



# Leading the World with a Next Generation Model: Why Innovation is Essential to Science and Technology Policies

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## Reconsidering the question: “What is Scientific Research?”



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More than thirty years ago, as a scholar interested in science and technology policy, I read a large number of articles and publications. At that time, I believe, a particular assumption underlay this discourse on science; namely, that science stood aloof as if it were a completely independent kingdom within academia. It seems that this naive perception existed naturally both among scientists engrossed in actual science in the laboratory and among the general public, who we can expect to enjoy the fruits of science.

Among those who debate science and technology policies, this assumption fell apart a long time ago. Yet, for ordinary people, “science” is still a far off thing. It continues to be an object of worship, criticized with warnings against excessive expectations, and something special and separate. Whether it is celebratory news such as winning a Nobel prize, the Hayabusa2 mission, or black hole photography, or whether it is regarding questions of responsibility for an appalling nuclear accident... either way, in our country Japan, science is just something that’s remembered occasionally when a sudden event occurs.

Perhaps that is the reason only a few politicians seriously engage with science, which doesn’t provide them with votes. Meanwhile, despite the fact that the practice of “big science” necessitates ever more huge investments of public funds, academics hesitate to approach politicians.

We are now already well into a knowledge-based twenty-first century society. Today, science has an extremely broad and diverse effect on society, so how should we understand the intellectual activity that is science? How should we think about the nation’s fiscal involvement in those activities? What direction should our country’s science and technology policies seek to take? These are the issues that I intend to consider in this essay.

## Science studies in Japan and our position in the world

As a full-time executive member of the Council for Science, Technology and Innovation (CSTI) since 2016, I have been involved in government discussions on science and technology policies. During these, every day we share our extremely strong sense of crisis regarding the current state and future of our nation’s science and technology.

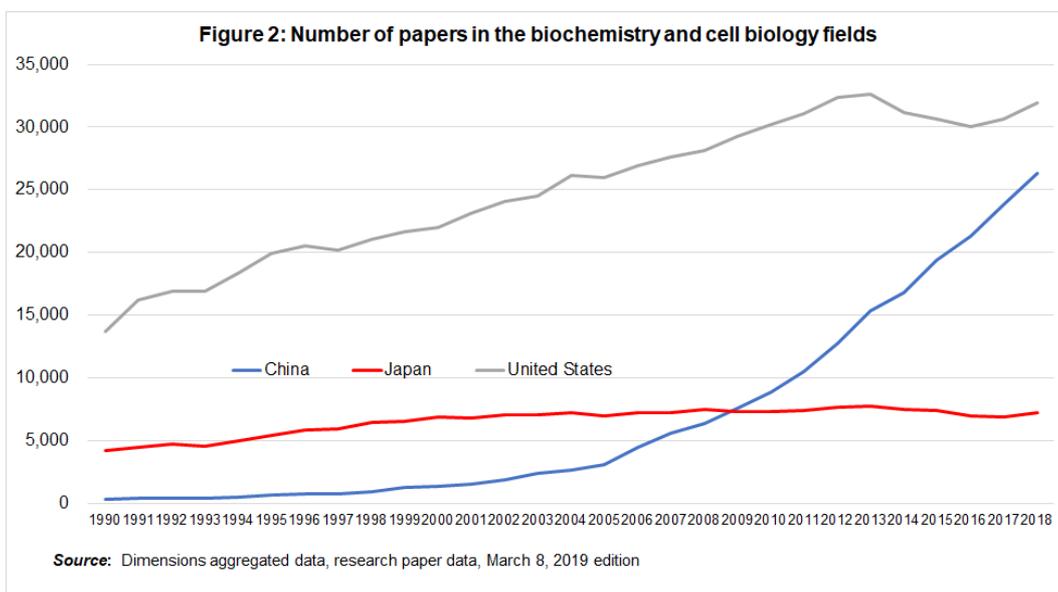
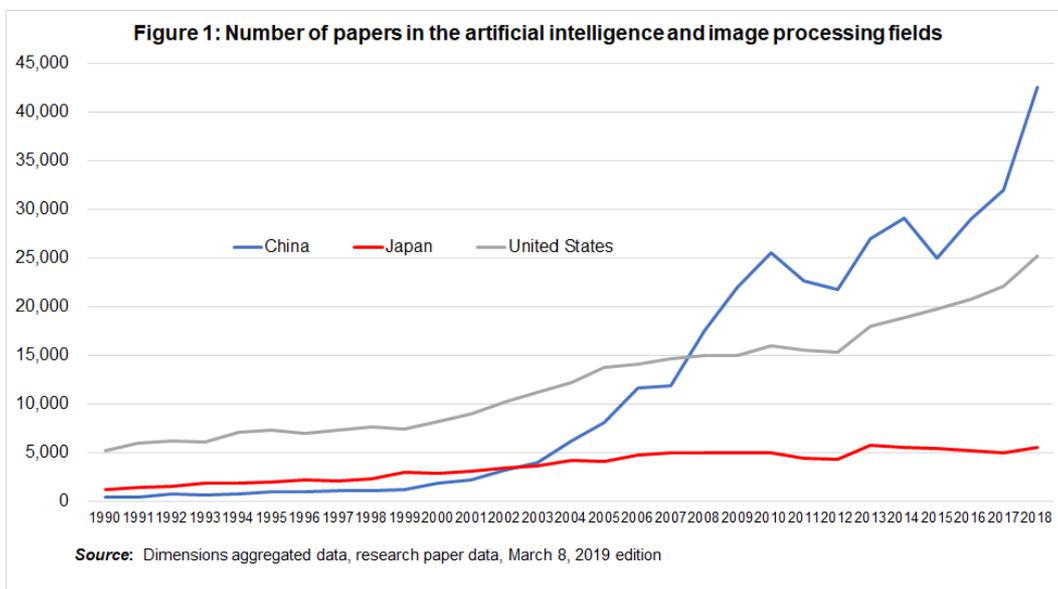
The reduction in basic research expenses at national universities, the worsening in the research environment at national universities in the regions that is produced by uneven distribution of competitive research funds, the widespread unease about their careers that talented young researchers feel, the rapid drop in students progressing to doctoral courses, the poor showing of Japanese

universities in global university rankings, Japan’s fading profile as countries compete fiercely in advanced fields of technology... all these facts seem to hint at a gloomy future for Japanese science.

Particularly critical is a weakening research capacity in Japan’s natural science fields. As is widely and often pointed out, whether one looks at the total number of papers or just the top 10% most impactful papers, since 2000 Japan’s position relative to other countries has rapidly got worse. If we continue like this without taking action, within five years academic studies in our nation will enter free fall, making recovery impossible.

There isn’t space here to discuss these international comparisons in detail. But we can take the AI field and the biochemistry fields as two examples, and I’d like to give some comparative data on the number of papers from the United States, China and Japan.

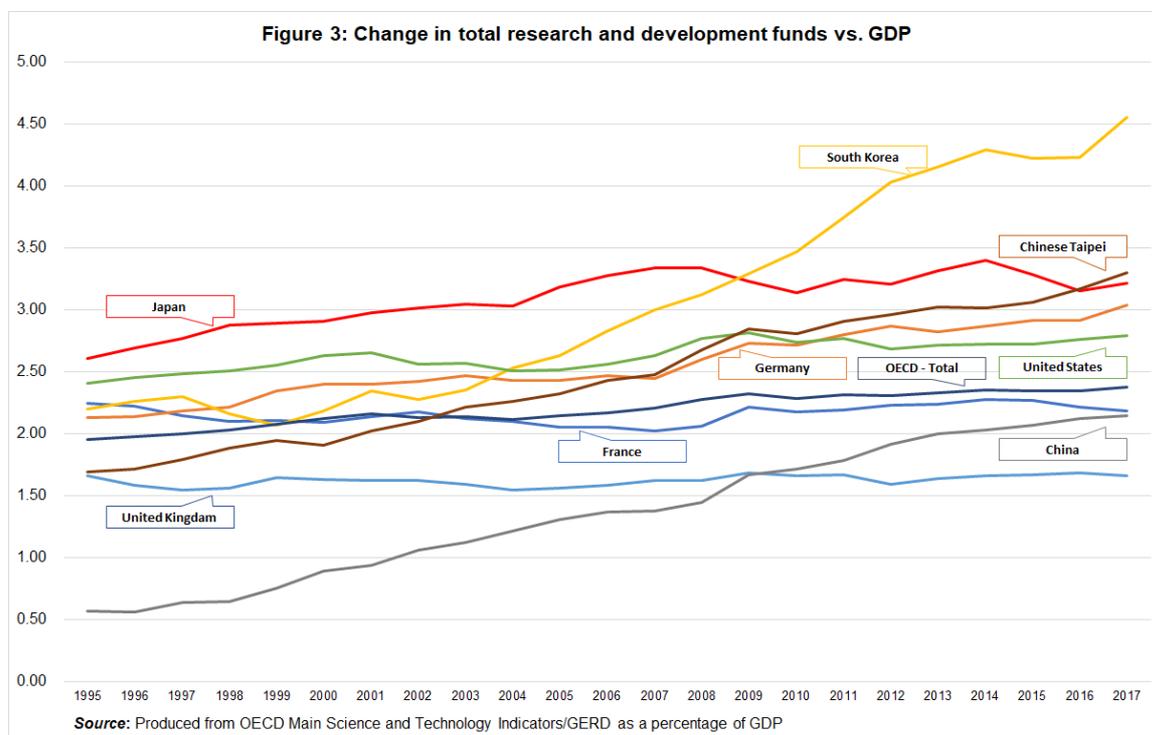
The most surprising thing is that, in AI and image processing, by 2008 China had already outstripped the United States. What’s more, if we look at life science basic research in biochemistry and cell biology, there too China was in the process of catching up with the United States. And I’d add that this is only data on the total number of papers, not the 10% of papers with the most impact (figure 1 and figure 2).

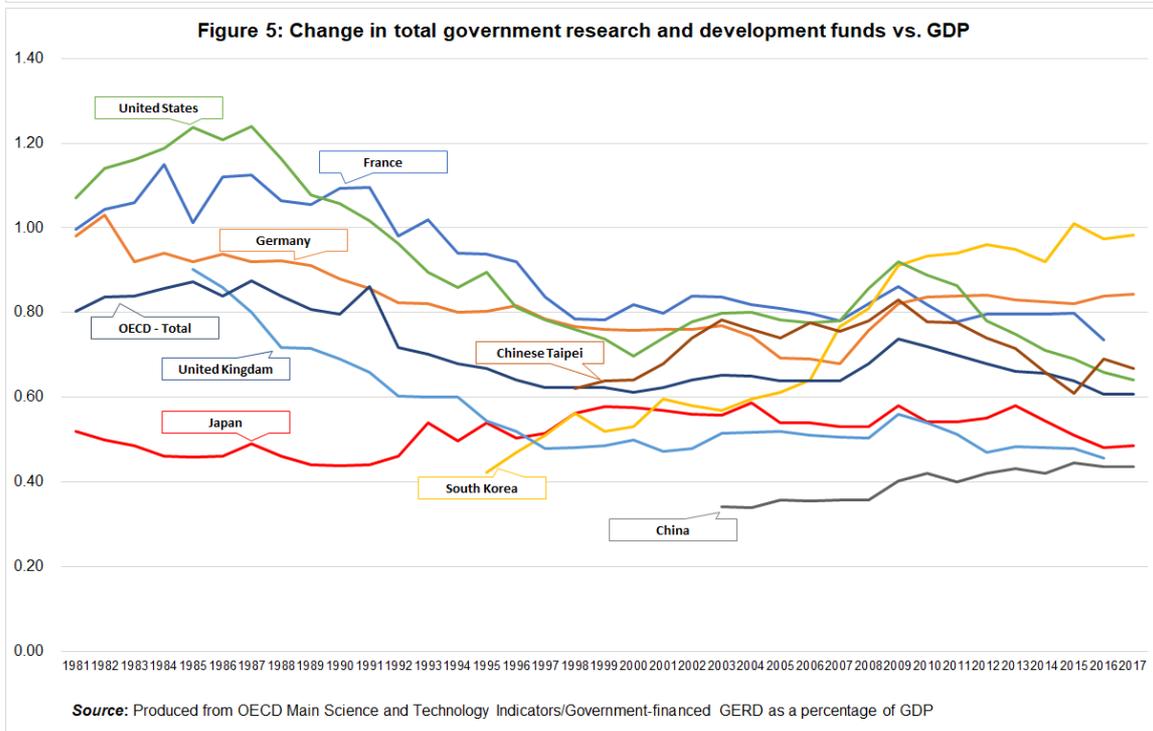
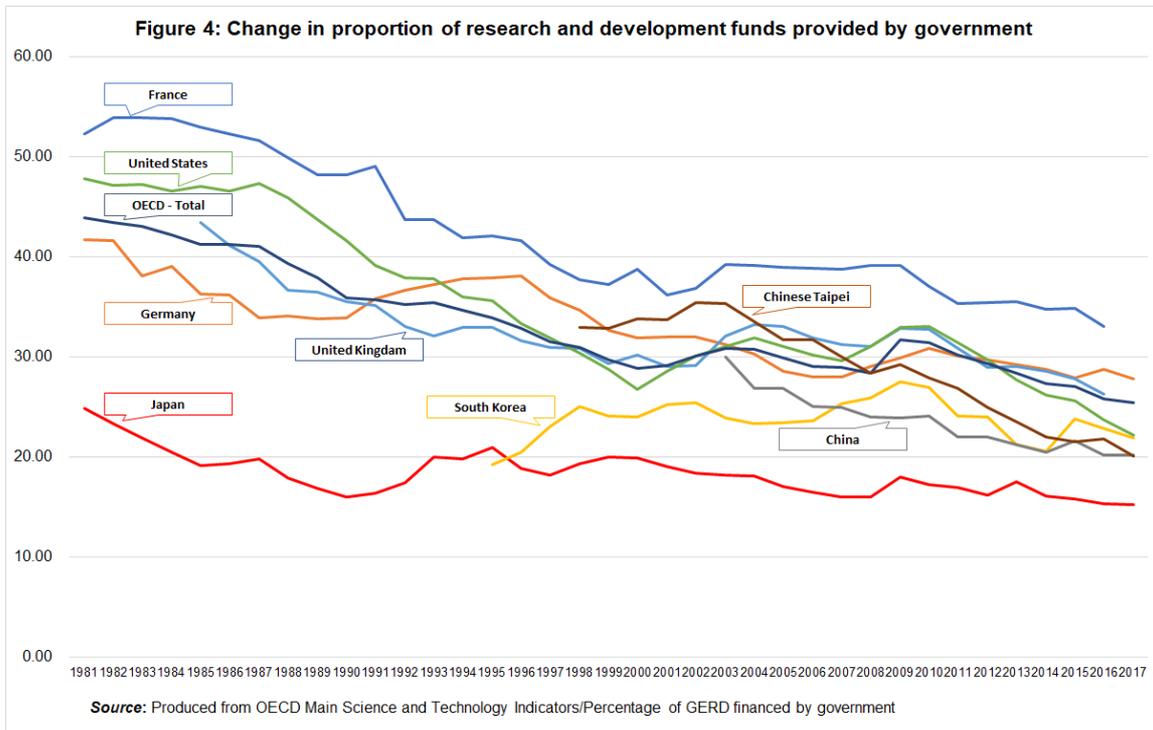


These facts are not simply a problem of our country’s relative position having fallen, despite us once being at the lead of cutting-edge science and technology in Asia. China is investing huge amounts of public funds in advanced fields. As a result, there is a rapid increase in the number of papers in fields that closely merge basic research and innovation, such as AI, robotics, bioinformatics and next-generation semiconductors. That’s because it knows that precisely this investment into such advanced basic research is pivotal for the creation of global wealth creation and security

Basic research itself is the root of innovation. Advanced nations, having suddenly become knowledge-based societies, are all investing enormous sums into advanced basic research. That’s because it’s the most effective investment to ensure they win out against global competition. If we take the examples of the United States and China, in the United States there is the National Science Foundation (NSF) and National Institute of Health (NIH), and also copious competition funds from the Department of Defense and others. As well as corporate venture capital from Google, Amazon and others, science studies are supported by huge funds from many private foundations: from the Rockefeller Foundation in the past up to the Bill and Melinda Gates Foundation more recently. China, meanwhile, is seeking to use an expansion of concentrated public investment to rapidly close the gap between itself and others.

To put this another way, our nation’s research and development investment is still small. If we compare our investment to GDP ratio to other OECD countries (excluding private investment which makes up over 70% of Japan’s total research and development) that figure in 2017 was small at 0.48%. (Although, if we look at per capita research funds, we are mid-placed.) Additionally, if we compare investment in basic research against the countries of Europe and North America, it is clear that it is less in Japan (figures 3 to 5).





To address this, in the 5th Science and Technology Basic Plan (2016), the government has already set targets of 1% vs GDP and a total 26 trillion yen of research and development investment during the five years to fiscal 2020. Considering that government debt has risen to 1,000 trillion yen, this increase target is quite ambitious. Even so, including the 250 billion yen in fiscal 2018 and 420 billion yen in fiscal 2019, the current total is expanding to be something like 18 trillion yen.

What Japan needs to do now is: steadily expand these investments into national academic studies; follow the example of countries such as the United States; and create a unique Japanese way of investing in science and technology while expanding private donations and joint research between universities and corporations.

## For Comprehensive Strategy on Science, Technology and Innovation

At the heart of that is the concept called “innovation.” The Council for Science, Technology and Innovation that I belong to changed its name in 2014 from the Council for Science and Technology Policy.

It seems that this change was in reaction to a kind of preconceived notion in the academic world. The criticisms were that the concept of innovation had made science and technology strongly outcome-oriented, that originally science was a curiosity-driven endeavor, and that preconditioning research support on later outcomes was putting the cart before the horse.

The original meaning of innovation, however, is to bring in new things; the concept is not necessarily premised on economic effects and outcomes. If we were to add a special meaning to innovation in the context of science and technology, we should think of it as actions that spread through society all the knowledge, ideas and “seeds” that are created by science and technology related activities. Personally, I believe that innovation means the results of advanced science, spreading those as widely as possible, and actions to make the fullest use of those results in society.

If we position spreading the benefits of science and technology as a central policy, it wouldn't be strange to consider almost all the nation's policies as related to science and technology. In fact, it would be hard to find anything in the lives of ordinary citizens in society that's not connected to science and technology or that hasn't benefitted from it. There are countless examples, such as autonomous drive tractors for agriculture, i-Construction and other infrastructure research, autonomous drive for traffic regulation, and in the healthcare field. Do any technologies exist — from Cyber security and quantum cryptographic communication technology to GPS big data — that are unrelated to national security? Furthermore the fruits of science and technology will be essential for optimizing ballooning social security costs.

Our country's science and technology related funds for fiscal 2019 (excluding those for regional public bodies and supplementary budget) were 4.2 trillion yen. But if we categorize the nation's science and technology initiatives as “creating innovation,” almost all national funding is somehow connected. To put that another way, when science-and-technology and innovation policies are drawn up, shouldn't we formulate concrete plans based not on four trillion yen, but on 60 trillion yen of national general expenditure?

If we assume that the purpose of science and technology policies is to promote science and technology, it would be better to consider the Comprehensive Strategy on Science, Technology and Innovation, a policy to expand the societal role and meaning of science and technology through the concept of innovation, to formulate processes to spread the seeds of science through society, and thus stimulate the nation's science and technology, as well as research and development investment. In other words, we need to reposition science and technology policies at the center of a substantial national strategy and work them out again with an eye on the budget of the whole government. In that sense, science and technology policies are more and more becoming a core element of the national strategy.

### The National Innovation System

When we talk about science and technology policies, on the other hand, there are many researchers who feel uneasy about the “nation” featuring prominently. Essentially, science is an international, cross-border and universal activity; and that is the sincere sentiment of individual researchers. Ever since the

establishment of the Royal Society in the seventeenth century, academia has sought a direction that makes it independent from individual nations and authority; so support for a free and independent academia must be at the core of science and technology policies.

However, complicating these important preconditions of academic freedom and academic independence is how, along with the twentieth century change from science studies to big science, sums of research funds that would have been unthinkable in the nineteenth century have become necessary, and how now it is only possible for citizens to provide this via tax money. What's more, whether it's basic research or applied research, everyone now understands how modern science and technology produces vast amounts of economic value. Copious public investment has been supported by the 1980 Bayh-Dole Act and other intellectual property strategies and policies to address technology transfer, as well as the growth in university-originated ventures, as typified by Silicon Valley. That is the mission of the twentieth century model that I mentioned earlier, and it is the fate of science studies to reflect the national interest of nation states.

If you look at nation states over a 500 or 100 year time span, they gradually shrink and in the far future they probably disappear. Even so — and at least over the next half-century — the role of the nation as a provider of funds for science and technology will certainly not decline. On the contrary, it will probably become even more significant.

### **Problems of historical importance for humanity and Japan's role**

What's more, I'd like to emphasize that a national strategy perspective like this is not unilateralism and that there are implications for contributing to human history.

Since the beginning of the nineteenth century, when human history first escaped from cycles of increased wealth and contractions caused by famine and poverty in response (the so-called Malthusian trap), and when explosive economic growth and increase in population started, the countries flatteringly once called "advanced nations" have all enjoyed the benefits of wealth creation. Clearly, it was science and technology that made that possible. The systems that linked science and technology to the expansion of wealth began in North-West Europe, and the later countries adopted that model the swifter and more extensively they recreated the structure of their societies. If we call this the "Pre-21st Century" development model, we could also call Japan one of the last "catch-up" nations.

But for latecomer countries, this twentieth century model is now becoming more and more difficult to achieve. As early as 1972, *The Limits to Growth* (a Report for the Club of Rome) was released, issuing strong warnings about the pressing problems of population growth and environmental destruction, and also how growth was squandering and exhausting global resources. Faced with the visible crisis of global warming, even if we don't heed the laments of COP21 and the Paris Agreement, we face a pressing need to change the social model at a global level.

If we accept that science and technology has brought humanity wealth and well-being, it must also be in the power of science and technology to bring improvement where it has stumbled. Our nation adopted this twentieth century model faster than any other country and enjoyed its benefits to the fullest. At the same time, it is was also Japan that faster than any other country, through advances in science and technology, impressively overcame the environmental damage failures that accompanied the period of rapid economic growth.

As we well know, now Japan has been given new trials: issues such as decreasing birthrate and aging population, the concentration of young workers in large cities, and the growing economic disparity

between regions. These are problems typical of developed nations, and since our country was one of the last to adopt the twentieth century model, we are the first to face these issues. The vision named “Society 5.0” is presented in the 5th Science and Technology Basic Plan as a conceptual model that seeks to solve these issues.

In the society that Society 5.0 aims to realize, the Internet of Things (IoT) connects all people and things, diverse knowledge and information is shared, and value that had never existed before is created. Additionally, it uses AI to provide necessary information at the necessary time, and aims to overcome the issues of decreasing birthrate and aging population, rural depopulation, and wealth disparity with robotics and autonomous vehicle technology. Furthermore, through innovation it aims to break through existing feelings of despair to create a society with hope; one in which different generations respect each other, and an inclusive human-centered society in which individuals can be active in comfort.

Although this concept is presented as a national strategy, the benefits of science and technology are not limited to creating wealth for just one country; contribution to global society is positioned as a central value.

### **The progress of the digital revolution and the nation state**

Truly, we are now right in the middle of the so-called digital revolution, and the Society 5.0 concept reflects that world view. Dramatic advances in semiconductor electronics technology such as memory, sensors and CPUs, the global spread of the Internet that we first saw in the 1990s, and also the development of innovative platforms such as AI, IoT, robotics, and big data, have all had a decisive impact on human societies.

This digital transformation is now causing a critical paradigm shift in systems to create added value and the global social structure. Assuming that the twentieth century economic model was an industrialized society tied to the provision of goods, in the twenty-first century all industries have switched to services provided through cyberspace, and that space is a boundless one that crosses regions and nations. For that reason, it easily crosses the national borders that governed the twentieth century model, and has created an economic system that produces enormous profits.

On the other hand, the success of industries based on knowledge and information really does predict the rise of a new twenty-first century cyber-empire. Digital capitalism, as represented by the GAFAs (Gang of Four big tech companies), was carried on the post 1980s current of globalization, and conducted its activities in a digital space that went beyond the nation state, and what’s more was even minded to negate the nation state itself. Because of that, it was a completely logical and natural thing to do for these huge IT companies to use tax havens and devise massive tax avoidance.

### **Digital capitalism and Japan’s trustiness**

The digital revolution currently in progress will probably see a struggle: will it in the end go beyond nations, or conversely, will it be completely controlled by states? Countries (such as China) have already appeared that are in the process of implementing complete control of information by the state. Meanwhile, policy frameworks such as the EU’s General Data Protection Regulation (GDPR), which addresses the control of personal information by GAFAs, is a healthy antithesis to this cyber-capitalism. The 2020s will surely be a battle for territory between these two.

The threat of digital capitalism isn’t limited to the GAFAs’ holding of personal information. Major

academic publishers are not just mapping nascent future ideas and seeds of thought that appear in the research papers sent to scientific journals, they are working to discover seeds of thought in early research by providing consolidated lab notes. In addition, they are downloading information on research trends from researchers' e-journal IP addresses, collecting it together, and seeking to link that to business. Bearing in mind that science and technology is supported by immense sums of public funds from various countries, a struggle between nations and information start-ups is apparent here, too.

Around the world, the GAFA and BAT (Baidu, Alibaba, Tencent) are in the process of taking control of digital data, while our country is lagging well behind. The main future battlefields however, are in so-called real data (real-world data); i.e., materials, cohort, weather/disaster and logistics data. Our country is rich in this data, and has capabilities in the basic research that produced Nobel laureates during the Heisei period (1989–2019), so there's a chance to recover.

Through science and technology and innovation, we should aim to contribute to the building of a next-generation world order via a new system of values called "trustiness." Practically, this means utilizing strong research capabilities based on real data with high trustiness, the creation of innovation, and leading global scale system innovation. The core concept that runs through these endeavors is trustiness; trustiness regarding data, trustiness regarding research ability and results, trustiness regarding the ability to achieve implementation in society, and trust and support from other nations as research is shared globally are all essential.

Rather than talking about our own national strategy, i.e. the Comprehensive Strategy on Science, Technology and Innovation, surely our country needs to closely follow the huge change that is the digital revolution, while asking how we can best contribute to the new world order that will be created.

### **From the Atlantic economic area to the Pacific economic area**

This struggle between the United States and China for supremacy over digital transformation is becoming clear in the Pacific economic area. It seems that the twenty-first century world order is in the process of repeating the path that history trod in the twentieth century. As was the case during the twenty years following World War I in the twentieth century, following a time of struggle between nations over resources and technology, once again our country may be among those that face the toughest of geopolitical trials during a process of world order recovery in the second half of the twenty-first century. Japan is positioned — geographically and otherwise — at the core of the Pacific economic area that will form the new world order during the second half of this century. Therefore, the nature of our policies during the five years from 2021 is likely to decide whether or not our country can become the leader of this economic area or not.

The twentieth century model that linked science and technology to wealth arose in North-West Europe and created great prosperity in an Atlantic economic area that extended to the East Coast of North America and South America. Even as hegemony shifted from Pax Britannica to Pax Americana, this model started in the knowledge bases of Europe, such as Oxbridge, the University of Paris, and the Max Planck Society for the Advancement of Science, then expanded to Harvard and other Ivy League Universities on the US East Coast, finishing up as a wide economic area that encompassed these bases for knowledge and science and technology.

Given a theoretical base in Vannevar Bush's well-known work *Science: The Endless Frontier*, during World War II the United States invested what were thought to be inexhaustible resources into basic research; and that research created the foundation for an industrial structure based on pure science and

technology in the second half of the twentieth century. Semiconductors, automobiles, electronics, biotechnology... a series of twentieth century industries were born and had their starting point in this economic area.

What's more, the frontier of scientific knowledge in the twentieth century crossed the Northern American Continent and reached the West Coast belt of land that looks out on the Pacific, leading to the discovery of a new source of wealth: the Pacific economic area. The most famous symbol of that is the global phenomenon known as Silicon Valley.

Yet, Silicon Valley, which had made an artificial base for science and technology in the suburbs, is the final horizon for the twentieth century model. Today, as the economic model of tangible goods founded on science and technology truly approaches its demise, the manifestations of innovation are shifting from the suburbs to the city. As part of that process, even Silicon Valley is suffering as it has to change its innovation ecosystem.

### **The next generation model and the Pacific economic area**

I'd like discuss expectations for the next generation. I believe that the following will probably be sought from innovation during the second half of the twenty-first century: an image of society, a feeling of well-being, lifestyle, morality, trustiness, art and science, next generation commonality, a connection with citizens, empathy with nature... How can we link these new soft power values to science and technology? Can we propose new values rooted in these "intangible" goods? Success or failure in this will likely determine who leads the new economic area. And that will lead directly to international business activities. Then, major stages for urban innovation and science and technology will probably appear in the Pacific economic area. And that is related to new types of venture start-up.

Which country will be the main upholder of this new model? Will the United States, which straddles the Pacific, increase its involvement? Will it be China? Will it be India? Will it be the overseas Chinese territories and Islamic region around Singapore? Will it be the countries of Oceania? We can't predict that right now. However, we can say one thing for sure; namely, that this economic area will be the center of wealth creation for the world in the second half of the twenty-first century. And, I would like to think our country will be a main player on that stage.

When we consider this value proposition based innovation, the Society 5.0 concept is very attractive. The concepts of "compact" and "neat" which are held up as indicators of superior Japanese values internationally, Japan's distinctive lifestyle with its technology that is an extension of the body's function and merges directly into daily life, its highly attractive cities (Greater Tokyo, Greater Kansai, and other cities in the regions), all show possibilities to heighten Japanese predominance in this new economic area.

For such a perspective, the fusion of humanities and social science is vital as we discuss science studies. We have to hurry up and rid ourselves of the phenomenon of separation between the humanities and science.

### **Based on freedom and trust: towards the Comprehensive Strategy on Science, Technology and Innovation**

From the second half of the nineteenth century to the early part of the twentieth century, a tide of globalization, then known as the "free-trade economic area," swept over Europe. Goods started to move freely across the borders between nations; meanwhile, the movement of people too became more active.

As profits were conferred on nations through the law of comparative advantage, it is a fact that disparities between nations became more apparent. Following World War I, which had been triggered by this conflict of national interests, the world economy split into blocks and a new world order was created at the end of World War II.

As we now approach 2020, the same kind of conflict between advantage and disadvantage that exposes national interest is appearing. A hardening of these blocks may lead to military action. But realistically, when the value of human life is vastly more respected than it was in the twentieth century, the chances of a physical world war may be less than before. Even so, when we consider the disparities between different countries regarding the value placed on human life, we'd be unwise to make predictions about the future. In fact, a major war has already started, not in physical space but in cyberspace.

As science, technology and innovation becomes a driving force to relieve such global-level conflict and create harmony, our country could make use of the Society 5.0 concept, as well as the technology platforms in which it has strong capabilities, such as AI, IoT and big data, to make bold contributions to the new world order and economic area in the latter half of this century. That policy direction will create a new science and technology diplomacy.

On the other hand, looking at science and technology in diplomacy, there is much room left for new measures. Thirty years ago, I don't know if our country, now one of the leading advanced economies, would have been in a position to implement ODA and overseas technology cooperation to improve the economies and welfare of developing countries. We must more actively bring science, technology and innovation into this framework of overseas aid.

Through science and technology, to maintain diversity of region, gender, language and culture, to realize both an all-inclusive society through freedom and trustiness, and a new world order in the Pacific economic area, and to have the courage to be at its center... that's the message I'd like to give to the next generation.

By bringing the universal global policies of science, technology and innovation to the fore, just as we extol the Constitution of Japan, shouldn't we express our "desire to occupy an honored place in an international society"?

*Translated from "Tokushu: Gakeppuchi no Kagaku-rikkoku / Kachi teiangata no jisedai moderu de sekai o shudoseyo (Feature: Science-oriented country is on the edge / We must lead the world with a value proposition based next generation model: Why Innovation is Essential to Science and Technology Policies)," Chuokoron, October, pp. 44–55. (Courtesy of Chuo Koron Shinsha) [March 2020]*

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