1.2 Toward Future Promotion of Science and Technology

Summary

Nowadays, Japan and other countries make large amounts of investments in the promotion of science and technology. In order to enable science and technology to continue to meet social needs in Japan, it is necessary to conduct research activities based on the support of the public and efficiently feed back the benefits thereof to society. To this end, it is important to have the spirit of science shared widely in society by providing comprehensive explanations and enhancing education. Also important is to cultivate an environment that unlocks the creativity of science and technology-related human resources in the industrial, academic and government sectors while allocating resources to the development of necessary technologies and to competent researchers in an appropriate and intensive manner based on proper evaluation.

1.2.1 Overview

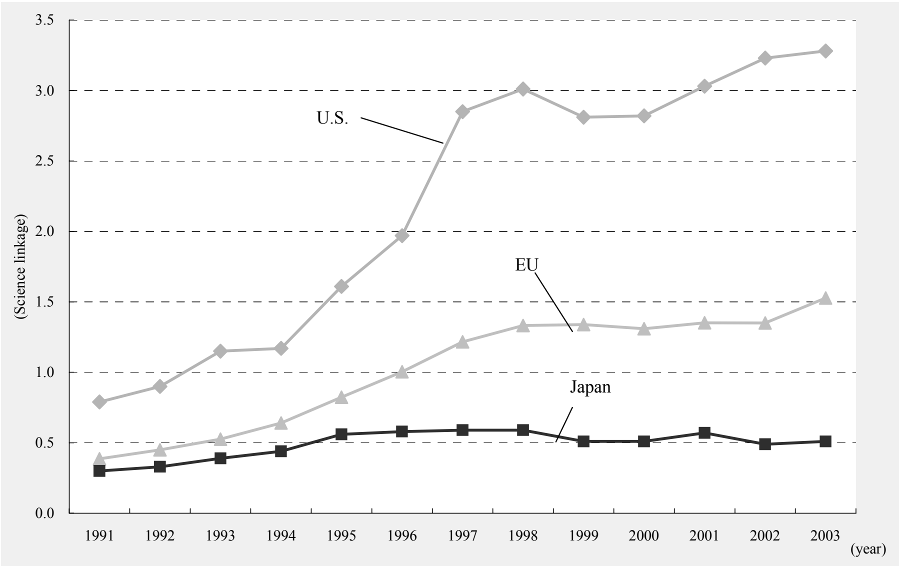
According to the "2006 Report on the Survey of Research and Development," compiled by the Ministry of Internal Affairs and Communications' Statistics Bureau, R&D expenditures funded by the government in Japan totaled approximately 3,389.6 billion yen and those by the private sector in the country totaled approximately 14,397.4 billion yen in fiscal 2005. These figures mean that each Japanese citizen pays about 30,000 yen per year through the government for R&D expenditures while private companies, etc. together spend about four times as much on R&D.

This report also shows that the number of people engaged in research-related jobs totaled approximately 1.04 million, accounting for 0.8% of Japan's total population, and about 820,000 of them, or about 0.6% of the total population, were researchers. Although the proportion of researchers and engineers in the total population is not large in the United States, either, they play a very important role in the industrial and medical sectors. According to a survey report issued by BankBoston in 1997, graduates of the Massachusetts Institute of Technology, one of the most prominent research-oriented universities in the United States, founded as many as 4,000 companies, which together employed 1.1 million people and generated global sales of 232 billion dollars.

As shown in Section 4, Chapter 1, the number of researchers has been increasing year after year in major countries around the world in line with the advance of a knowledge-based society, with the ratio of researchers to the total workforce showing a notable rise in the industrial sector in particular. The social needs as shown by this situation have been met by an increase in the ratio of people educated at universities and graduate schools.

1.2.2 Lessons to be Learned from the Past

The Third Science and Technology Basic Plan calls for "science and technology to be supported by the public and to benefit society" as its primary basic tenet. In light of specific examples cited in Chapter 1, we have sorted out matters for consideration in promoting science and technology in line with this principle.



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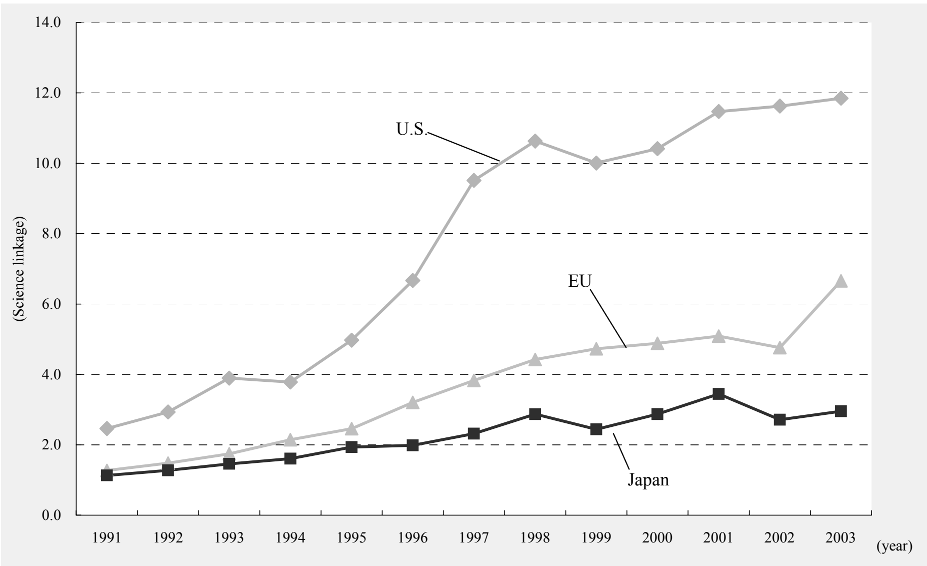

Life sciences

Figure 1-2-1 Trend in science linkage in US patents

Note: "Science linkage" is the number of cited scientific papers in the U.S. patent examination reports per registered patent. It indicates a frequency of the use of scientific knowledge among patents.

Data: CHI Research Inc. "International Technology Indicators 1980-2003"
Source: "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" by National Institute of Science and Technology Policy (NISTEP REPORT No. 83, March 2005)

(1) To surpass boundaries of industry, academia and government

The contributions of science to society represent a dynamic process that involves interaction between the two. In Section 2, Chapter 1, we showed that a variety of modern technologies have derived from quantum mechanics and high energy physics, both of which appeared to be fields of pure basic science and that the evolution of technology, for its part, has contributed to the advance of basic research. As shown in Section 3, Chapter 1, in many cases, benefits of science and technology are fed back to society over a long period of time and through a variety of processes, and they should therefore be judged from a long-term perspective. To cite one notable example, knowledge concerning the structure of DNA did not offer any prospect for specific applications at the time when it was discovered. However, this achievement eventually led to technologies such as genetic engineering, and it is continuing to have a substantial impact on a wide range of sectors including the pharmaceutical industry. This episode offers a contrast to the case of the development of chemicals such as DDT, PCB and fluorocarbons, all of which initially appeared to offer benefits but whose production or use has already been discontinued.

Advanced knowledge is fertile ground for the development of a high-value-added industry. In the U.S. Silicon Valley, IT companies and life sciences-related companies clustered around universities are leading economic growth. The importance of the role of universities and venture companies in R&D activities has increased in the United States relative to the importance of the role of big companies' research laboratories. In countries such as China, South Korea and Singapore, as well as in the United States and Europe, efforts are underway to develop industrial clusters with universities as their cores. In recent years, the science linkage indicator, which measures the strength of the relationship between patents and scientific knowledge, has risen in the United States and Europe, particularly in life science fields. (Figure 1-2-1).

In order to maintain the vitality of Japanese industry, it is becoming increasingly important for researchers engaged in the development of advanced technologies to broaden and deepen their understanding with regard to basic research. This, coupled with a rise in the number of researchers at private companies, increases the importance of education and research at universities and graduate schools (Figure 2-2-5). Therefore, mutual exchange between private companies and universities should be promoted in an effective manner. In particular, it will be useful for next-generation researchers to get acquainted with social needs through such intercourse at an early time. It is necessary to make earnest efforts to deepen industry-academia-government collaboration and ensure sustainable development thereof by making effective use of internship and other initiatives.

(2) To surpass various fields

The discovery of the double-helical structure of DNA by James Watson and Francis Crick, which spurred explosive development of biology, was made based on data obtained with the use of a technique of physics research called X-ray crystallography[41]. In the subsequent development of biology, too, magnetic resonance imaging, mass analyzer, chromatography[42] and other techniques and devices derived from knowledge in other fields such as physics and chemistry played a very important role. For the spirit of inquiring into the various phenomena of the universe, which acts as the prime mover of the advance of science, the boundaries of research fields do no matter at all. The essence of science lies in questioning and seeking to resolve unknowns, regardless of whether they concern basic research or practical applications. Knowledge and activity in various fields of science and technology are not developing independently of one another but they form a dynamic system as they interact with one another in a complex manner.

Amid the global trend of crossing academic field boundaries, Japan is aiming to devote intensive efforts to the establishment of advanced interdisciplinary research centers at universities and other institutions. Among examples of efforts to establish interdisciplinary research centers in the United States is Stanford University's Bio-X project[43]. This project introduces innovative approaches not only on the hardware resource side, for example by adopting the kind of laboratory room layout that can be arranged flexibly in a manner suited to the method of research and by securing spaces for facilitating socializing among colleagues, but also on the human side, by

[41] X-ray crystallography: When an X-ray enters matter, each atom emits scattered waves, which interfere with one other and create a strong diffraction wave in a specific direction. The arrangement of atoms of matter can be determined by examining the diffracted X-ray.
[42] Chromatography: Chromatography is a technique used to separate chemical substances. As this technique enables far more effective separation than distillation and extraction, it can handle samples with complex structures.
[43] Bio-X: Bio-X is an innovative project that seeks to promote interdisciplinary research activities in the field of biosciences by providing a bridge among biology, medical science, engineering and physics.

encouraging researchers from different fields to avoid using cryptic jargon in communications with one another and speak "plain English everybody understands." Communicating with other people in an open manner without being locked up in the area of specialty broadens the perspective of researchers and brings a fresh breeze of ideas.

Of particular importance is to enable young researchers whose thinking is not constrained by conventional values to play an active role.

(3) To surpass organizational boundaries

Science is a human activity. As the scale of the world of science grows, the fields of research become increasingly segmented, which in turn leads to segmentation of the organization of research institutions. Even a scientist with an independent mind cannot avoid relating to the organization to which he/she belongs.

Dr. Hideki Yukawa, while he was teaching at Osaka Imperial University, which was a new institution at that time, was able to attain achievements that later led to a Nobel Prize award, as he was granted the freedom to engage in research without being constrained by his lecture subject. Meanwhile, what prompted Dr. Shizuo Akira to start his research work, which is still continuing to have significant impact around the world, was his relocation to Hyogo College of Medicine. Research organizations, particularly those engaged in basic research, need to ensure the freedom of research that enables researchers to fully exercise their capabilities. In order to enable talented researchers with a variety of backgrounds to inspire one another, it is important to facilitate exchange of information among various organizations, employ researchers in a fair manner, irrespective of whether they are alumni members or not, and from a global perspective and make efforts to increase the mobility of human resources.

(4) To surpass the boundaries of age and gender

As shown in Section 4, Chapter 1, young researchers play a significant role in the advance of science and technology. As well, promoting the activity of female researchers, whose ratio remains conspicuously low in Japan will be very significant for the future development of science and technology in the country. As science is an activity that pushes human knowledge to the limits, it is important for researchers to tackle fundamental issues irrespective of their age or gender. To do so, it is essential to foster a broad perspective and hone the ability to formulate research plans. In addition to promoting the implementation of systematic education and the independence of young researchers under the Support Program for Improving Graduate School Education, it is necessary to carry out measures such as adopting a competitive funding program that attaches importance to the novelty of research plans and utilizing young researchers in screening of research programs.

(5) To surpass national borders

Science is basically a cross-border activity. Many researchers cross national borders so as to exchange opinions with foreign researchers, develop their own capabilities and find a place where they can tackle a challenging task. To attract such capable researchers, it is necessary to make intensive efforts to establish bases in Japan that will serve as a magnet for top-level researchers. In addition, as the scale of research programs expands, the need is growing for international cooperation in prompting science and technology.

(6) To surpass the boundary between scientists and ordinary people

Throughout the 20th century, science and technology activities expanded and became increasingly organized. The promotion of science and technology has now become a huge project into which national resources are poured. Therefore, it is necessary for scientists and ordinary people to discuss issues related to science and technology and society on an equal footing so as to ensure appropriate public understanding of the benefits of science and prevent science from going out of control unexpectedly.

Non-experts tend to assume, erroneously, that science always provides a clear-cut, factual answer or solution. Although science represents a body of well-established answers and solutions verified over a long period of time, it is also an activity that tackles the remaining problems that have not yet been fully understood. The various problems posed by society are often difficult to solve as they involve complex elements and manifest themselves in forms unique to the circumstances of the time. Exactly for this reason, a broad perspective is becoming increasingly necessary. In some cases, practical problems posed by society may provide a fresh viewpoint with regard to basic research.

Since time immemorial, anxiety about "the unfamiliar" has been a universal feeling, and the better people are educated, the more questions they ask. In order to promote science and technology, with the support of the public, as something beneficial for the future of Japan, it is increasingly important to facilitate dialogue, in as plain language as possible, between scientists and ordinary people and form a national consensus.

(7) To surpass the boundary of conventional thinking

The advance of science is a process of trial and error. Ideas such as the Copernican theory and the theory of evolution were initially regarded as heretical but eventually came to be accepted as conventional ideas, after being verified through a variety of observation activities conducted over a long period of time. As recently as 2003, an observation activity led to a startling finding that as much as 96% of the matter and energy contained in the universe are of a kind unknown to us. Future creative scientists willing to tackle the unresolved and unknown are sure to find the way to a solution by furthering their reasoning beyond the boundary of conventional thinking and by exercising their sound skepticism to the full. Of a newly acquired body of knowledge, valuable parts will be distilled and retained through the process of communication conducted in the form of education. Science is a culture that is rooted in mankind's unceasing spirit of inquiring and that is shared by people around the world.

1.2.3 How Science and Technology should be Promoted in the Future

(1) Investment in science and technology

Major countries around the world are increasing their R&D expenditures as forward-looking investments. China's expenditures have shown a particularly sharp increase, and according to an estimate by the OECD, they exceeded Japan's expenditures in 2006 on a purchasing power parity basis (Figure 1-2-2). Although Japan made efforts in the past to raise government-funded R&D expenditures, such expenditures have remained almost flat in recent years, in contrast to the rapid increases in the expenditures of countries such as China and South Korea (Figure 1-2-3). Compared with the situations in other countries, the government's share of expenditures on R&D and basic research in Japan is relatively small (Figures 2-1-6 and 2-1-18), and public financing for higher education accounts for only 0.5% of GDP, a level about half of the figures for the United States, France and Germany and about two-thirds of the figure for the United Kingdom (Figure 1-2-4). In order to keep attractive the career path for people willing to make contributions to society by acquiring advanced knowledge in science and technology fields at graduate schools, it is necessary to make strenuous efforts to cultivate an environment that enables the implementation of sufficient education and research, reduce the financial burden on students enrolled in master's degree and doctoral programs and reform the contents and method of education so as to allow students to acquire knowledge and capabilities useful for real-life society.

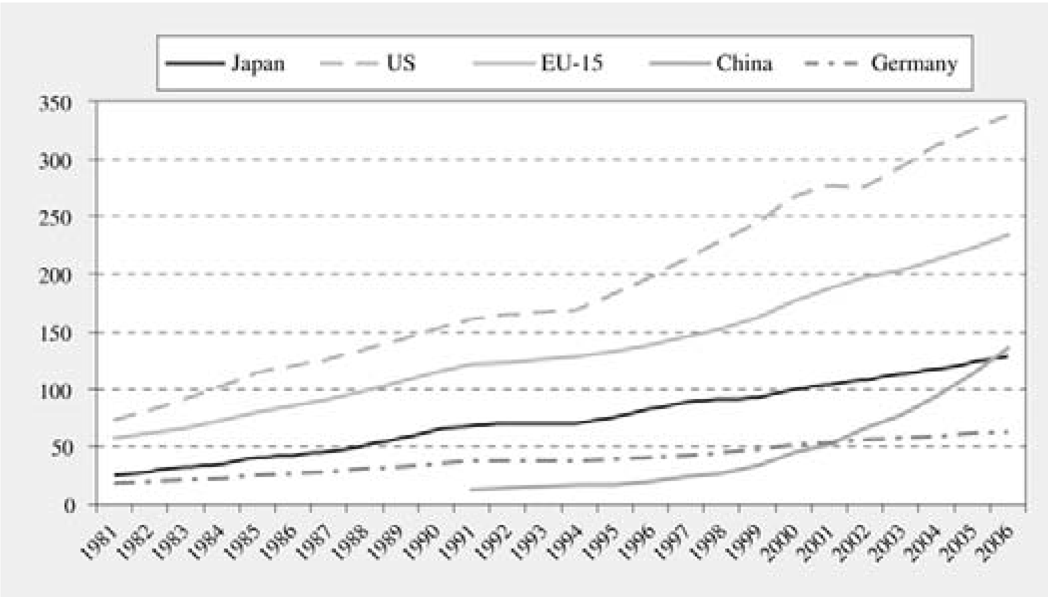

Figure 1-2-2 Total domestic expenditures on R&D (unit: US$1 billion, purchasing power parity basis)

Note: Figures for 2005 and 2006 are estimates calculated based on the assumption that the growth rate of R&D expenditures in these years was the same as the average growth in 2000 to 2004.
Source: "Main Science and Technology Indicators, 2006-I" by OECD

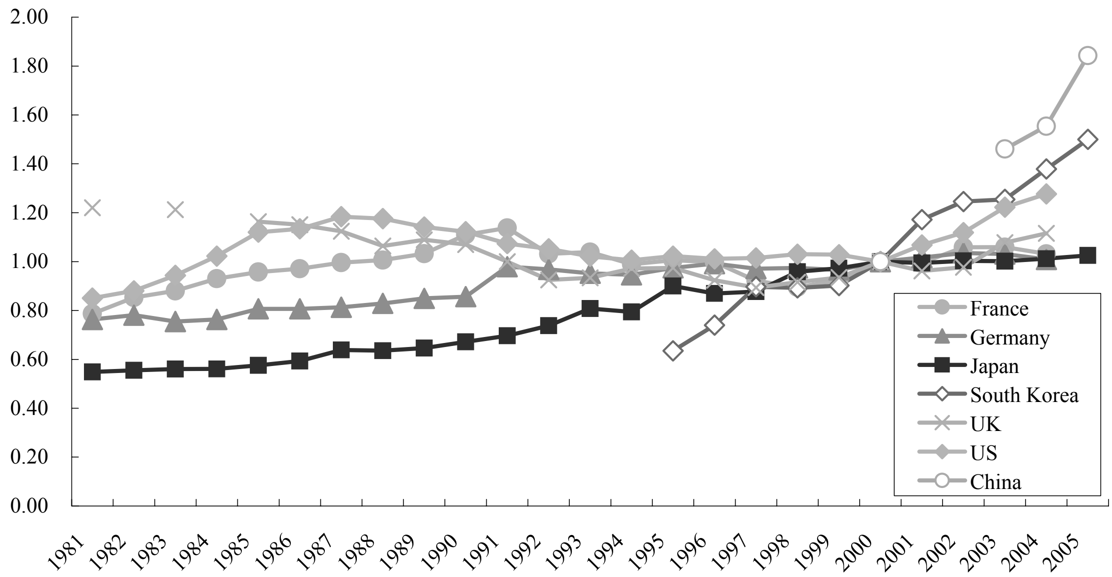

Figure 1-2-3 Trends in government-funded real R&D expenditures in major countries with figures for FY2000 taken as the base of 1

Notes:
1. Real R&D expenditures are calculated with the use of the Implicit GDP Price Indices of "Main Science and Technology Indicators" by the OECD (2000=1.00).
2. Figures for 2000, the earliest year when data for all of the seven countries covered became available, are taken as the base of 1.

Source: "Report on the Survey of Research and Development" by the Statistics Bureau of the Ministry of Internal Affairs and Communications

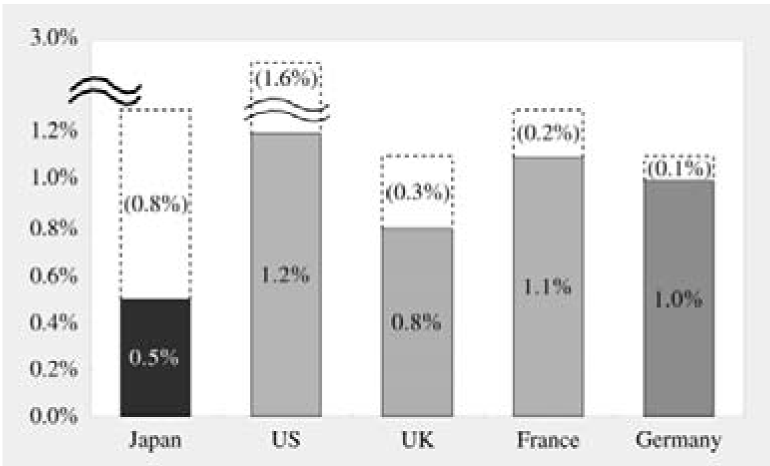

Figure 1-2-4 Public financing for higher education as a percentage of GDP

Note: Figures in parentheses represent private-sector expenditures as a percentage of GDP.
Source: "Education at a Glance" (2006 Edition) by OECD

(2) Selection and concentration

In order to maximize the effects of government-funded R&D investments, it is important to ensure appropriate evaluation of research programs receiving public support and effective utilization of research facilities and equipment and to promote the communication and utilization of research results. The Third Science and Technology Basic Plan calls for promoting strategic priority setting for government-funded R&D expenditures through selection and concentration and selects items targeted for intensive investments during the period of the plan as "strategic prioritized S&T." Moreover, of the strategic prioritized S&T items, long-term, large-scale projects conducted "under a government-supervised consistent framework to develop world-leading human resource" for which "concentrated investments" are required to "maximize social and economic effects and to ensure overall national security" during the period of the basic plan are characterized as "Key Technologies of National Importance." Such technologies include: the "Next-generation supercomputer" that will be the most

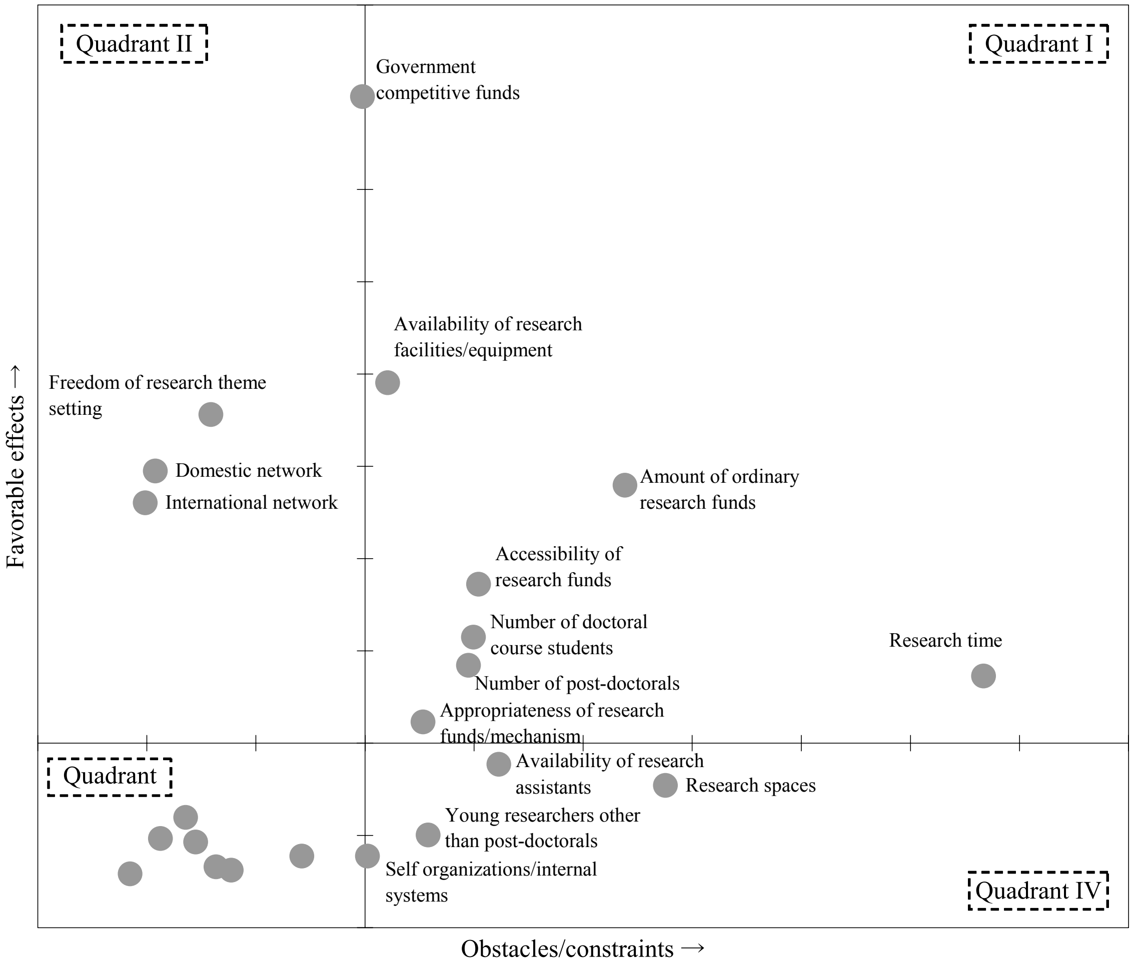

Figure 1-2-5 Relation between "obstacles/constraints" and "favorable effects" with regard to each research environment item

Note: Each graduation represents 2% of the total replies in both the horizontal and perpendicular axes. Please note that this graph is laid out so that the median figure of the percentages of the 22 reply items (4.5% for the horizontal axis and 3.1% for the perpendicular axis) represents the origin. This means that the reply frequencies for items located in the minus side of the graph are not zero but merely relatively low

Source: "Characteristics of excellent research activities" (Research Material No. 122, March 2006) by National Institute of Science and Technology Policy advanced and boast the highest performance in the world, the "X-ray Free Electron Laser project," the "Space transportation system technology" that will enable Japan to conduct space activities independently, the "Earth Observation and Ocean Exploration System" that will form the basis of observation and exploration activities essential for comprehensive national security such as global environment observation, disaster surveillance and resource exploration, and the "Fast Breeder Reactor (FRB) cycle technology" that is necessary for ensuring stable energy supplies in the long term.

Meanwhile, in order to enable individual researchers to develop original and challenging ideas, it is important to expand competitive funds and enhance research evaluation while maintaining a certain level of basic expenditures. The importance of such steps is shown by the results of a questionnaire survey conducted on authors of frequently cited research papers, which showed that while expanded "government competitive funds" have a positive impact on research outcome, the shortage of the "amount of ordinary research funds" is acting as a constraint in spite of their favorable factor for the research environment (Figure 1-2-5).

(3) Promoting science and technology in ways to obtain public support

The advance of science and technology has benefited mankind by bringing about long life and material welfare. Given the expected increase in affluence due to a rise in the living standards of more countries and the expected expansion of the global population, however, the level of technology as it is would be insufficient to prevent us and our offspring from being confronted with environmental constraints in the future. Under such circumstances, we face the critical decision of which sorts of science and technology we should seek to develop further: the future for us and our offspring depends on this decision. In making this decision, it is important to obtain the understanding of the taxpayers regarding the sorts of science and technology to be selected for promotion and the way of advancing them. To this end, researchers and people involved in the promotion of science and technology should make constant efforts to provide comprehensive explanations concerning their activities and advance science and technology in the right direction with the participation of ordinary people.

[Column 9]

Cherishing Creativity of Individuals

How should Japan promote science and technology in the future? We posed this question to Dr. Leo Esaki, a 1973 Nobel Prize laureate for physics who has attainted great achievements as a corporate researcher in Japan and the United States and is still playing an active role as an educator.

Science Mind

To start with, if there is such a thing as a "science mind", I would like to consider what it actually is. If you put it into one word, it could be encompassed by the Latin word "cogito" (the intellectual processes of the self or ego). From a wider perspective, you could also say that it is the "capacity for logical thinking of the many great natural philosophers" who put their heart into laying the foundations of science.

Descartes (1596-1650) is a representative example of someone with the "science mind". With his astute wit, he placed knowledge within a rational framework. It was Descartes who promoted the idea that the universe is principle-controlled and obeys rational rules; everything is connected by cause and effect, and mathematical analysis is possible.

He was not satisfied with the unreliable scholarship of the Dark Ages and tried to build a reliable science that was based as much on logic as mathematics. He also proposed the so-called principle of reductionism, the style of research in which the whole is analyzed by breaking it down into fragments. Mathematical analysis and reductionism have become two very powerful tools in the dramatic development of modern science. "Cogito, ergo sum" (I think, therefore I am) is indicative of Descartes' philosophy. It is a very well-known phrase.

Newton (1642-1727), when asked how he was able to produce so many important achievements that would be recognized long into the future, answered: "If I have seen further [than other men] it is by standing on the shoulders of giants." It is thought that one of the giants to whom Newton was referring was Descartes.

Science is such that by each generation standing on the shoulders of giants in turn, progress is able to continue non-stop in a logical and consistent manner. When I think of my own work in electron tunneling or semiconductor superlattices, I know that I would not have been able to do it without the shoulders of giants such as Bloch, Zenner and Shockley to stand on. In fact, new work is presently being done even on my shoulders.

The strength of science as a part of civilization definitely lies in the fact that progress is an inherent part of it. The cultures of art and literature are ever-changing but I wonder if this can really be called progress in the true sense of the word. I may not be Descartes, but I take pride in knowing that because science is based on logic, it is a discipline with the highest of reliability and certainty.

During the war, when I was 18 years old and still in high school, I remember being moved by a lecture by a teacher named Torakazu Doi, who was famous throughout our school. "Logic began in ancient Greece. First it touched Socrates, then it flowed on to his apprentice Plato and developed further yet in the hands of his apprentice, Aristotle," he said. In the preface to his book, "Primordial Logic - The Development of the

Hegelian Logos", on which the lecture was based, he wrote of how he had completed the book using all the energy of his youth and by pushing himself to the limit. The fire sparked by his ideas and his mind, so fixated on the discipline, won the affection of the minds of all his students. We were drawn deep into the world of logic. Only such a "science-possessed" teacher can teach high school students about the "science mind".

Age of Individual

The greatest invention of the 20th century would have to be the semi-conductor transistor (1947) by Bardeen and Brattain, which enabled the developments of today's advanced information society. On the other hand, the award for the greatest discovery would have to go to Watson and Crick for DNA (1953).

According to inherent genetic information, each and every one of us has our own individual characteristics of appearance, capability, personality. Right now, if two people were arbitrarily chosen, comparing the over 3 billion ATGC 4-type base sequences of their genomes, you would find that they were 99.9% identical. However, they are also 0.1% different. Even with such a small difference, we are able to distinguish between people. This difference is often used in criminal investigations and paternity cases.

Conventionally, 99.9% the same was considered in Japan, as everywhere, to be the same as 100%. People were treated and educated uniformly. Now there is more of an emphasis on the uniqueness of "individuals" that are distinguishable by that 0.1% difference, so we can say that we are truly entering "the age of the individual".

The thing to do for Japan to further develop science is to let "individuals" with logical minds suited for math and science fly high. It is said that one in 200 children in the United States is gifted in this regard. U.S. educators are devoting much effort to developing the capability of such children. In Japan, too, we must create various scouting opportunities and try to find and foster children gifted with talents suited for math and science, just as we look for children with athletic or artistic talents. If we encourage Japanese high-school students to participate in International Science Olympiads in large numbers, it would provide a handy opportunity to discover talents.

Our intellectual ability really has two facets: The "judicious mind" and the "creative mind." The former allows us to analyze and understand things and to select and make fair judgments; this is essentially covered by the body of existing knowledge. On the other hand, the latter allows us to pinpoint core issues and create new ideas through the activities of imagination and perceptiveness. The ability to pinpoint core issues leads to discoveries and the ability to create new ideas leads to inventions.

There are two types of education that can foster natural talent, "being taught" and "self-teaching." "Being taught" is more passive and involves imitation, listening, reading, and remembering. This is how the "judicious mind" is acquired. On the other hand, the autonomy of "self-teaching" through questioning, considering, searching, and doing, cultivates the "creative mind" which is the driving force of progress in science.

The tendency in Japan to put emphasis on "being taught," while successful in developing the "judicious mind," has usually been insufficient to nurture "creative abilities." Sayings such as "Great talent matures late" and "Promotion by seniority" are not appropriate in the field of science. The progress of science today is very much reliant on young people's "creativeness". In Japan, as we as in any country, it will be desirable to build such an environment that young people, men and women alike, can perform freely and effectively.

Era of Intellect

Let us think about individuals and groups in developed countries. Previously, the prevailing view held that societies should be group-oriented, with priority placed on stability and prosperity of groups and with individuals relegated to the role of serving for the whole. Now, however, it seems to me that societies are becoming increasingly individual-oriented, with emphasis placed on prosperity brought about by the exercise of the creative minds of individuals and with groups seen as the place where individuals display their capabilities.

Currently, developed countries that have reached the talent-developing "age of the individual" are moving from group-oriented to individual-oriented, and from vertically-stratified to horizontally-networked, societies. A major paradigm shift towards a reliance on "individual creativeness" in a knowledge-intensive "era of intellect" has been seen. We are witnessing the dawn of an "era of intellect," in which everything, from economic and industrial activity to cultural activity, is led by knowledge. In this new era, a systemic body of knowledge serves as the prime mover of society. To ensure further development of Japan, we must now work hard to create an "intellect-based nation." Now, Japanese universities have a more important role to play than ever in creating knowledge, communicating it and putting it to use.

Knowledge can be classified into the following four categories:

1. Basic knowledge (physics, chemistry, biology, math, etc.)
2. Knowledge for society's infrastructure: social sciences, engineering, etc.
3. Knowledge for individual human beings: humanities, medical sciences, etc.
4. Knowledge for human survival and security: environmental sciences, international relations, etc.

Of course, each and every type of "knowledge" is important; however, the developed countries have recently been focusing more of their research efforts on fields 3 and 4. Consequently, the progress made in these fields has been especially noteworthy. And, today, thanks to the advances in information technology, the internet culture has prospered and global competition in the field of knowledge creation is intensifying. In this competition, the penetrating insight and rich creativity of individuals are the most powerful weapons. And one last word: we will certainly be hugely satisfied if we thrive thanks to our insight and creativity.

* Leo Esaki (Currently President of Yokohama College of Pharmacy and Chairman of the Science and Technology Promotion Foundation of Ibaraki), born in 1925; graduated Faculty of Science Tokyo University in 1947; worked for Kobe Kogyo Corporation (1947-1956) and Tokyo Tsushin Kogyo (now Sony) (1956-1960); obtained Doctorate of Science from Tokyo University in 1959. He has experience as the Senior Researcher at IBM, U.S.A (1960-1992); President of Tsukuba University (1992-1998); President of Shibaura Institute of Technology (2000-2005). He became President of Yokohama College of Pharmacy in 2006; Chairman of the Science and Technology Promotion Foundation of Ibaraki in 1998.
Awards he received and memberships he came to hold include: Nishina Memorial Award (1959), Asahi Press Award (1960), Toyo Rayon Foundation Award for the Promotion of Science and Technology (1960), Morris N. Liebmann Memorial Prize from IRE (1961), Stuart Ballantine Medal from the Franklin Institute (1961), Japan Academy Award (1965), Nobel Prize in Physics (1973), Order of Culture from the

Japanese Government (1974), Member of the Japan Academy (1975), Foreign Associate of the National Academy of Engineering (USA) (1976), American Physical Society International Prize for New Materials (1985), IEEE Medal of Honor (1991), Japan Prize (1998), Grand Cordon of the Order of the Rising Sun (1998)
The committees joined include: Chairperson of the National Commission on Educational Reform, Chairperson of the Selection Committee for the Japan Society for the Promotion of Science Prize, Chairperson of the 21st Century COE (Center of Excellence) Program Committee