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Assessing Japan's Innovation Policy Landscape

Missed Opportunities to Nurture Doctoral Talent

Rie Hiraoka

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Shorenstein Asia-Pacific Research Center
616 Jane Stanford Way, E301
Stanford, CA 94305-6055

650.723.9741 | **aparc.fsi.stanford.edu**

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About the Author

Rie Hiraoka was a visiting scholar at the Walter H. Shorenstein Asia-Pacific Research Center (APARC) for the 2024 calendar year. She is currently a professor at Kyoto University for Advanced Sciences, as well as advisor for the Institute of Future Initiatives. Previously, she served as a director at the Asian Development Bank. While at APARC, she conducted research regarding public policies for innovation, science, and technology development.

Summary

This paper considers whether Japan has lost or is losing innovation capabilities, and whether the government's apparent interest in promoting science, technology, and innovation (STI), articulated in a series of STI public policies, ultimately contributed to strengthening Japan's innovation capabilities. The paper focuses on the most consistent among STI policies, namely, those related to nurturing doctorate degree holders, essential human resources for quality research and development. The paper finds that Japan is still a leading country in innovation, but its quality of innovation may be trending down. Incoherences within the STI policies, and between the STI and university reform policies, and insufficient coordination among the government, the private sector, and universities have all undermined the chance of nurturing doctorates and fully taking advantage of their talents to further innovation. The paper also notes recent changes that may contribute to reversing the trend. To ensure that public policies achieve their intended objectives, it is essential to assess and evaluate the policies, as well as make timely evidence-based adjustments.

Assessing Japan’s Innovation Policy Landscape

Missed Opportunities to Nurture Doctoral Talent

Productivity growth in developed countries has decelerated in recent years. Some conventional sources of growth are declining in importance. Stagnating or declining populations in several countries of the Organisation for Economic Co-operation and Development (OECD) means long-term economic growth cannot come from increasing labor input, even as returns to investment in physical capital are diminishing. Instead, innovation has become an important driver of growth in OECD countries (OECD 2010). Bloom, Reenen, and Williams (2019), in their study of the U.S. economy, suggest that innovation is the only way for the most developed countries to secure sustainable long-run productivity growth.

Emerging global challenges also demand new, innovative solutions. For example, the COVID-19 pandemic is still quite fresh in our minds. The onset of the pandemic, caused by a rapidly spreading and mutating virus, triggered the production of new vaccines at record speed. International organizations established new COVID vaccine procurement, distribution, and delivery systems to help developing countries access the vaccines as the more advanced economies bought up the scarcely available vaccines. Climate change is another serious global challenge. As Bill Gates said, “Innovation is the key to helping all countries eliminate their emissions” (Gates 2023).

Thus, many developed countries have looked to innovation as a main driver of growth and a source of solutions to social challenges. The Japanese cabinet’s latest economic policy document, “Principles for Economic and Financial Operations and Reforms” (2023), proposes five main areas of action for expanding investment and economic reforms: (i) expanding domestic investment and strengthening supply chains through public-private collaboration; (ii) accelerating green and digital transformations; (iii) promoting start-ups and restructuring industry; (iv) promoting science, technology, and innovation through public-private collaboration; and (v) inbound strategy principles.[1] The word “innovation” appears 24 times in the document (Cabinet Office 2023).

The word “innovation” has often been used interchangeably with science and technology development in Japan’s economic policies. Science and technology have been important to Japan’s economic development strategies for a long time. The government was already vigorously pursuing adopting advanced technologies to build and modernize domestic industry in the Meiji Era (1868–1912). Japan’s economic growth was indeed accompanied by rapid technological advancements: in the 1960s, the bullet train became world-renowned; electronic products exported in the 1980s, like the Sony Walkman, were in great demand; and Japanese cars began to dominate the world market. Japan has produced many Nobel laureates in science, second only to the United States. Japan’s industrial policies and the government-business coordination of this rapid growth period offer fascinating case studies (e.g., Johnson 1982; Okimoto 1989). In the 1990s, recession caused a decline in research and development (R&D) investment. Japan’s fear of potentially losing its industrial competitiveness led to the introduction of the Science and Technology Basic Law in 1992 and subsequent Basic Plans to enhance science and technology capabilities and thereby achieve sustainable growth.

This paper considers whether Japan has lost or is losing innovation capabilities, and whether the government’s apparent interest in promoting science, technology, and innovation, and a series of public policies, have contributed to strengthening or maintaining that nation’s capabilities for innovation. The paper reviews the state of common innovation indicators and public policies promoting the development of science, technology, and innovation. The policies are complex, covering a wide range of sectors and areas, and have undergone changes; some policies have not persisted long enough to demonstrate results. To further understanding of the relationship between policies and innovation performance, the paper focuses on the most consistent policies, namely, those related to highly skilled professional human resources, especially human resources required for quality R&D.

1 Inbound here extends beyond traditional tourism promotion and covers the restoration of international exchange centered on Japan and the establishment of a brain circulation process encompassing areas of business, education, research, culture and the arts, and sports.

A Sluggish but Complex Economy

Japan's economy grew rapidly after the devastation of World War II until the recession following the oil shock in 1973. After recovering from the recession, the economy grew more or less steadily, but the bubble burst in 1989, when Japan's economic growth dropped and Japan entered a prolonged period of stagnation that has lasted over 30 years (figure 1). While its declining population and capital expenditure contributed to the stagnancy, the slow growth of labor productivity was a critical factor, too. According to a government white paper released in 2022, a decrease in the total hours worked caused Japan's labor productivity to fall behind that of other countries (Cabinet Office 2022). The growth of gross domestic product (GDP) per hour worked also slowed substantially in the 2000s (table 1).

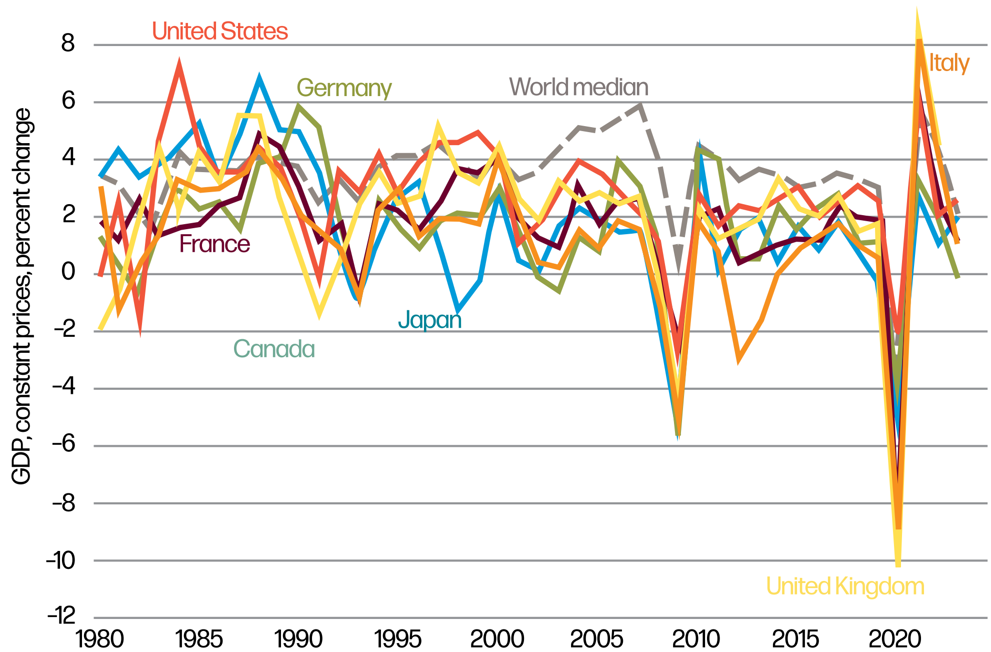
Despite lackluster growth, Japan's economy has remained the world's most complex since 1981, earning it the highest score in the economic complexity indicator,[2] reflecting Japan's sophistication in production and its export of highly advanced products and services. Bahar et al. (2024) note the nation's economic structure has changed during the stagnation period: exports have shifted from goods to services, especially to knowledge-intensive services, for example, intellectual property. The authors assume that Japan's global leadership in innovation, in terms of quantity and quality, is one of the central drivers of its economy's high complexity and its increasing returns to economic activity abroad. But they also suggest that the quality of innovation might have declined in the past few years.

An increase in total factor productivity (TFP) is often associated with technological advancements and innovation. TFP growth has slowed among developed countries, including Japan, since the 1990s (Dieppe 2021, 57), indicating slowing technological advancements. Trends of TFP growth in Japan provide some insights into its technological advances and innovation. According to Fukao, Makino, and Settsu (2021), labor productivity growth accelerated substantially in the postwar period and was twice as high as that in the prewar period. The postwar growth was fueled by increases in TFP and the capital-labor ratio, while the prewar growth was mainly driven by improved labor quality due to increased educational attainment. TFP growth was hit hard in the 1990s but has recovered somewhat since the late

2 "The Economic Complexity Index (ECI) captures the diversity and sophistication of the productive capabilities embedded in the exports of each country. The researchers place the diversity of productive knowledge—or knowhow—that a society has at the heart of the economic development process. Economic growth requires the accumulation of new knowhow and its use to diversify production into more sophisticated—aka complex—activities. ECI is able to closely explain differences in country incomes—and to predict future growth" (Growth Lab 2023).

1990s (Danninger 2015). Company TFP rates hint at dichotomized productivity growth. The TFP gains in Japan have been concentrated in companies with overseas subsidiaries that have far higher TFP rates than companies without them (Bahar et al. 2024).

FIGURE 1 Real GDP growth of G7 countries, 1980–2023



Source: World Bank World Development Indicator data, accessed January 8, 2025.

TABLE 1 Productivity: Average GDP growth per hour worked (%)

Year	Australia	Japan	Korea	United States
1971–2022	1.44	2.43	—	1.57
1971–1980	1.63	4.28	—	1.51
1981–1990	1.08	3.99	—	1.45
1991–2000	2.09	2.24	—	1.81
2001–2010	1.32	1.08	—	2.22
2011–2022*	0.97	0.85	2.46	0.92

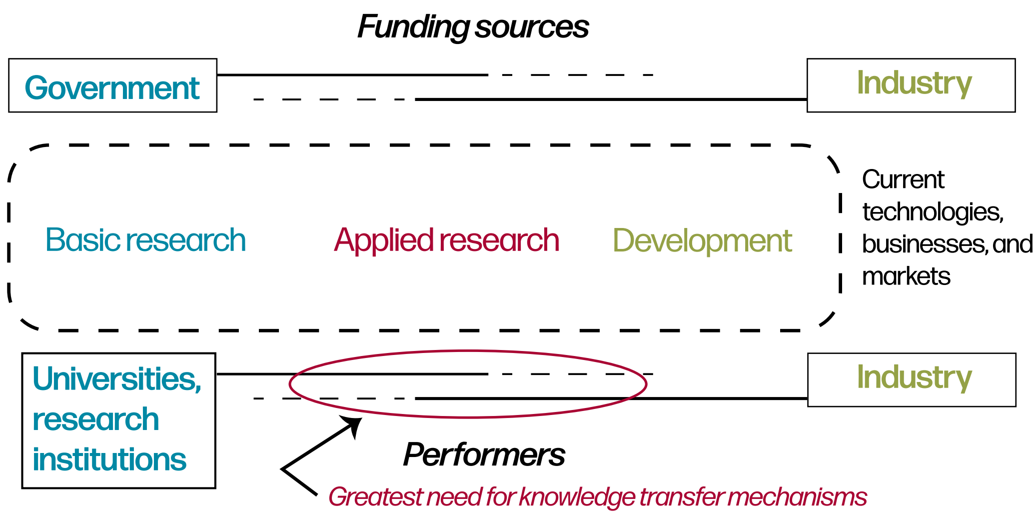
Note: *For Korea, the average is for the period 2012–2022.

Source: Original compilation based on OECD data.

Review of Innovation Indicators

Innovation refers to the introduction of something new—whether it is a novel idea, method, or device, or an improvement to existing products, ideas, or processes. An invention or a new idea alone is not an innovation unless agents (e.g., individuals, research institutions, firms, or governments) put it into practice using various resources (e.g., R&D, human resources/talents). There are three main institutional actors furthering innovation: the government, universities/research institutions, and industry (figure 2). Industry develops and markets new, innovative products and services.

Figure 2 Sector roles in the innovation pathway



Source: Dasher, Richard B. 2023. "National Innovation Systems: What Science Policy Fellows Need to Know." Presented at the Sci Com Fellows Symposium, Okinawa Institute of Science and Technology, February 23.

While no definite measures of innovation exist, TFP, the Global Innovation Index (GII), patents, and R&D are proxy indicators often used for innovation capabilities. This section reviews common proxy indicators (except TFP, which has already been discussed) to examine the trend of Japan's innovation capabilities. These indicators shed light on the performance of these three institutional actors.

Global Innovation Index

After a gradual improvement over the previous decade, the 2024 GII report ranked Japan 13th, still behind fellow Asian countries such as China (11th), Singapore (4th), and the

Republic of Korea (6th) (Dutta, Lanvin, León, and Wunsch-Vincent 2024).[3] The GII is constructed from the variables innovation input and output.[4] As for the pillars of the Input index, Japan ranked 23rd in institutions, 19th in human capital and research, 13th in infrastructure, 8th in market sophistication, and 6th in business sophistication. Among the pillars of the Output index, it ranked 12th in knowledge and technology outputs, and 22nd in creative outputs.

Research and Development

When countries begin to catch up to and compete with those ahead of them in terms of per capita income, they must develop their own R&D, which is essential to compete. The East Asian experience shows that when countries' incomes reach roughly one-third of that of the highest-income countries, they must invest in developing effective R&D institutions to achieve sustained high growth (Perkins 2013, 159). R&D is the critical source of new scientific knowledge and new products and services. The most frequently used indicators for R&D capabilities are the number and frequency of citations of patents and published research papers. R&D spending and the quantity and quality of researchers affect countries' overall R&D capabilities.

Patents

Patent count is closely linked to innovation (Shambaugh, Nunn, and Portman 2017) and is one of the most commonly used proxies for innovation. Japan is among the world's top countries in terms of the quantity and quality of patent applications. Figure 3 shows the performance of the top 10 countries, according to World Intellectual Property Indicators (WIPO 2023). In 2022, innovators worldwide filed 3.46 million patent applications. In terms of the absolute count,[5] applicants from China filed approximately 1.58 million patent appli-

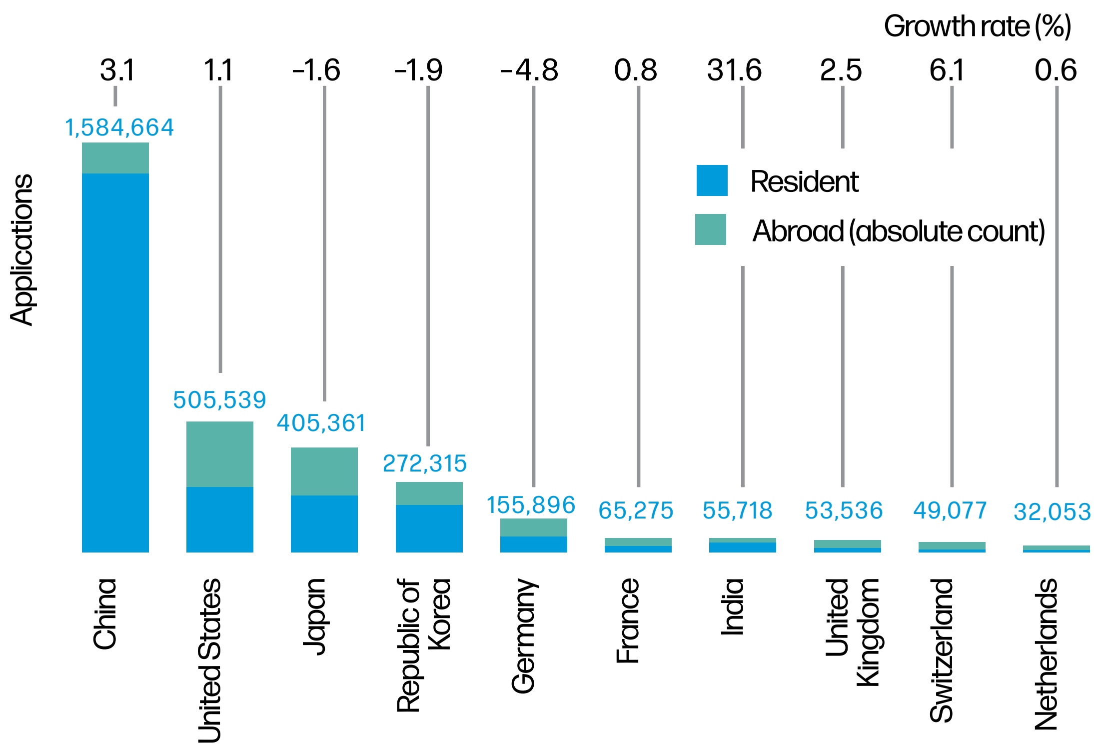
3 The Global Innovation Index has been published since 2013. Japan ranked 22nd in 2013, 19th in 2015, 14th in 2017, 15th in 2019, and13th in 2021 and 2023

4 Overall, recognized weaknesses are found in entrepreneurship policies and culture, expenditure on education, tertiary education (specifically, the percentage of graduates in science and engineering), venture capital value, knowledge-intensive employment, foreign-financed R&D, foreign direct investment inflow, labor productivity growth, and exports of cultural and creative services.

5 Data by origin can be calculated based on either the absolute count (an application filed at a regional office is counted once) or an equivalent count (an application filed at a regional office is counted multiple times).

cations worldwide (resident plus abroad).[6] China was followed by the United States, Japan, Korea, and Germany. A significant share of the total applications originating from Germany (61 percent), Japan (46 percent), and the United States (51 percent) are filed abroad, whereas more than 90 percent of Chinese applications are filed within the country.

FIGURE 3 Patent applications in top 10 origin countries, 2022



Source: WIPO 2023.

Japan's number of applications declined by 15 percent from 473,220 in 2013 to 406,374 in 2022—the biggest decline among the top five countries. This decline could have been due to, among other causes, a shift in companies' focus from quantity to quality, or it could mean declining R&D activities, or both. Of Japan's total patent applications, only 2.4 percent came from universities—the lowest rate among the top five countries. Among other countries, the United States, for example, saw 7.9 percent of its total patent applications come from

6 According to Sun et al. (2021), the Chinese government has played an important role in the remarkable increase in China's patent applications this century. The government planning system set quantitative targets and timelines for patenting and using them in government performance evaluations. But the authors also suggest there has been a trade-off between the quantity and quality of patent applications resulting from the government planning system.

universities in 2020–22. The number of university-originated patent applications could be increased if universities are supported in commercializing research findings (Suzuki 2024).

The frequency of citation is a measure of patent quality. Nagaoka and Honjo (2023) find that, between 1980 and 2015, Japan was second among the top 5 percent most frequently cited patents registered in the United States, following the United States itself. However, the quality of patents may be trending down in recent years as measured by forward citations or the OECD's patent quality indicators (Bahar et al. 2024). It is worrying that Japan significantly lags behind the United States and Europe in its ability to translate scientific developments into new inventions (Nagaoka and Honjo 2023). A relatively low share of Japanese patents cite scientific papers compared with other countries leading in patent applications. Multiple factors may explain this. This may suggest that companies' capacity to absorb new scientific discoveries may be weakening, or that the industries most active in filing patent applications are mature, and mature technologies undergo only incremental innovations. The low share of university-originated patent applications in the total patent applications may also partially explain the weaker link of patents to scientific papers.

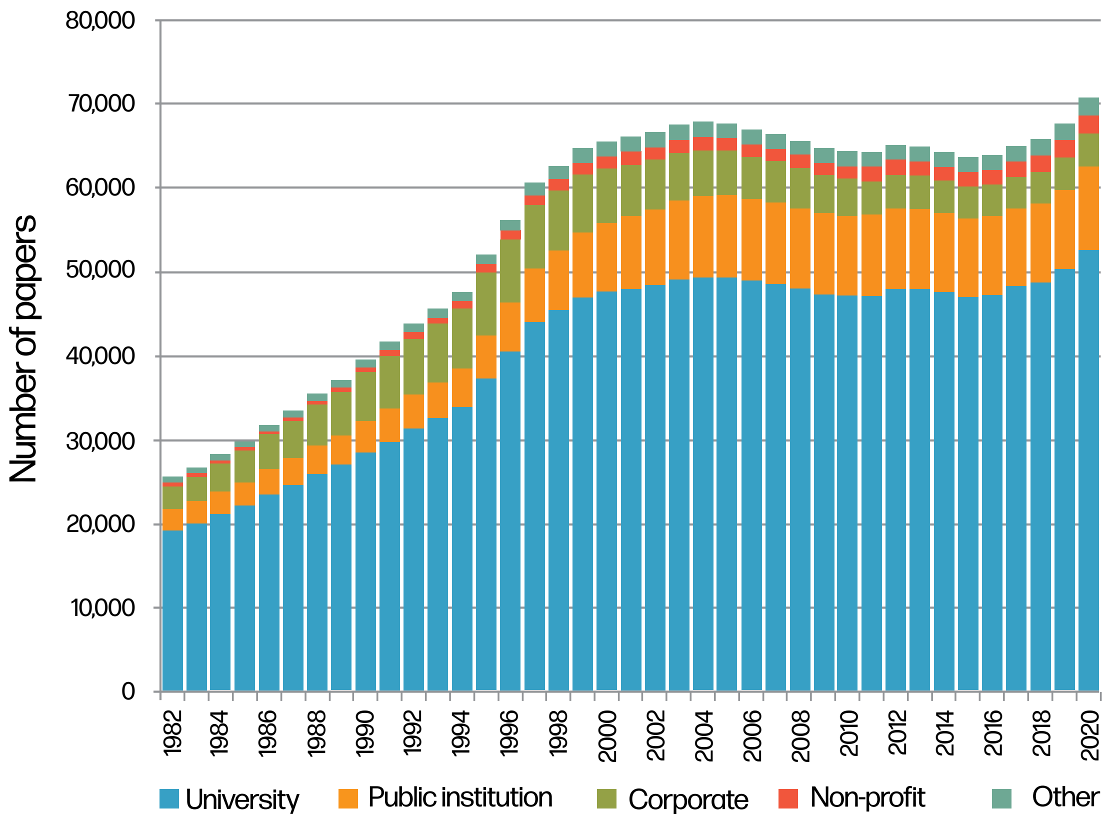
Research Papers

The number of research papers worldwide is increasing, and the number of internationally coauthored papers is growing even faster. The number of published research papers originating from China has dramatically increased recently, while that of Japan has only moderately increased. Since about 2004 or 2005, Japan's world ranking in terms of the number of papers (a measure of quantity)—as well as the number of top 10 percent and top 1 percent cited papers (measures of quality)—has been declining. The onset of the ranking decline coincided with a 2004 university reform that will be discussed later. Japan ranks worse in the most frequently cited papers than in the total number of papers. Using a whole-count method, in 2019–21, Japan ranked 6th for the total number of papers, 12th for the top 10 percent adjusted paper count, and 12th for the top 1 percent adjusted paper count. Using the fractional-count method, Japan ranks 5th for the total number of papers, 13th for the top 10 percent adjusted paper count, and 12th for the top 1 percent adjusted paper count. China leads using both the methods above, followed by the United States (Murakami, Nishikawa, and Igami 2023).

Universities and public institutions have produced the largest share of papers. In 2019–21, an average of 70,000 papers were published annually (figure 4). Universities represented

75 percent of the total, public research institutes represented 14 percent, and private firms represented only about 6 percent. The private sector's contributions have gradually diminished since about 1995—to less than half of the peak in 2019–21. Its share in the top 10 percent most frequently cited papers has declined even faster. This diminished contribution to research publications may be explained by the closure of companies' research centers in the mid-1990s.

FIGURE 4 Share of published papers originating from Japan, by sector, 1982–2022



Source: Based on data from Murakami, Nishikawa, and Igami (2023).

R&D Spending

The R&D investment size and the number of researchers influence outputs such as patents and research papers. Japan's R&D spending as a share of GDP (table 2) and the actual total spending (figure 5) are among the highest in the world. Global R&D spending decreased between 2009 and 2013 due to a decline in business R&D spending following the Lehman shock. While R&D spending has since recovered worldwide, Japan's total R&D spending growth has not kept up with that of the United States and Europe, whose R&D spending have more than doubled, and of China, whose R&D spending has grown more than 10 times.

TABLE 2 Expenditure on R&D as a share of GDP (%), 2015–21

	2015	2016	2017	2018	2019	2020	2021
Australia	1.88	—	1.79	—	1.80	—	—
France	2.23	2.22	2.20	2.20	2.19	2.28	2.22
Germany	2.93	2.94	3.05	3.11	3.17	3.13	3.13
Italy	1.34	1.37	1.37	1.42	1.46	1.51	1.45
Japan	3.24	3.11	3.17	3.22	3.22	3.27	3.30
Korea	3.98	3.99	4.29	4.52	4.63	4.80	4.93
United Kingdom	2.27	2.31	2.32	2.70	2.67	2.93	2.91
United States	2.79	2.85	2.90	3.01	3.17	3.47	3.46
China	2.06	2.10	2.12	2.14	2.24	2.41	2.43
Singapore	2.17	2.07	1.90	1.81	1.90	2.22	—
Taipei	3.00	3.09	3.19	3.35	3.49	3.61	3.77

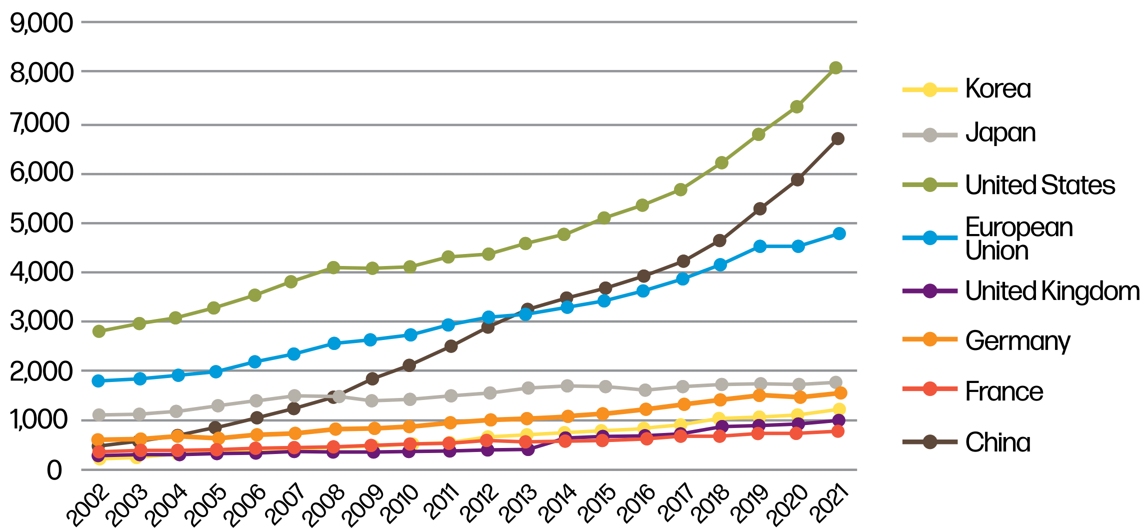
Source: Original compilation based on OECD data.

Japan's sizable R&D investment primarily comes from active business sector spending. The business sector had a 73.1 percent share in total R&D spending in 2022.[7] The government's share was modest (figure 6) compared to other countries and only a small share of the modest government R&D spending supports businesses—through direct funding support or tax credits. Direct support constitutes about 1 percent of the total R&D spending of businesses; 79.1 percent of the support went to large companies with more than 500 employees in 2021. While the United States and France also allocated 81.4 percent of government support to large companies in 2020 and 70.7 percent of it in 2017, Korea allocated almost

7 Data from the Statistics Bureau of Japan (2022).

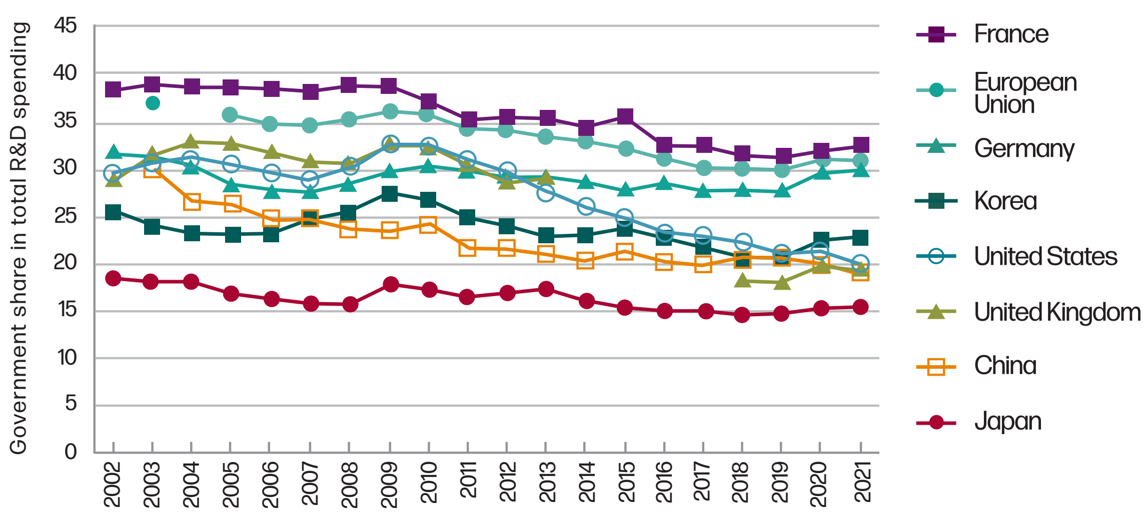
half (47.6 percent) of it to small companies with fewer than 49 employees in 2021 (Kanda et al. 2023).

FIGURE 5 R&D spending (in $ millions), 2002–21



Source: CRDS 2023.

FIGURE 6 Government share of total R&D spending, 2002–21



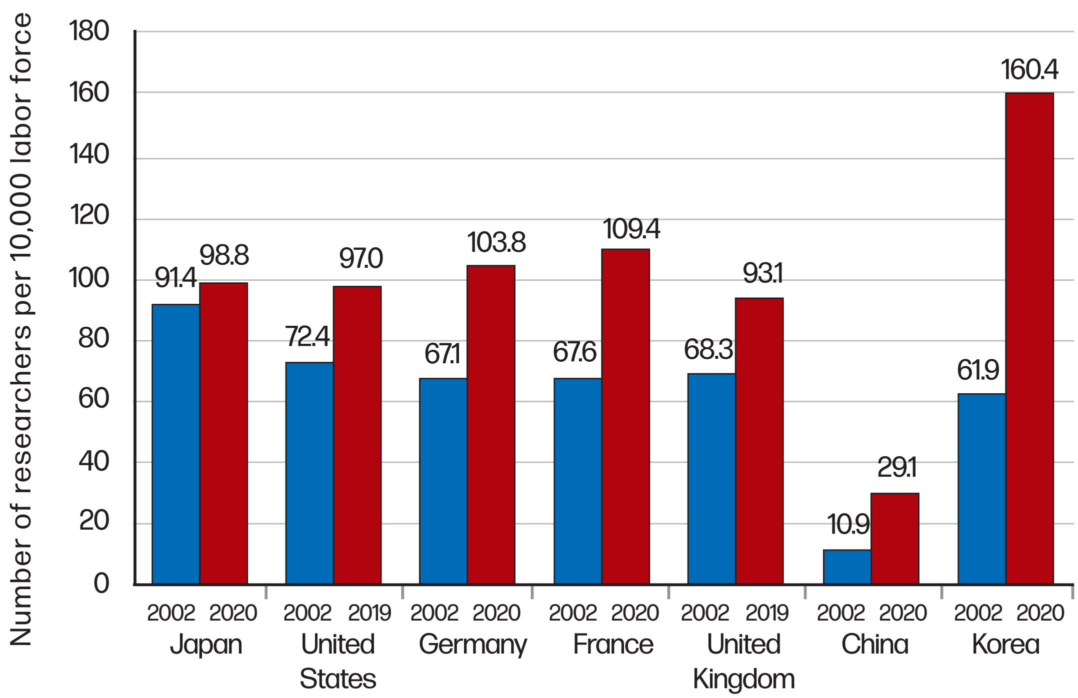
Source: Created by the CRDS, based on the data on the percentage of GERD financed by government in the OECD's Main Science and Technology Indicators, September 2023.

Tax credits do not benefit start-ups, which are not yet profitable, while supporting larger, established companies. But the relatively meager government support is unlikely to have a significant impact on large companies, which already have their own resources. Considering these points, government support may have a greater impact if it is allocated to smaller enterprises and start-ups in promoting innovation.

Researchers

Japan had the highest number of researchers per 10,000 persons employed in 2002, and the fourth highest in 2020 (figure 7). About 60 percent of these researchers were in the private sector and 40 percent in the public sector. The number of researchers in Japan increased from 8.4 million in 2013 to 9.1 million in 2022; it grew even more substantially in other countries (e.g., the United States, Germany, France, the United Kingdom, China, and Korea). In particular, the share of researchers among the employed more than doubled in China and Korea.

FIGURE 7 Number of researchers per 10,000 persons employed, 2002 and 2019/20



Source: Kanda et al. 2022.

In summary, Japan is still a global leader in innovation, yet a review of some indicators points to a declining trend for innovation in recent years. Rapid growth in other countries, especially China and Korea, could explain Japan's lower rankings in, for example, R&D spending and number of researchers, but it does not fully explain the steep decline in frequently cited papers. While Japan is still among the top countries in patent quantity and quality, the declining number and quality of patent applications is concerning mainly because the knowledge outputs of Japanese businesses (research papers and patents) are declining. The business sector may need to increase its R&D spending, which, although substantial, has been almost at the same level for many years. The sector has already reached the frontiers of numerous technologies, and it tends to take more financial resources to produce new technologies. Another concern is that the capacity of businesses to absorb or translate science into new innovations might be weakening. Stronger university collaboration or recruitment and integration of individuals with the latest scientific knowledge might help businesses create more innovative products and services.

The Emergence of Public Policies for Science, Technology, and Innovation

Science and technology have played important roles in economic transformation since the time of the first Industrial Revolution. For East Asian economies—Japan, Korea, Taiwan, and China—building a technology-based domestic industry has always been an important part of economic development strategy. Stiglitz and Yusuf (2001) predicted that East Asian countries' "convergence to the incomes of the advanced countries would depend on the speed of movement toward the technological frontier and eventually their ability to push this frontier outward in selected areas" (18). All these countries indeed not only caught up but have pushed the frontiers and the commercial production of many technologies, including electronics, semiconductors, and solar panels. Given the importance of R&D to science and technological advancement, it is no coincidence that these East Asian countries are among the top spenders on R&D.

Japan's public policies promoting innovation evolved from policies promoting science and technology development. In fact, "science and technology development" has been used as a synonym for innovation in Japan's policy documents. The concept of innovation first appeared in the 1956 Economic White Paper, as *gijutsu kakushin* (技術革新), or "producing new technology" (Economic Planning Agency 1956). By the late 1960s, the phrase "from copy to creation of technologies" emphasized the creation of new technologies rather than the adoption of existing technologies (Economic Planning Agency 1968). By 1980, the focus had shifted to the creation of new technologies and the importance of R&D and high-quality human resources (Economic Planning Agency 1980). The 1992 Economic White Paper concluded that incremental process innovation benefited consumers through high-quality, reasonably priced products, and future technology development should, thus, shift to product innovation (Economic Planning Agency 1992).

Basic Laws (1995 and 2021) Focused on Science, Technology, and Innovation

In the early 1990s, the bubble economy collapsed. The export industry was hit by the appreciation of the yen. Japan's population was aging. International competition was intensifying. The economic downturn had also diminished investment in R&D. Japan realized that it should be at the forefront of technological innovation, now that it had caught up to those ahead of it. A new approach to science and technology development was needed to develop new industries, help achieve long-term economic growth, and overcome the associated challenges. In this context, the Science and Technology Basic Law was enacted in 1995 by unanimous consent of the ruling and opposition parties. The Basic Law stipulates that the government should secure a budget, and it comprehensively promotes science and technology. In 2020, the name was revised to the Science, Technology, and Innovation Basic Law, enforced in 2021.[8] The law requires the government to prepare a Science, Technology and Innovation Basic Plan every five years and finance its implementation. Each plan is implemented through annual integrated innovation strategies. The Sixth Basic Plan (2021–25) is under implementation. The Basic Plans present aspirations, directions, and priority issues and industries, while annual integrated strategies describe operational details.

As we saw above, Japan recognized the need to promote science and technology and improve innovation capabilities well before its world rankings in various innovation indicators started to decline. More than 30 years ago, it enacted a legal framework to support science and technology development and innovation, and has been regularly updating strategies to improve science, technology, and innovation. The state's foresight in creating the Basic Plans is to be commended, yet it is not easy to gauge how these plans have contributed to actual capabilities.[9]

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8 Innovation is defined as creating new value and bringing changes in the economy and society through scientific discoveries or inventions, the development of new products or services, and other creative activities.

9 Understanding the achievements of the first five Basic Plans is not straightforward, mainly because clear measurable targets and interim output indicators to measure progress and achievements were not set in the plans. Such indicators were introduced only from the Fifth Basic Plan. According to MRI (2023), such indicators were not introduced even in the Fifth Basic Plan, since logical

Nurturing Human Resources

While the Basic Plans have become more complex, covering an increasing number of agendas over the years, a persistent central objective across all six Basic Plans is the development of the necessary human resources. Given that public policies typically take years to fully implement, and their results take even longer to materialize, it is necessary to choose older, rather than newer, policies when studying impact. This paper thus takes a closer look at the specific policies for promoting the development of high-level professional human resources to enable an understanding of the actual effects of the Basic Plans on science and technology development and innovation.

People are at the heart of the innovation process. They generate ideas and knowledge; produce new technologies, products, and services; and then apply the generated knowledge and the resulting technologies, products, and services. Studies of the rapid and relatively equitable growth of East Asian countries in the 1960s–1980s often point to investment in human capital and the availability of educated workers among the key explaining factors (e.g., World Bank 1993). Education is arguably the most important contributor to human capital formation. An OECD study (2010) suggests that if the average time spent by a population in education rises by one year, the economic output per person should grow by 4–6 percent in the long run.

For Japan, the prewar productivity growth largely stemmed from increased educational attainment and the consequent improvement in labor quality (Fukao, Makino, and Settsu 2021). During the postwar rapid-growth years, the Japanese government actively responded to business demands for skilled labor in science and technology by increasing tertiary education capacity (Suzuki, Yasuda, and Goto 2021, 115–16).

However, while the importance of human capital in economic growth and innovation has been officially acknowledged, Japan now spends only about 2.5 percent of its GDP on education—lower than the 3.3 percent OECD average—and its spending on tertiary education is among the lowest (figure 8). As we saw earlier, this meager spending on education has affected Japan's GII ranking.

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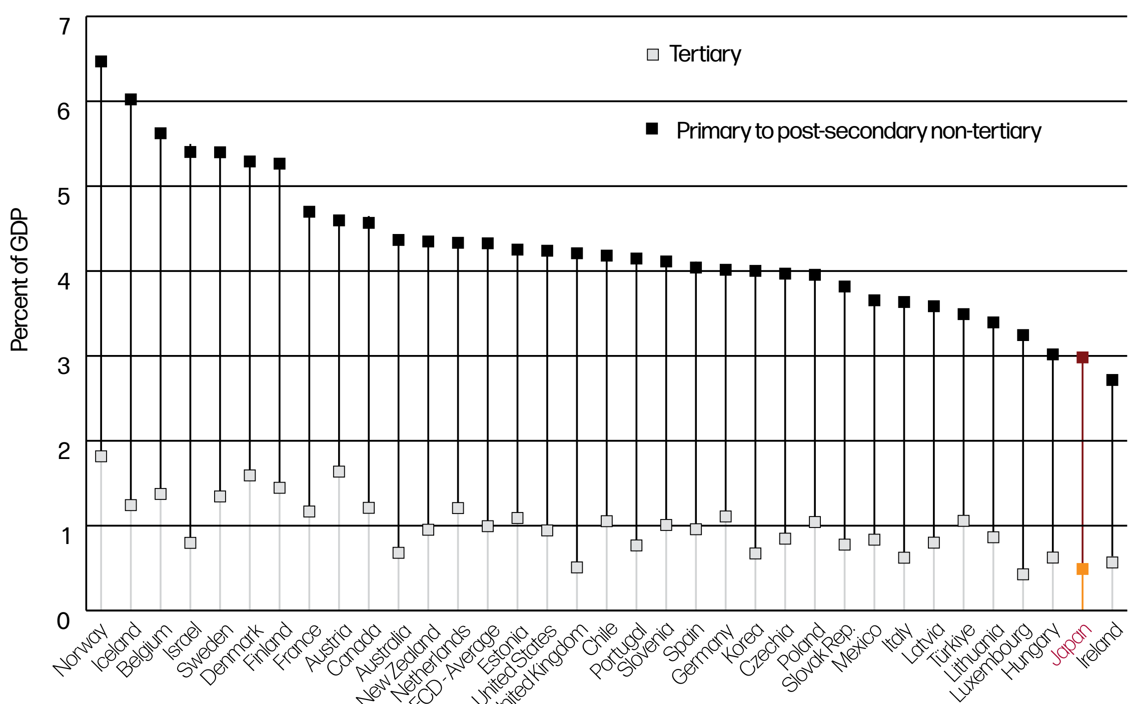
links between policy objectives and the associated indicators were not always clear. The monitoring framework of the Sixth Basic Plan was substantially improved compared with the framework of the Fifth Plan. This improved framework enables the assessment of progress in achieving the intended objectives.

Nonetheless, Japanese secondary school students are among the most competent in the world. They did well in the OECD's 2022 Programme for International Student Assessment (PISA), ranking third. PISA measures 15-year-olds' ability to use their reading, mathematics, and science knowledge and skills to tackle real-life challenges. These competent students offer a good foundation for human capital formation in Japan. The Basic Plans have paid special attention to post-secondary education, namely tertiary and postgraduate education. The plans have consistently stressed a need to nurture young researchers to build R&D capacity. Since the First Basic Plan was endorsed in 1996, all the plans have had one persistent objective: increasing the supply of highly educated researchers—namely, researchers with doctoral degrees.

FIGURE 8 Public spending on education, by level (% of GDP)



Source: OECD indicators, "Public Spending on Education," 2020 or the latest available indicators.

The First Basic Plan focused almost exclusively on improving R&D capabilities. The plan proposed a comprehensive approach to R&D improvement, encompassing factors ranging from the quantity and quality of researchers to the research environment, to research funding, to researchers' mobility and increased knowledge spillover. The 10,000 Postdoctoral Researchers Program is the best-known policy of the First Plan (MEXT 1996). The program aimed to engage 10,000 postdoctoral researchers by creating fixed-term paid postdoctoral positions. Before the program, those researchers may have stayed in a university as so-called over-doctors without pay until they found regular positions.[10] The target of 10,000 was achieved by 2000. Postdoctoral researchers were included in various public organizations as part of multiple schemes, including as part of research fellow programs of the Japan Society for the Promotion of Science, in positions in projects of the Japan Science and Technology Agency, and in nonregular posts in national universities. The First Basic Plan also introduced fixed-term employment for university researchers to increase mobility and promote competition among them. The fixed-term appointment system became more widely implemented during the Second Basic Plan (2001–05) (Cabinet Office 2001). While the Second Plan also suggested that private companies should actively consider hiring doctoral graduates and postdoctoral researchers, no significant actions were taken to this end.

By the early 2000s, however, the issue of postdoctoral researchers' uncertain career paths surfaced. The number of researchers completing doctoral degree programs or postdoctoral programs outpaced the number of open regular research positions or university faculty positions. At the same time, private companies were not ready to absorb them. The Third Basic Plan (Cabinet Office 2006) indicated a need for private companies to hire doctoral program graduates and encouraged industry-university collaboration in nurturing human resources. It suggested a few concrete measures, such as internship programs, postdoctoral researchers' participation in university-industry research, and industry participation in university education reforms. In 2008, during the implementation of the Third Basic Plan, a plan to increase the number of international students to 300,000 by 2020 came into effect. The target was achieved by 2019, a year early (MEXT 2021a).[11]

The Fourth Basic Plan (Cabinet Office 2011) continued efforts toward career path diversification for doctoral program graduates, and continued financial support for students in doctoral programs. The plan also suggested adjusting graduate school education to help students acquire the soft skills required by private companies. The Fourth Basic Plan acknowledged the increasing international competition for securing talent and the need to

10 The postdoctoral program intended to cultivate the abilities of young researchers and enable them to play an important role in research, in turn enhancing Japan's R&D capacity.

11 Of the 312,214 international students, 53,089 were in graduate school and 92,952 were studying in universities or colleges. This means that international students constituted 5 percent of the total students in higher education (2,918,668) in 2019 (MEXT 2021a). The rest were in technical, language, or prep schools. The number declined due to COVID-19, and is recovering. In 2023, there were 279,274 international students (MEXT 2023).

attract international talent (researchers and students) to Japan. Meanwhile, the devastating earthquake of 2011 led foreign scholars and students to leave Japan; the fear of losing them may explain Japan's emphasis on internationalization. The Fourth Basic Plan included support provisions such as fellowships (research grants) and scholarships, renewable contracts of three years or more, measures related to immigration control, and the development of an international environment in neighboring municipalities, including the creation of an environment suitable for families. These provisions were made to promote the acceptance of outstanding international researchers and students at universities and public research institutions.

The Fifth Basic Plan (Cabinet Office 2016) pursued the same direction for human resources as the Fourth Plan, including special support for foreign researchers and students. In addition, the government promised educational reforms specifically for nurturing engineers, and particularly encouraged the growth and retention of engineers in fields with notable talent shortages (e.g., in information and communication technology fields) through industry-academia collaboration at universities, technical colleges, and vocational schools. The plan also addressed the need to reform primary and secondary education to cultivate students' interest in science.

The Sixth Basic Plan (Cabinet Office 2021) emphasizes the importance of creating an environment that allows researchers to fully utilize their diverse abilities and continuously challenge problem-solving. It discusses career path enrichment for excellent young individuals, especially postdoctoral researchers, and highlights the need for academia to reform graduate education and industry to recognize the potential of doctoral talent. While the earlier Basic Plans had left education, support, and career path development for young researchers, including those with doctoral degrees, almost exclusively to the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Sixth Plan finally assigned other government agencies, such as the Ministry of Economy, Trade and Industry (METI) and the Cabinet Office, to help increase postdoctoral career opportunities in industry and government offices.

All the plans included efforts to increase the number of young researchers and doctorates. The plans have resulted in a gradual increase in financial support for doctoral students, and additional research grants have been made available to postdoctoral researchers. Meanwhile, the plans' focus has gradually expanded to cover international students. Attracting international students and researchers, together with nurturing Japanese students, was a clear talent acquisition strategy since the Third Plan. A shift in the talent acquisition strategy is well illustrated by the portfolio theory of talent development (Shin and Gordon 2024; Shin forthcoming). The strategy has expanded from an exclusive focus on domestic talent to include foreign talent—that is, from an exclusive “brain train” to a mix of “brain train” and “brain gain” strategies. But the fundamental challenge of improving career paths has remained unresolved. The government did not help increase regular positions in universities, nor did it make serious attempts to boost employment opportunities in the private sector.

After almost 25 years and five Basic Plans, the number of researchers with a doctoral degree increased from 121,326 in 2002 to 180,943 in 2020, 13–15 percent of whom are employed in private firms (Kanda et al. 2021). But MEXT is concerned that the number of doctoral degree holders per 1 million persons in Japan is still significantly lower than in several OECD countries. In 2018, this number was 375 in the United Kingdom and 336 in Germany, but only 120 in Japan—or only a third of the UK and Germany. Moreover, the number of doctoral program applicants has been decreasing in Japan. Defying the trend, MEXT announced in 2024 a plan to triple the ratio of doctoral program entrants to university graduates by 2040.

As for the objective of improving research capacity, there is a sign that postdoctoral researchers have helped improve research quality. Postdoctoral researchers constitute about 4 percent of the researchers in universities and public institutions, and they play an important role in research. According to the Japan Society for the Promotion of Science (2018), the research papers produced by postdoctoral researchers were of significantly higher quality than the average for all researchers—measured by the share of the top 10 percent cited papers.[12] This positive effect, however, was not enough to reverse the trend of a declining share of frequently cited papers, as discussed earlier.

Recent studies show personal economic gains from obtaining a doctoral degree. For example, Morikawa (2024) studied microdata for doctoral degree holders and found that the probability of being employed is significantly higher for them, especially among women, compared with master’s degree holders. Persons with a doctoral degree tend to be employed in higher-wage occupations and earn about 40 percent higher wages than those with a master’s degree (who already earn 25 percent higher wages than those with a bach-

12 Among Japanese researchers, those who had joined postdoctoral programs contributed to a substantially higher share of the top 10 percent cited papers than the average.

elor's degree). An employment survey also shows that doctoral degree holders' annual income is substantially higher than that of master's degree holders (Sakamoto 2019).

Meanwhile, anxiety over insecure career paths has overwhelmed the probability of personal economic gains. Uncertain career paths and difficulty finding permanent research jobs in academia are said to have discouraged students from pursuing doctoral programs and resulted in fewer applicants (Suzuki, Yasuda, and Goto 2021). The number of doctoral program entrants declined from a peak of 18,232 in 2003 to 14,976 in 2019. The number of postdoctoral researchers also declined from a peak of 15,590 in 2018 to 13,657 in 2021.

The composition of doctoral program students also has changed, with more students entering after gaining work experience. Of the doctoral program graduates in 2018, more than 50 percent had entered a program after having worked or while employed. Some students are, in fact, encouraged by their employers to get a doctoral degree. The number of international students in doctoral programs has also increased. In 2023, 19,233 of 75,841 students in doctoral programs, or a little over 25 percent, were international students (MEXT 2023b). Also, a third of postdoctoral researchers are international (MEXT 2024).

Job insecurity is a common concern among postdoctoral researchers in many OECD countries (OECD 2010, 2021, 2023), even though most of them continue to have an increasing number of doctoral program entrants. Only a limited share of doctoral degree holders find tenure-track positions. For example, in the United States, in 2017, only 20–30 percent of PhD holders held a tenure-track position, and private sector employment (42 percent) was nearly on par with educational institutions (43 percent)(Langin 2019).

In Japan, however, limited tenure-track positions aside, opportunities in the private sector are very limited. While some suggest that doctoral students' narrow career focus on university research jobs is part of the issue, there is evidence that private companies' attitudes toward doctoral students have made an uncertain career path even worse for doctoral degree holders in Japan. The reluctance of private companies to hire doctorate holders is partly explained by recruiters' (mis)perceptions and deficient assessment capacity. Company recruiters often think that doctorate holders are inflexible or too narrowly focused and that those who pursued doctoral degrees are unprepared for positions in private companies. Even an executive of a major recruitment company and a few elite government officials shared such views. Also, recruiters' education level influences their inclination to hire master's or doctoral degree holders (Hamanaka 2015). Recruiters with doctoral degrees had the greatest inclination to hire doctoral students or doctorates, followed by recruiters with master's degrees. There is anecdotal evidence, however, that the value of doctorates is being increasingly recognized.

Hiring people with advanced degrees or expertise is logical given the growing demand for specialized knowledge and businesses' declining in-house investment in human resources. The educational attainment of innovators has increased over time in the United States, for example, as science and technology progress, new researchers need to spend more time simply reaching the frontier of their field of study (Jones 2009). Innovation, as measured by high-quality patent activity, is almost exclusively achieved by individuals with advanced degrees (Shambaugh, Nunn, and Portman 2017). Nagaoka and Honjo (2023) indeed propose that, for Japanese companies to increase their ability to absorb science, they should actively engage doctoral degree holders and make better use of their talent while expanding cutting-edge research.

During Japan's period of high economic growth, in-house R&D and talent development in large companies led to process improvements and innovation, and innovation significantly contributed to improving corporate performance (Suzuki, Yasuda, and Goto 2021). Large companies used to recruit fresh graduates and extensively train them in-house to achieve a fit with the company culture and workflow and learn skills and technologies. This is no longer the case. Firms have been investing less in educating and training employees. Japanese firms' investment in talent development, as measured by its share in the GDP, has declined since the mid-1990s and was merely 0.1 percent during 2010–14—among the lowest in the OECD countries (METI 2022; Ministry of Labor, Health, and Welfare 2018). Large firms' per-employee spending on education and training declined almost 30 percent over 2011–19, while the per-employee spending by smaller firms (with 999 or fewer employees) increased significantly (Sanro Research Institute 2022).

It is indeed a regrettable loss for individuals, companies, and for Japan as a whole if businesses' (mis)perception or deficient assessment capacity is hindering them from leveraging opportunities to utilize doctorate holders' advanced knowledge and skills, and the consequent job insecurity is discouraging people from pursuing a doctoral degree. An analysis of U.S. patent data illustrates a beneficial relationship between the academic field and the patent domain (Oroku 2024). Firms that effectively absorb and apply academic knowledge appear to gain a competitive advantage, as indicated by patents with increased value and technological diversity. This relationship highlights the importance of developing strong connections between industry and academia, which can produce high-quality innovation and generate profitability through the exchange of knowledge and ideas.

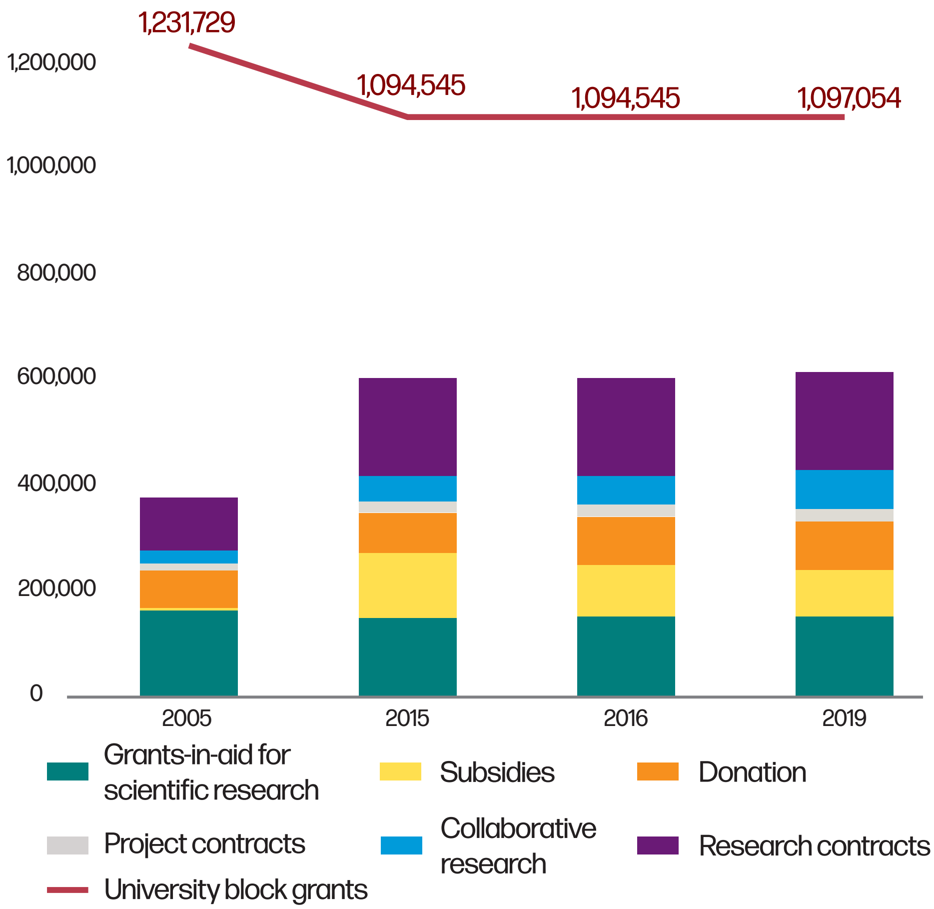
University Reforms Affecting University Research

The above sections illustrate the mixed results of the Basic Plans' policy measures to nurture human resources in research. There is incoherence within the plans—for example, the introduction of fixed-term appointments resulted in career uncertainty. Also, another set of policies external to the Basic Plans, in fact, undermined them.

In 2004, a major university reform was launched and national universities were partially privatized. The reform was justified on the grounds that the autonomy of universities would allow them to manage themselves efficiently and that introducing competition among universities would encourage them to improve. This reform was also part of an overall administrative reform (Mitsumoto 2004) that sought to make the government more efficient through, among other things, privatizing and reducing the number of public employees (Cabinet Office 2004). MEXT declared the introduction of (i) management with a "private sector mindset"; (ii) autonomous and agile operations through deregulation of budgets and personnel; (iii) a flexible personnel system based on ability and performance (noncivil servant type); and (iv) appropriate resource allocation through third-party evaluation, proactive information disclosure, and increased social contribution (MEXT 2016).

The partial privatization was accompanied by a reduction of university block grants by 1 percent every year; this pressured the national universities to expand their revenue sources. The block grant size was reduced for 10 years and remained around the same level thereafter (figure 9). At the same time, national universities received about the same amount of the grants-in-aid for scientific research, which is the main competitive research fund. This pressured national universities to expand their revenue sources. The share of research and project contracts in the overall financing substantially increased. In 2016, a partial performance-based allocation system was introduced to the block grants with the aim of improving university quality. The system tended to benefit bigger universities with more resources and further reduce resources for smaller universities. National universities, although fewer in number than other public and private universities, produce the majority of research in Japan (Murakami and Igami 2018). Thus, privatization and reduced block grants had a significant impact on the research environment.

FIGURE 9 Financing sources of 86 national universities and 4 inter-university research corporations(in ¥ millions)



Source: MEXT 2021b.

University presidents and researchers have voiced concern that university reform and university grant reduction have had negative effects (e.g., Yamamoto and Masutani 2024; MEXT 2010). The competitive research fund may also have increased government influence on research topics and increased the administrative tasks surrounding applications and the submission of monitoring reports.

Such a shift from conventional block funding toward more project-based competitive funding has also occurred in other countries, including EU countries. The main assumption underlying this shift is that competitive funding would encourage research performance and promote the efficient use of scarce financial resources. Empirical evidence, however, is inconclusive. A study of EU countries confirmed the positive role of funding amounts for research outcomes—measured by the quantity or quality of the papers produced. The study also confirmed that competitive project funding has no significant effect, positive or negative, on the quality of publications—measured by the share of publications among the top 10 percent most cited papers (Zacharewicz et al. 2023).

As mentioned earlier, Japan's ranking in the number of frequently cited papers started declining rapidly around 2004–05. Kikuchi's analysis (2023) of publications during 1999–2009 suggests that the partial privatization of universities led to a decline in the quality and quantity of national universities' research outputs soon after the 2004 reform. This negative effect was pronounced in medical science; some sectors were not affected. A study of the publications over 2001–06 that had at least one author affiliated with a Japanese organization warns against potential biases in competitive funding allocation procedures (Wang, Lee, and Walsh 2018). The study's authors found that projects supported by competitive fund had greater novelty on average than those supported by block grants, but only for high-status researchers (who tend to be senior and be male); for researchers with lower academic status (particularly researchers who are junior and female), the relationship is reversed: novel projects are less likely to win competitive funding. These findings indicate that the university reform affected research outputs, and whether competitive funding would yield better research is an empirical question, and competition leading to better research cannot be taken for granted.

The university reform significantly affected the situation for researchers. The university block grant reduction has led to the number of open tenure-track positions stagnating in national universities, in turn contributing to uncertain career paths for young researchers.[13] Competitive research funding only finances fixed-term researchers and staff for project periods. Permanent faculty or staff positions need to be financed by block funds. The reduction of university grants has led universities to reduce support staff positions, thus increasing administrative tasks for faculty members.

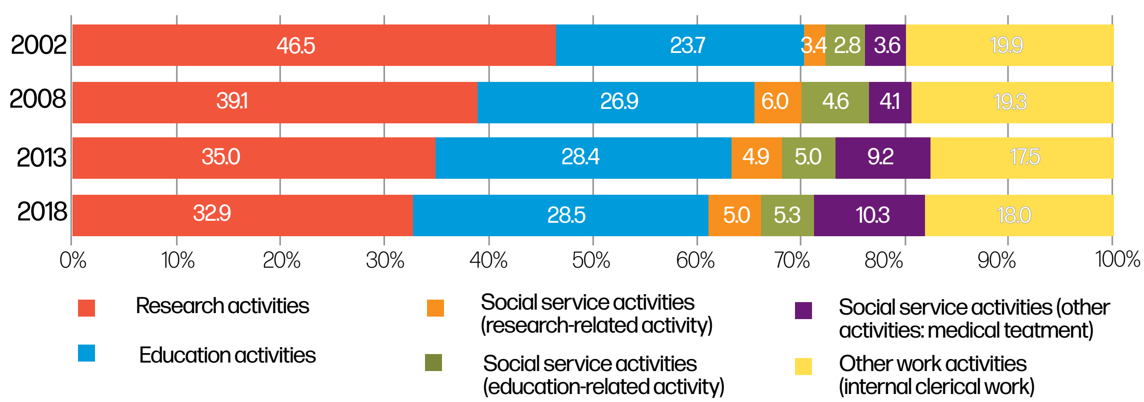
Besides teaching and community engagement, administrative tasks, including those related to competitive research grant applications and reporting during and after the grants' implementation, lead to a decline in the research time for faculty members (figure 10). While the number of faculties hardly grew, competing demands on their time led to the actual hours spent on research declining from 46.5 percent in 2002 to 32.9 percent in 2018 (Kikuchi 2023).

13 As universities could not fire already existing faculty, the number of new positions opening up became very limited and too few to accommodate the increasing number of doctoral program graduates.

Thus, the total hours spent on research by university faculty has declined. The largest drop, between 2002 and 2008, was likely due to the partial privatization of national universities. About 80 percent of university faculty feel they have insufficient time for research due to other tasks (meetings, support for entrance exams, compliance with local administration rules, and applications for research grants) (Yamashita et al. 2024).

The number of researchers (factoring in the percentage of time spent on research) and the number of published papers have a strong correlation. Longitudinal analysis of the number of papers from Japanese universities in the fields of science, engineering, and agriculture shows that (i) a decrease in the share of time spent on research and a stagnant number of faculty members explain the decline in the number of research papers during the mid-2000s up till 2010, and (ii) a decrease in the number of doctoral students and inadequate expenditures on research materials explain the reduction since around 2010 (NISTEP 2023).

FIGURE 10 Changes in the ratio of time spent on work activities by university faculty members in all fields



Source: Prepared by MEXT based on its Survey of Full-Time Equivalency Data at Universities and Colleges.

Other countries also introduced the privatization of universities, business management tools, and a shift from block grants to competitive funding for universities, with mixed results in terms of the quality and quantity of higher education (Pritchard, Pausits, and Williams 2016). Existing findings for Japan appear to indicate that the university reform has adversely affected university research by reducing the aggregate time spent by faculty members on research and limiting predictable financial resources, even though the reform may have positive effects on other aspects, such as increasing university-industry collaboration. Meanwhile, the university reform did not help increase the number of researchers with doctoral degrees: the limited openings of tenure-track faculty positions worsened career insecurity, and competitive research funding may have disadvantaged younger researchers.

Discussion

Despite sluggish growth, since 1981 Japan has continued to be the world's most complex economy and remains among the leading countries in innovation. Japan's economy is very knowledge intensive and Japan is the second largest exporter of intellectual property in the world (WTO 2023). But does the country have an equally strong flow of innovations and new intellectual properties to sustain this trend? The quality of innovation seems to be trending down. Universities and businesses both show warning signs of declining R&D, which is a critical instrument to generate innovation. This paper considers whether a series of science, technology, and innovation public policies contributed to strengthening Japan's R&D and innovation capabilities.

Beginning in the 1990s, Japan developed and implemented a series of five-year Science and Technology Basic Plans (as of 2020, Science, Technology and Innovation Basic Plan). While the Basic Plans have multiple objectives and agendas, all the plans have had one persistent objective: increasing the supply of highly educated researchers—namely, researchers with doctoral degrees—since the First Basic Plan was endorsed in 1996.

As science and technology advances, it takes more time for new researchers to simply reach the frontiers of their fields of study; in response, in places like the United States the educational attainment of innovators has increased and innovation is achieved by individuals with advanced degrees. Given that, focusing on R&D and nurturing researchers with doctoral degrees is a justifiable cause, and the government's foresight was commendable. Yet, 25 years of persistent attempts to increase the number of doctoral degree holders and thereby enhance R&D capability have had mixed results. There have been some positive results from the policies: financial support for students in doctoral degree programs and for postdoctoral researchers has increased, and there are signs of the internationalization of postgraduate education. However, incoherences within the Basic Plans' policies, and between the Basic Plans and the university reform policies, and the inadequacy of coordination between the government, the private sector, and universities compromised achieving the objective.

By the mid-2000s, it had become evident that uncertain career paths and job insecurity discouraged eligible persons from pursuing doctorates. Neither academia nor business provided stable employment for young postdoctoral researchers. The fixed-term employment system introduced and rolled out under the Basic Plans disproportionately affected young researchers and aggravated job insecurity.

The 2004 university reform, which included the privatization of national universities, university block grant reduction, and a shift to competitive research funding, constrained the number of permanent research positions and worsened the insecure career paths of young researchers. Moreover, faculty members' reduced time spent on research and the smaller number of doctoral students diminished research outputs, and the quality of research papers, as measured by rankings of most frequently cited papers, started declining with the onset of university reform. Overall, the 2004 university reform unintentionally undermined efforts to improve R&D capabilities, especially the goal of increasing researchers with doctoral degrees and improving R&D quality, although it has brought positive changes, such as increased collaboration between universities and businesses.

The university reform was part of a broader administrative reform that specifically sought to increase the economic efficiency of national universities by introducing management tools traditionally associated with the private sector, including increasing competition. Such reforms have produced mixed results elsewhere. Pursuing economic efficiency like private companies does not always bode well with public goods, such as research outputs. From the budget perspective, or the Ministry of Finance's point of view, universities are cost centers, especially now that the university-age population is declining, and economic efficiency is a priority under the tight budget. On the other hand, from the perspective of science and technology development, higher education is an important investment in human resources, and research is a fundamental investment that generates long-term returns.

Although the government mandates policy evaluation, the feedback loop from policy implementation assessment to evaluation to policy adjustment did not seem to fully function in addressing the 25 years of unresolved issues. The effectiveness of the Basic Plans' public policies relevant to research-related human resources, together with the university reform, must be analyzed rigorously—considering what worked and what did not—instead of debating what should have worked or what should work. It is time to critically evaluate whether there needs to be a different cost-benefit analysis for the long term and a different resource allocation for universities and research to optimize the benefits to the country. As Nobel laureate in physics Takaaki Kajita noted, "The experiment [to test] the hypothesis that competition without resources would produce results has failed" (Kyodo News Service 2022).

Because of their reluctance to hire doctorate degree holders, businesses probably missed out on valuable opportunities to take advantage of those human resources to contribute innovations to the private sector. The need for an increasing number of doctorate holders did not appear to be an agenda shared by the government and the private sector even though young researchers with advanced degrees would transfer new knowledge and likely help companies link new scientific discoveries to their innovations. But also, the Basic Plans failed or did not do enough to increase private-sector jobs for young researchers. The Basic Plans only continued to "expect" or "hope for" the private sector to hire doctorate holders. A few former and current government officials have expressed the view that the government cannot influence businesses' recruitment behaviors.

The apparent lack of government-business coordination might be counterintuitive to some. Studies analyzing Japan's industrial policies and the government-private sector coordination during the rapid growth of the 1960s–80s suggest that the government, especially the Ministry of International Trade and Industry,[14] coordinated with different stakeholders and managed a complex set of negotiations (e.g., Johnson 1982; Okazaki 1997; Okimoto 1989). Even then, not all industrial policies were coherent or successful (Okimoto 1989). Compared with then, these days the private sector in general, and large companies in particular, rely far less on the government, whose influence on businesses, especially large companies, has diminished. Also, MEXT, which is responsible for policies to nurture researchers, especially policies promoting an increase in doctorates, does not have strong networks with businesses. Therefore, MEXT alone would have limited capacity to dialogue and negotiate with businesses, let alone influence private companies' hiring practices.

However, the tide may have finally turned several years ago, when the government and the business sector came to share a common agenda for overall human resources and engaging doctorate holders. Political stability provided the opportunity for the change. Human resource development is a long-term agenda. It took the long-lasting Abe administration (2013–20) to include in its political agenda human resource matters that had been simmering beneath the surface until then. Finally the government and businesses came to share a common agenda for overall human resources and engaging doctorate holders.

14 The Ministry of International Trade and Industry (MITI) was the previous incarnation of METI.

An official system of dialogue among MEXT, universities, and the private sector finally emerged in 2019, as the Council on Industry-Academia Collaboration for the Future of Recruitment and University Education was established. The Sixth Plan (2021–26) assigned other government agencies, METI, the Cabinet Office, and all other ministries to help increase postdoctoral career opportunities in industry and government offices. *Keidanren* (the Japan Business Federation) made the cultivation and advancement of doctorate holders and women in STEM (science, technology, engineering, and mathematics) fields a primary focus in 2023. In February 2024, it published "Proposals for the Development and Advancement of Doctor's Degree Holders and Women in STEM Talent," a set of recommendations that include specific measures to create an environment where highly specialized professionals can contribute to economic growth, as part of a broader strategy to make Japanese companies more competitive. In 2024, the MEXT minister sent a letter to businesses asking for their support, including providing employment, internships, and scholarships to doctoral program participants or graduates, while MEXT and other government agencies also plan to increase the hiring of doctorate holders. These movements signify that the government and the business sector now share the urgency of improving R&D and securing human resources with advanced knowledge. After all, private companies play the most critical roles in producing innovative products and services. Augmenting the latest scientific knowledge to the existing technical capabilities of businesses would likely offer fresh fields for innovation.

Universities have also been gradually changing. More of them are making efforts to prepare doctoral program students for jobs outside academia, as well as promoting entrepreneurship. International students constitute as much as 30 percent of doctoral program students in Japan, and about a third of the international students remain in Japan to work after receiving their doctorates, indicating that at long last, the talent portfolio strategy is diversifying from an exclusive "brain train" to a mix of that and "brain gain."

Another hopeful sign is a steady growth in university-based ventures, whose number increased from 130 in 1996, when the First Basic Plan was adopted, to about 4,300 in 2023. In 2022, 38 percent of the chief executive officers of university-based ventures and 45 percent of chief technical officers had a doctoral degree (Nikkei BP Consulting 2024). Being an entrepreneur is now becoming a realistic career option for doctorates, and these university-based ventures would likely accelerate linking science and innovation and add to Japan's innovation capability

A much-needed increase in university research funding is also happening. The research grant size has hardly changed, meaning that the real value of grants has been significantly reduced over the past 10 years. The government established a ¥10 trillion university fund in 2022 that will benefit only some universities, not all. The returns on research funds are expected to diminish beyond a certain point, and increased disbursal may yield better results. A substantial body of empirical research demonstrates stagnant or diminishing returns to scale for the relationship between grant size and research performance (Aagaard, Kladakis, and Nielsen 2020). The effect of the fund, as well as of the concentration of resources in a few universities, needs to be monitored and evaluated to enable policy adjustments if necessary.

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Stanford
Walter H. Shorenstein
Asia-Pacific Research Center
Freeman Spogli Institute

Shorenstein Asia-Pacific Research Center
616 Jane Stanford Way E301
Stanford, CA 94305-6055
650.723.9741 | **aparc.stanford.edu**