese version of the Bayh-Dole system, the Ordinance for Enforcement of the Act on Special Measures concerning Industrial Revitalization, an act on special measures, became the Industrial Technology Enhancement Act, Article 19, which was a perpetual law (Koide et al, 2018). In this way, deregulation was being pursued with the aim of promoting innovation by encouraging companies to use the knowledge gained at national universities and government funds.

To further enrich the path to innovation, the government decided to support the establishment of start-up companies. The knowledge gained through research is not just formal linguistic knowledge, but rather, a combination of formal knowledge and tacit knowledge. It was therefore feared that it would not be efficiently transferred to partner companies. It was moreover highly likely that existing companies would not be able to correctly evaluate the future potential of creative knowledge, and that companies that could act as partners to assist industrial expansion would not materialize. Therefore, it was hoped that researchers who gained such tacit knowledge would themselves become entrepreneurs, start-up university-based start-up companies, and innovate. In 2001, Takeo Hiranuma, the then Minister of Economy, Trade and Industry, proposed the Hiranuma Plan, which featured a policy of launching 1,000 startups from universities. As part of this policy, it was aimed to increase the number of patent applications from universities by 10 times in 10 years, and increase the number of university start-up companies to 1000 in 3 years by aggressively introducing competition into university research, promoting administrative reform of the universities, and formulating a strategy for technology transfer from academia to industry. Support was also given to found, finance and develop the human resources of start-up companies. Later, in January 2014, it became possible for national universities to invest in approved venture capital companies under the Industrial Competitiveness Enhancement Act. An environment was thereby created in which universities provide start-up companies with not only technical consultation and support personnel, but also an investment and management support.

Although in Japan, the way has now been paved for companies to use the research results produced by university researchers to innovate, the rigid governance of national universities has been an obstacle. Since Japanese national universities were considered to be internal organs of MEXT, there were significant restrictions on how to use the budget, the inability to make organizational changes, and the fact that the salaries of employees were determined uniformly as public servants. To solve these problems, a law was enacted in 2004 to make national universities independent of the state. With the incorporation of national universities, the country is no longer in direct control, and a corporate management approach under the leadership of the university president has now been adopted, thus allowing strategic personnel and budget allocation decisions. Due to the financial constraints of the Japanese government, it has been decided that operating expense subsidies allocated to national universities as basic budgets will continue to be reduced by about 1% every year. As a result, universities have been forced to increase external research funding, such as competitive research funds like KAKENHI and collaborative research with companies. Through the incorporation of national universities, each national university will hone its unique strengths in a competitive environment with other universities, raise external funding to achieve research results and attract more talented people, thereby leading to future innovations.

In Japan, collaborative research between universities and companies was conducted at the discretion of the university faculty, not in a formal way involving a contract, and the company paid scholarship donations to the university in return for compensation (Florida & Cohen, 1999; Saito & Maki, 2017). In the era when Japanese national universities had no corporate status, universities could not hold and manage intellectual property rights. The university wrote a paper on the results of collaborative research, and a company was assigned to apply for a patent. Later, the deregulation and reform of university corporations by the Japanese government urged formal business-academia collaboration in Japan, just as in the United States, where the Bayh-Dole Act was enacted earlier. Universities and companies began to exchange contracts when conducting collaborative research, and clarified where research expenses and intellectual property belonged. With the option for researchers to obtain patents, the knowledge gained through research can now be transferred to a wide range of companies through the TLO, and this has increased the potential for innovation.

3. Status of Science, Technology and Innovation in Japan

Figure 1 shows the trend of R&D expenditure in the entire country, including companies and universities. R&D expenditure in Japan declined after peaking in 2008 but has since leveled off. China's R&D expenditure is the fastest-growing, surpassing Japan in 2009 to rank second in the world. R&D expenditure in the US, Germany and Korea is also on the rise.

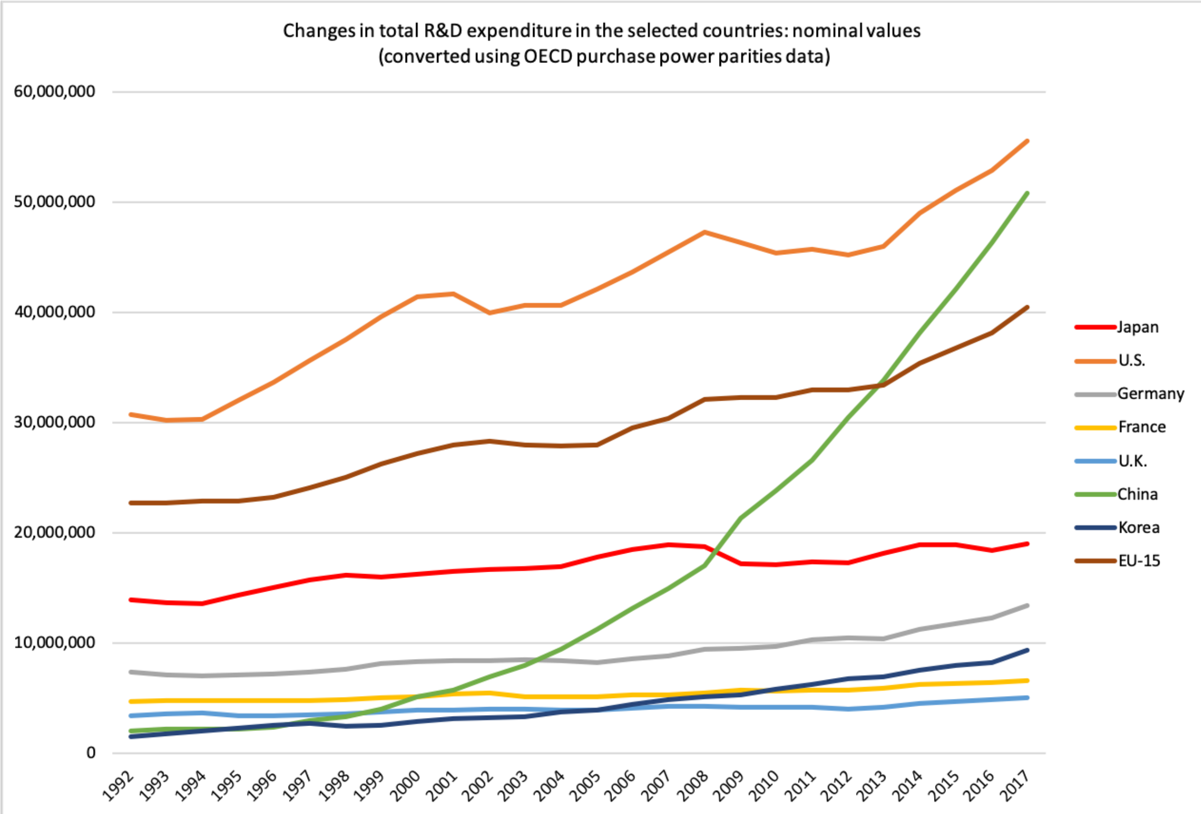

Figure 1. Changes in total R&D expenditure in selected countries: nominal values (converted using OECD purchase power parities data)
Units: million yen
Source: Based on MEXT NISTEP, “Japanese Science and Technology Indicators 2019", NISTEP RESEARCH MATERIAL No. 283, created by the author.

Figure 2 shows the transition of the science and technology budget expended by the Japanese government. It had been increasing until 2001, but had stayed the same since 2002 without any significant change. In FY2018, it increased to ￥3,840 billion.

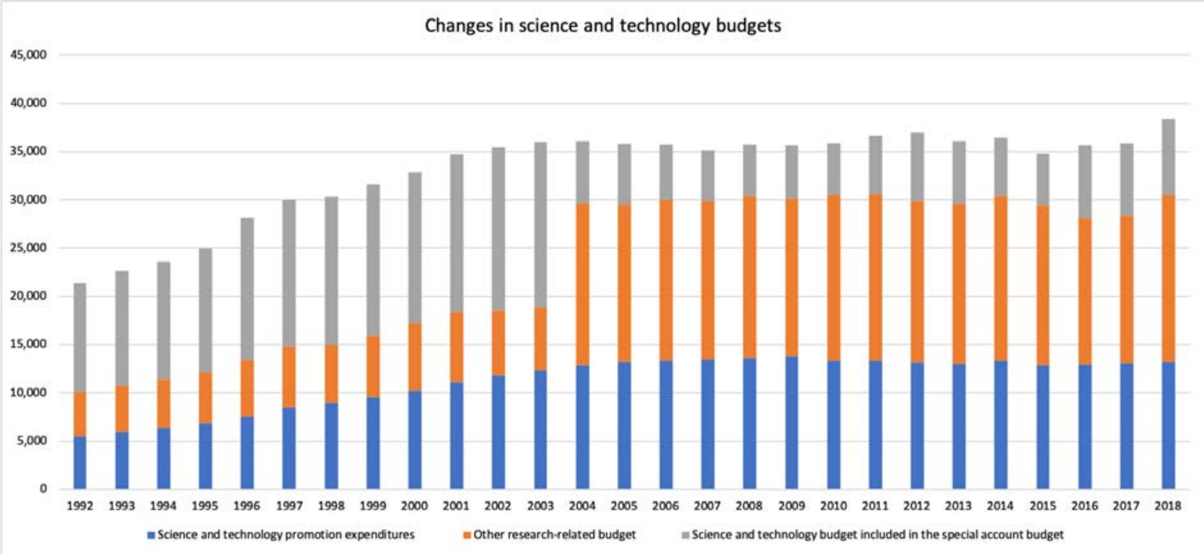

Figure 2. Changes in the science and technology budget
Source: Based on MEXT, "White Paper on Science and Technology", created by the author.
Units: 100 million yen

Research results are mainly published as papers, and those that are frequently cited by other papers may be regarded as high-quality papers that have attracted attention. Therefore, the number of top 10% highly cited papers is an indicator that reflects the research ability of the country to publish high-quality papers. Figure 3 shows the number of top 10% highly cited papers. The results were averaged for each of three periods (1995 to 1997, 2005 to 2007, and 2015 to 2017) to compare the changes in the number of papers in each country.

The United States, the United Kingdom, Germany, and France have steadily increased their number of high-quality papers, and during this period, China came world second. South Korea is also rapidly increasing the number of papers, but only Japan was unable to increase its number of papers, and is in a state of sluggishness.

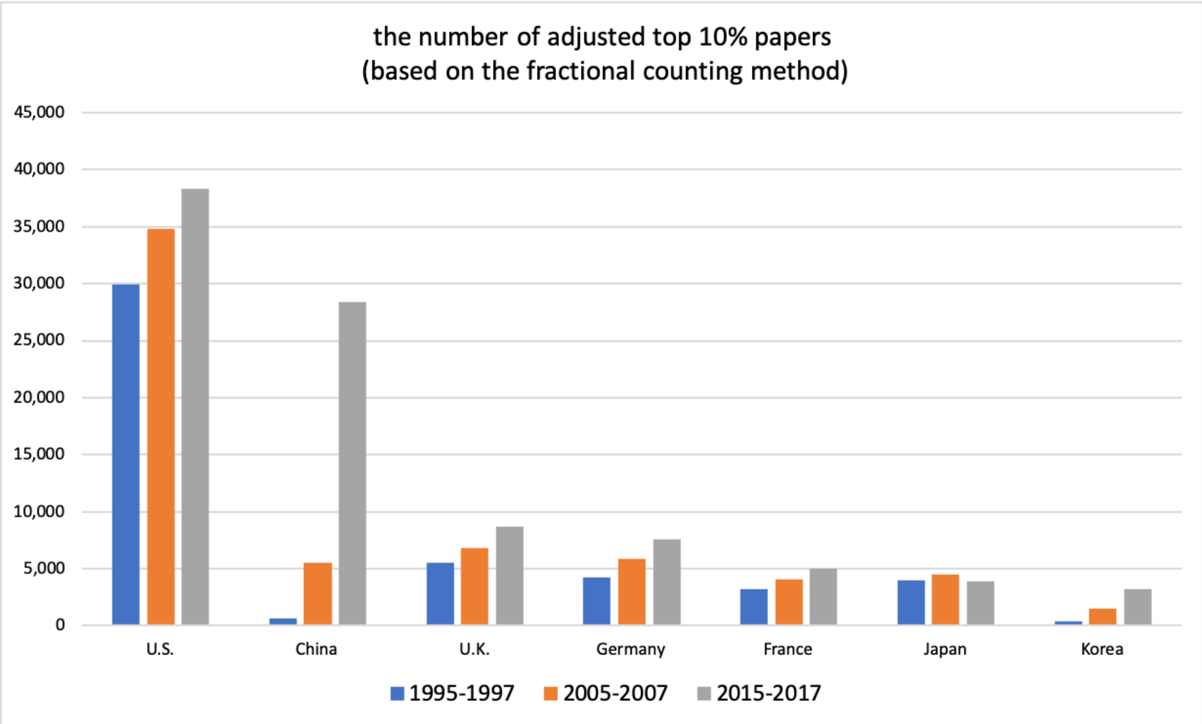

Figure 3. Adjusted top 10% number of papers (based on the fractional counting method)
Units: No.
Source: Based on MEXT NISTEP, "Japanese Science and Technology Indicators 2019", NISTEP RESEARCH MATERIAL No. 283, created by the author.

The subsidy for operating expenses, the basic fund distributed to national universities, has been decreasing every year since its incorporation in 2004. The Ministry of Finance recommended that "national universities need to encourage the input of private funds, and to strengthen their ability to manage with their own profits rather than relying on national expenditure (subsidies for operating expenses)". Therefore, national universities are also required to obtain research funds from outside. For this reason, national universities have been trying to obtain external research funds, such as competitive funds and collaborative research with companies. Universities are responding to the needs of external stakeholders and changing to a financial structure where they finance their own research by addressing attractive research projects.

The deregulation policies that promote industry-academia collaboration such as the establishment of TLO, the development of the Japanese version of the Bayh-Dole Act, and the incorporation of national universities, have stimulated collaborative research between universities and companies. Figure 4 shows the trend of research funds received from the private sector. The research funding that universities received from companies was ￥50 billion in 2005, but started to increase from 2014 and reached ￥107 billion in 2018. The government has indicated that it will continue to strengthen collaborative research between universities and companies. At present, collaborative research expenses per project are small (around ￥1 million) compared to overseas universities, and it is conjectured that the themes handled by collaborative research are limited. For small-budget research projects, researchers at universities and companies have limited opportunities to exchange opinions, and there is concern that less knowledge will be transferred from universities to companies. Therefore, in order to enable high-density human exchange and capital investments, it is recommended to close large projects with more than ￥10 million per project. Looking at the trends in the number of collaborative research projects, there is a trend that while the number of low-priced projects is increasing, the number of contracts for large projects of ¥10 million or more is now also increasing.

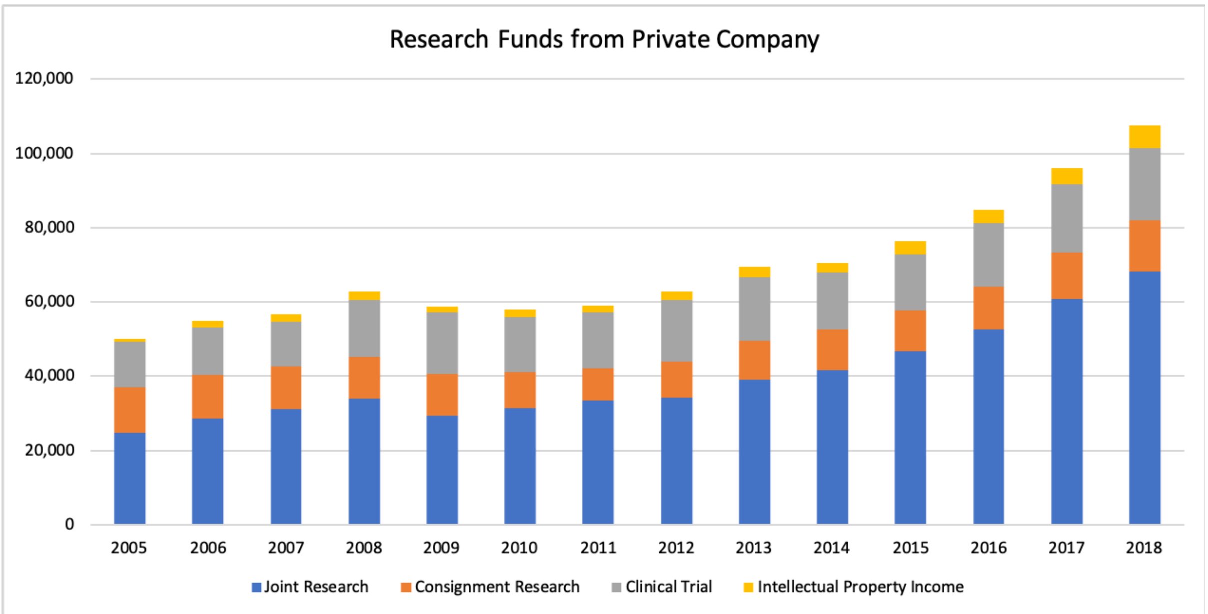

Figure 4. Research funds from private companies
Units: million yen
Source: Based on MEXT, "White Paper on Science and Technology", created by the author.

Figure 5 shows the trend in the number of university startups. From the time the Hiranuma Plan was launched in 2001, until 2005, start-up companies were rapidly established. After that, the number of founders dropped sharply in the wake of the 2008 Lehman Shock. Around 2014, when university venture capital emerged, it started to rise again, suggesting that start-ups have become active.

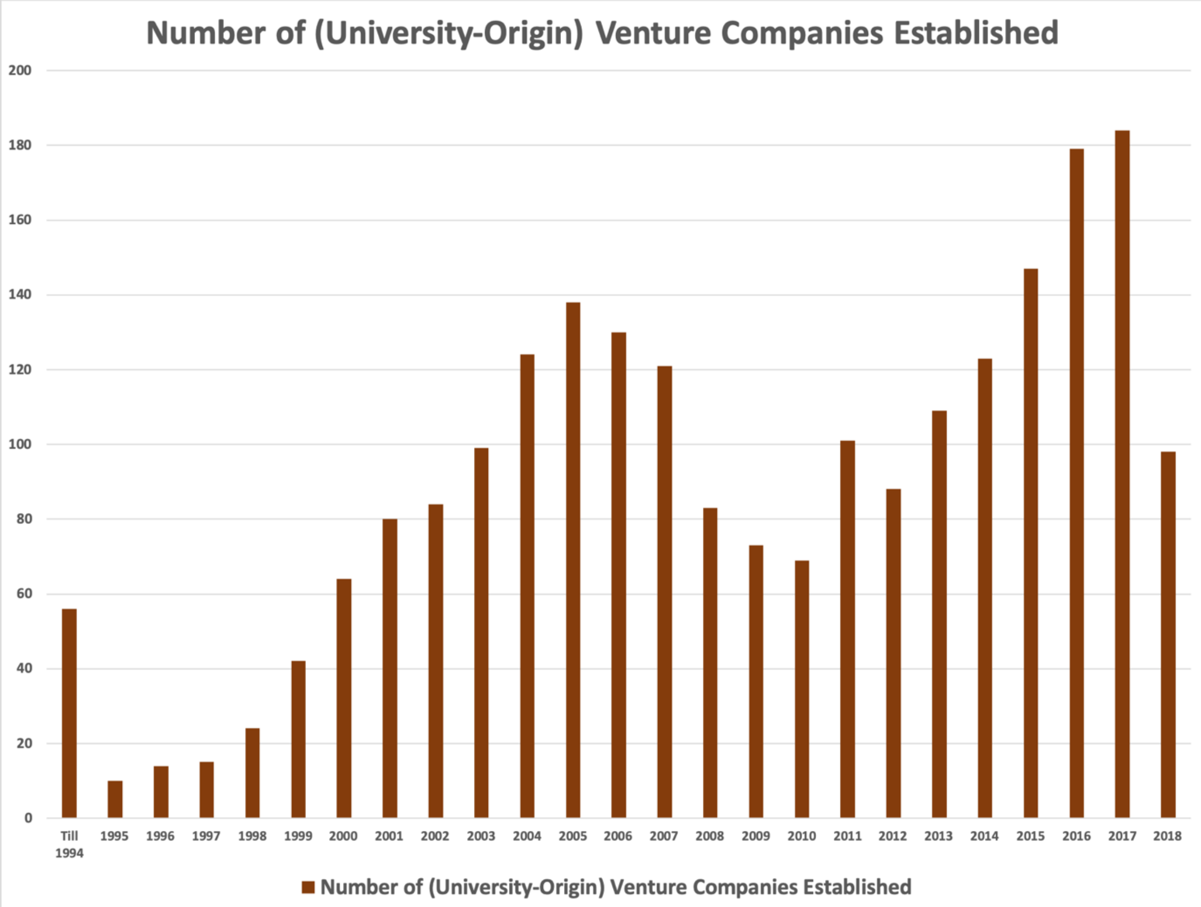

Figure 5. Number of university start-up companies established
Units: No.
Source: Based on METI, "FY2018 University start-up survey results", created by the author.

With the advent of TLO, the environment for acquiring patents from university research has improved, and since 2005, around 7,000 patents have been applied for each year. Revenues from intellectual property rights exceed ￥3.5 billion, but their share in the total university budget remains small.

Looking at the share of the number of patent families (all technical fields, 3-year moving average) shown in Figure 6, Japan maintains the top position in the world, and from the patent aspect, it can be seen that the R&D of Japanese companies is very active.

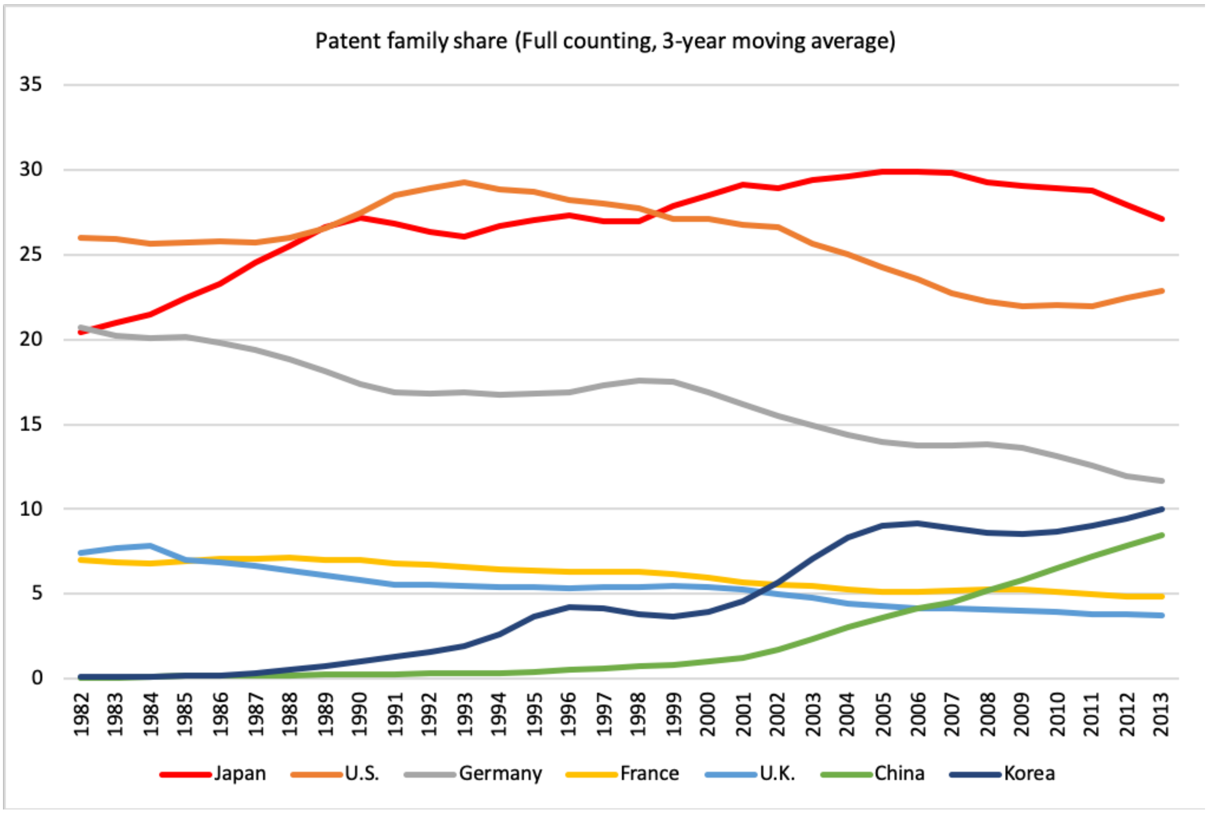

Figure 6. Patent family share (Full counting, 3-year moving average)
Units: World share (%)
Source: Based on MEXT NISTEP, "Japanese Science and Technology Indicators 2019", NISTEP RESEARCH MATERIAL No. 283, created by the author.

4. Science and technology innovation policy after the 5th Science and Technology Basic Plan

An overview of Japan's innovation policy since 1995 reveals that deregulation and structural reforms have been implemented to make it easier to transfer the knowledge generated at universities to industries. Policies that encourage university researchers to collaborate with companies, and policies that support the creation of university start-ups have been implemented, indicating that the amount and number of collaborative research projects, and the number of start-ups established, have both increased. On the other hand, while the US, China and the EU are increasing R&D investments, Japan's budget for science and technology has not seen significant growth. Japan's share of the number of papers has declined, while the number of highly cited papers has not increased and has been stagnant. From the data of the paper, it can be seen that Japan's research capabilities have declined significantly.

Under such circumstances, the 5th Science and Technology Basic Plan compiled in 2016 stipulated that the following four items should be strongly promoted:

1. Acting to create new value for the development of future industry and social transformation, 2. Addressing economic and social challenges, 3. Reinforcing the “fundamentals” for science, technology, and innovation, and 4. Building a systemic virtuous cycle of human resources, knowledge, and funding for innovation. These four items will be summarized here based on the Science and Technology White Paper 2019 (MEXT, 2019).

In the 5th Science and Technology Basic Plan, the concept of Society 5.0 was proposed as a future society that Japan should aim to achieve. According to the Cabinet Office's definition, Society 5.0 is a "human-centered society that achieves both economic development and solution of social problems through sophisticated fusion of cyberspace and physical space. This is a society in which cyberspace consisting of a network of electronic data, and physical space where humans actually live, are highly integrated. What happens in physical space is detected and collected by sensors and the Internet of Things (IoT) to form big data in cyberspace. The result of analyzing this big data by artificial intelligence (AI) is shown to humans, and is fed back to physical space directly through actuators. Currently, humans access and analyze data on networks, and use it on site. However, in Society 5.0 of the future, intentional human intervention is not required, and timely and appropriate countermeasures will come to humans from cyberspace to solve problems. If useful data becomes available in a timely and low-cost manner, it will contribute to resolving economic and social issues such as optimal use of transportation means, promotion of medical treatment optimization and disease prevention, streamlining of the supply chain, smart agriculture, food allergy/loss management, disaster prevention, and energy efficiency. The 5th Science and Technology Basic Plan is unique in that it presents a concrete social image that the government hopes to realize in the future as a vision. It shows the future world of Society 5.0, and lights up the trail of R&D to be followed in Japan by backcasting from there.

4-1. Acting to create new value for the development of future industry and social transformation

In order to achieve Society 5.0, where both economic development and solving social problems are compatible, it is necessary to actively create discontinuous innovations. Therefore, the government established the Moonshot R&D Program as an effort to encourage researchers to take on challenges based on bold ideas and without fear of failure for themes that are not in the scope of conventional research, and set the following six goals to be achieved.

1. Realization of a society in which human beings can be free from limitations of the body, brain, space, and time by 2050.
2. Realization of ultra-early disease prediction and intervention by 2050.
3. Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.
4. Realization of sustainable resource circulation to recover the global environment by 2050.
5. Creation of the industry that enables sustainable global food supply by exploiting unused biological resources by 2050.
6. Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.

In addition, the government has set up a system that can support the Moonshot R&D program for up to 10 years by funding its budget.

The problem-solving systems required to realize Society 5.0 and the basic technologies required in cyberspace and physical space, extracted from the Science and Technology White Paper (MEXT, 2019), are summarized in Table 1.

The Council for Science, Technology and Innovation also set forth issues based on the development of basic technologies necessary for the realization of Society 5.0 in Phase II of the Strategic Innovation Creation Program (SIP), and a system for conducting research aimed at industry-academia collaboration was established centered on the Program Director.

Table 1. Systems and fundamental technologies to realize Society 5.0

11 systems to solve specific economic and social issues	Basic technologies in cyberspace	Fundamental technologies in physical space
● Optimizing the energy value chain ● Building a global environment information platform ● Maintenance and upgrade of an efficient and effective infrastructure ● Attaining a resilient society against natural disasters ● Intelligent Transport Systems ● New manufacturing systems ● Integrated material development systems ● Promoting integrated community care systems ● Hospitality systems ● Smart food chain systems ● Smart production systems.	● Cybersecurity technology ● IoT system building technology ● Artificial intelligence technologies ● Device technology ● Network technology ● Promotion of mathematical science	● Technology for robots, actuators and human interfaces ● R&D of sensor technology ● Promotion of R&D in materials and Nanotechnologies ● Promoting R&D on technologies for optical and quantum sciences (optical and quantum technologies)

Source: White Paper on Science and Technology (MEXT)

4-2. Addressing economic and social challenges

As we have already seen, the Japanese government has presented the concept of Society 5.0 as a desirable image of the future, but it will also need to create innovations to solve urgent economic and social issues that have already emerged in

Japan and the world. The 5th Science and Technology Basic Plan aims to integrally promote initiatives from R&D to social implementation as regards 13 important policy issues. Table 2 summarizes themes and important policy issues from the Science and Technology White Paper (MEXT, 2019).

Table 2. Economic and social issues

Theme	Important policy issues
Sustainable Growth and Self-sustaining Regional Development	Ensuring stable energy and improving energy efficiency
	Ensuring stable resources and cyclical use
	Securing a stable food supply
	Achieving a sustainable society to handle hyper-aging, depopulation
	Improving competitiveness in manufacturing and value creation
Ensure Safety and Security for Our Nation and its Citizens and a High-quality, Prosperous Way of Life	Addressing natural disaster
	Ensuring food safety, living environments, and occupational health
	Ensuring Cybersecurity
	Addressing national security issues
Addressing Global Challenges and Contributing to Global Development	Addressing global climate change
	Responding to biodiversity loss
Pioneering Strategically Important Frontiers	Promotion of oceanographic R&D
	Promotion of R&D in space science

Source: White Paper on Science and Technology (MEXT)

4-3. Reinforcing the “fundamentals” for science, technology, and innovation

In Japan, there is a marked decline in the research capability as seen from the data of publications, and there is an urgent need to improve the basic research capability. In order to create innovation and achieve Society 5.0, it is necessary to rebuild basic research capabilities that have fallen behind. The 5th Science and

Technology Basic Plan proposes to bolster excellent young researchers, improve the research environment, and optimize the allocation of research funds.

It is young researchers who will create innovations for the future. However, the ratio of full-time faculty members under 40 in Japanese universities is declining, making it difficult for young researchers to obtain stable research posts. The career path of researchers is limited, and the percentage of researchers who find employment at private companies is low. Even if they pay their own tuition and living expenses to enter a doctoral program, it is difficult for them to obtain a teaching position and continue their research. As a result, the ratio of students entering the doctoral course from the pre-doctoral course (master's course) has also decreased, and the total number of students enrolled in the doctoral course, including adult students, has been declining.

Further, the ratio of women researchers in Japan was 16.2% as of 2018, compared to 20.1% in Korea (2017), 28.0% in Germany (2015), and 38.7% in France (2015), so employment of women in the research field is not increasing (NISTEP, 2019). With the birthrate falling and the number of students themselves declining, the problem of financially burdensome and opaque career paths preventing the best students from abandoning the path of research must be solved.

Therefore, the government is expanding the number of posts with no time limit for young researchers, introducing the principle of a tenure track system, and lengthening terms of appointment. It is planned to expand scholarships for doctoral students and young researchers, and make research funds available to young researchers. The ratio of women researchers hired through training and promotion of female leaders, is also aimed at.

NISTEP (2019) states that university faculty members are spending less time on research. Although the degree of decrease varies depending on the discipline, the percentage of research time decreased from 2002 to 2013 with no exception. It has been pointed out that the number of papers will decrease if the time allocated for research decreases (Aoki and Kimura, 2014). There is a need to ensure that university faculty members have time to devote to research. In this connection, the number of assistants per researcher in Japan is 0.24, which is less than 1.29 in China, 0.64 in Germany, and 0.54 in France (NISTEP, 2019). In other words, in other countries, some work can be done by assistants, but in Japan, researchers are doing everything themselves. Therefore, through the allocation of university research administrators (URA), and the recruitment of research assistants and technicians, a system whereby research will not solely rely on teaching staff, but instead utilize the mutual expertise of team members, is now being promoted.

MEXT is implementing the World Premier International Research Center Initiative (WPI) to improve the research environment. Up to ￥700 million will be provided annually for 10 years to centers that rank top in the world in academic achievements and employ many researchers from other countries, the aim is to attract outstanding researchers from overseas and accumulate cutting-edge knowledge through international academic symposia. As specific examples of such advanced large-scale research facilities, a large synchrotron radiation facility (SPring-8), an X-ray free-electron laser facility (SACLA), and a high-intensity proton acceleration facility (J-PARC) are now in operation, and research that meets the needs of academia and industry is being carried out. It is planned to develop a “Fugaku” successor to the "K" supercomputer and a next-generation synchrotron radiation facility. In addition, support programs aimed at consolidating and improving the research environment are being implemented so that any researcher can conduct experiments using high-performance equipment by sharing research facilities within the university, rather than keeping it individually in each research group.

MEXT and the Japan Society for the Promotion of Science (JSPS) have implemented Grants-in-Aid for Scientific Research (KAKENHI) to support research based on the free ideas of researchers. This is a historic grant system established in 1939, and is a competitive fund for all academic fields. Among the research plans submitted, selected projects are decided by peer review of researchers. In 2019, 28,892 new entries were selected among 101,857 applications (JSPS, 2019). A total of ￥237.2 billion has been invested in 78,650 research projects, including ongoing projects that span multiple years. KAKENHI is a competitive fund used by many Japanese researchers, and has a significant impact on science, technology and innovation policies. In 2018, the examination system was reformed, and exams that had been conducted in the subdivisions of each research topic until then were to be comprehensively evaluated in a larger framework. The reason for this was that while examinations in the subdivisions of each research topic were highly reliable for specific issues in the field of examiners’ expertise, interdisciplinary and multidisciplinary issues were too difficult to evaluate by only a few experts. Therefore, starting in FY2018, JSPS has switched to a policy of conducting comprehensive reviews within large field categories, eliminating the subdivision of issues with large budget allocations. This made it possible to evaluate research projects from multiple perspectives. On the other hand, for issues with small budget allocations, a two-step documentary review system was adopted, and evaluations were reviewed again by other examiners to decide whether or not to accept them. This aimed to reduce the time required for examiners to hold meetings and increase efficiency, while ensuring the quality of examiners' decisions on large-scale, interdisciplinary research proposals as well as small-scale but highly specialized research proposals.

4-4. Building a systemic virtuous cycle of human resource, knowledge, and funding for innovation

In order to develop technologies and products from new knowledge and apply them in society, universities and public research institutions should cooperate with companies. To this end, it is necessary to promote open innovation (Chesbrough, 2003; Chesbrough and Appleyard, 2007), where the knowledge is imported from outside the organization, or the knowledge that is not used internally is made available to other organizations.

In addition, investments by companies is indispensable for developing technologies from research knowledge, and designing products and services that incorporate new functions. However, the new knowledge that has just been created at universities has high technical uncertainty, and in many cases, it is difficult for companies to commit themselves and invest. Therefore, policies are being promoted to realize industry-academia collaboration by officially supporting collaborative research conducted by universities and companies. JST has an “Optimum Research Result Deployment Support Program” that supports promising "seeds" from universities up to their commercialization, a “Strategic Innovation Promotion Program” that supports technological development based on outstanding research results, and a “Cooperative Industry-Academia Basic Infrastructure Research Program” to support basic research that contributes to solving technological problems in industries. There is also an “Industry-Academia Joint Commercialization Project” in which JST bears the development risk of commercializing university "seeds" by companies. For companies, an R&D tax system has been set up, whereby a certain percentage of experimental and research expenses are deducted from corporate tax. When universities or companies do collaborative research that leads to open innovation, part of the collaborative research fund can be deducted, which encourages companies to actively cooperate with other institutions. Perhaps partly because of these measures, industry-academia collaboration has been on an increasing trend in both the number and amount of projects implemented.

When it comes to knowledge and its social application, companies that actually use and implement the knowledge stand out from the rest. As regards collaborative research between academia and companies, in some cases, knowledge-sharing can be made to function effectively if university researchers become closely involved in company activities. If researchers are re-assigned to companies, the needs that the company feels at their site of business can be communicated to those researchers, which will certainly make collaborative research far more efficient. Therefore, some universities and corporations are trying to contribute to the mobility of human resources and innovation through a cross-appointment system, in which researchers devote a fixed amount of time to work at companies while remaining enrolled at universities.

In some cases, it may be desirable to have a startup with fast decision-making in order to quickly commercialize the technology "seeds" created by the university through research. It is particularly advantageous for the researchers themselves to establish a start-up company and run it, because there is no cost for knowledge transfer. However, in order to establish a start-up company and make it successful, the knowledge of business management is also required, and researchers generally do not have such knowledge. To address this need, the “Next Generation Entrepreneur Development Project (EDGE-NEXT),” which trains university students and researchers as entrepreneurs, has been implemented by MEXT since 2017. In order to succeed in a start-up, a human network must be formed in the social ecosystem of companies and venture capital, and the necessary management support must be provided. As a policy to comprehensively support entrepreneurs from such a viewpoint, the Ministry of Economy, Trade and Industry, through NEDO, has an “R&D-Type Startup Support Project” to support practical development costs on condition that cooperation from human resources, venture capital, research institutes, and business companies are obtained.

4-5. Discussion

Until the 1980s, economic growth was realized in Japan by companies developing and selling high-quality, low-cost products around the world. Later, the tide turned heavily toward research that produces scientific knowledge, which is a source of innovation. Following the flow of Japan's science and technology policy and science and technology innovation policy after 1995, deregulation and structural reforms were promoted so that creative and advanced knowledge generated by researchers could be more easily applied to industries. Specifically, this stimulated exchanges with industries by encouraging collaborative research between universities and companies, obtaining patents and starting start-ups, which reduced the barriers to innovation.

While the above-mentioned measures were aimed to reduce obstacles, on the other hand, one of the incentives to encourage universities and industries to collaborate was investments of competitive resources to resolve specific problems and realize specific objectives. In the 5th Science and Technology Basic Plan, " Addressing economic and social challenges", is an item that addresses emergent problems. When market and social issues have been identified, but solutions have not yet been developed or are very costly, new products and services that solve those issues are desired. This can, therefore, be seen as a policy promoting needs-pull innovation based on needs from the demand side (Mowery and Rosenberg, 1979). Companies can estimate the market size for such emerging issues, so the risk of commercialization is relatively low. In addition, it is assumed that researchers who apply for assignment to a technical issue have prospects of resolving it, and technical risks can thereby be reduced. In other words, the provision of competitive funding on the theme of solving a specific problem enables an efficient matching of universities and companies that is optimal for solving the problem. The success or failure of a project may also be evaluated based on whether it has contributed to solving the problem, and government public expenditure may be easier if its commercialization in society can be envisaged.

However, this is not to say that there are no challenges. Most of today's large competitive funds take the form of setting themes and tackling issues, and only a few, such as KAKENHI, engage in free research based on the ideas of researchers. While these approaches can be said to be efficient fund management from a short-term perspective, there will be challenges in the long run if universities let their research projects rely on funds for specific issues. Specifically, it is a problem if only the knowledge that contributes to the solution of a specialized task has been accumulated, and diverse knowledge searches are no longer performed (Levinthal and March, 1993). If the diversity of knowledge accumulated in universities is lost, interdisciplinary research does not happen. Also, if a university focuses on the immediately useful research projects avoiding wasting budget, it can hinder the creation of innovative ideas (Abernathy, 1978). Therefore, it is necessary to build a portfolio of research activities from both a short-term and long-term perspective. Looking at the frequency of use of the word "social implementation" in the Science and Technology White Paper issued by MEXT, it first appeared in 2012, less than 5 times until 2014, but more than 20 times since 2016 (MEXT, 2019). It seems that the government is now focusing on implementing the results of R&D in society. However, if research is evaluated solely on the basis of producing the knowledge that is useful to society, it is feared that the diversity of knowledge may be lost, and long-term global research capability will decline.

On the other hand, in the 5th Science and Technology Basic Plan, the concept of Society 5.0, which is the shape of the future society to come, was outlined in the form of "1. Acting to create new value for the development of future industry and social transformation". From this, the concept of backcasting and developing the necessary elemental technologies and platforms was adopted. This can also be seen as the promotion of concept-driven (Numagami, 1989) innovation that guides technological development and product development by offering a vision and a business concept. While indicating future directions, it is expected that the diversity of technological development and academic research will be guaranteed by spanning a wide range of technologies. Although market and technical feasibility risks are higher than those of emerging social and economic issues, this is expected to have the effect of encouraging people to search for means other than solving the immediate issues. On the other hand, it is necessary to allocate funds while maintaining a balance between problem-solving and future-oriented policies.

Thus, the 5th Basic Plan is characterized by incorporating concept-driven innovation without being biased towards needs-pull-type innovation, and to achieve this, the various efforts described in "3. Reinforcing the “fundamentals” for science, technology, and innovation,” which are to reestablish basic research capabilities, are essential. Although total research costs at universities do not appear to have changed, it is probable that, due to lower basic costs and a higher percentage of competitive funding, researchers are spending time preparing and reviewing application forms. Since the time allotted for research is directly related to the number of papers that are the result of research (Aoki and Kimura, 2014), it would be desirable to increase the number of posts, increase the number of staff, and provide financial support so that researchers can concentrate on research. For example, improving the treatment of doctoral students and young researchers would increase the number of students enrolling in doctoral programs, and the number of students transferring from companies to universities, leading to an improved research base.

Creating a URA staff framework is also useful for securing time for research, and at the same time contributing to enhancing the career path of young researchers. Finally, “4. Building a systemic virtuous cycle of human resource, knowledge, and funding for innovation” is an initiative that provides incentives to promote inter-organizational collaboration and establishment of new companies, and through this, it is expected to strengthen the foundation of innovation.

In summary, first of all, it is necessary to secure the number of researchers in Japan to maintain a minimum research base. To that end, the first step is to create an environment where young researchers can be supported and allowed to concentrate on their own research, and where diverse knowledge can be gained through research. In addition, it is necessary to create innovation by promoting industry-academia collaboration. At that time, if only research that helps solve the latest issues is pursued, there is a risk that the country will not be able to innovate in the long term. The fact that the concept of Society 5.0 was presented in the 5th Basic Plan, while still taking account of the aforementioned bias toward "research that will help solve the latest issues", may be considered an attempt to change the whole nature of policy-driven innovation.

5. Conclusion

Japan is facing a rapidly declining and aging population with a declining birthrate and an increasing burden of social security costs, making it an advanced country with social challenges. In order to solve such social issues and revitalize the economy, creating value through innovation will play an important role.

However, since 1995, the budget for science and technology has not increased in Japan compared to other countries, and the share of highly cited papers has declined. In this context, researchers are being allocated less time to research, and the proportion of women researchers is low. It is thus necessary to foster an environment in which young researchers, and women researchers can effectively utilize their abilities and manifest their performance.

If policy encourages the creation of demand-pull-type innovations, which are problem-solving competitive funds, research that meets the demand would be conducted efficiently in the short-term, but the research that does not fit these needs would be disregarded. As a result, there is a concern that the diversity of knowledge accumulated in universities would be lost, and long-term research capabilities would be impaired. The 5th Science and Technology Plan, which reveals the future vision of Society 5.0, has led to rethinking the balance between free research and problem-solving.

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