Foreword

Science and technology brings new “knowledge” to mankind, and greatly contributes to improving our lives and developing the society and economy. Today, the environment surrounding Japan is becoming severer with the advancement of the declining birthrate and aging of the population as well as a decrease in the total population. In order for Japan, which is poor in natural resources, to achieve a safe and secure society while continuing to maintain its international competitiveness, science and technology will be expected to play an increasingly important role in the future.

This year marks the tenth year from the promulgation and entry into force of the Science and Technology Basic Law, which indicates the basic framework of Japan’s science and technology policies. At the same time, it is the final fiscal year for the Second Science and Technology Basic Plan—key principles based on the Basic Law—and the year for preparing for formulation of the Basic Plan for the next period. Thus, it is an important year, which will be a turning point for science and technology administration.

Since the enactment of the Science and Technology Basic Law the government has engaged in various measures including an increase and prioritization of science and technology budget and reform of the science and technology system. These efforts are steadily producing results and spillover effects. On the other hand, because science and technology has become ever more sophisticated and complicated and has deeply penetrated people’s lives, people have become less aware of science and technology. This is possibly one of the causes for people’s declining interest in science and technology.

As a country is supported by its “people,” development of talented human resources is essential for promotion of science and technology, and moreover, as the basis for nation-building. Therefore, in order to raise people’s interest in science and technology as part of such effort, the White Paper on Science and Technology FY 2005, entitled “Japan Ten Years after the Enactment of the Science and Technology Basic Law and Its Future,” comprehensively analyzes and evaluates the recent achievements, challenges, and international level of Japan’s science and technology, by referring to familiar case examples, people, and facilities as much as possible to make it easy to understand.

The Japanese government intends to exert further efforts toward becoming an advanced science- and technology- oriented nation by positioning science and technology as an important policy issue. It is hoped that this white paper will help people understand the trend of science and technology in Japan and overseas, and the Japanese government’s efforts for promoting science and technology.

June 2005

Minister of Education, Culture, Sports, Science and Technology
Nariaki Nakayama

Preface

This report deals with measures taken for the promotion of science and technology under the provisions of Article 8 of the Science and Technology Basic Law (1995 legislation No. 130).

Part 1 and Part 2 of this report introduce the trend of diverse activities related to science and technology, and helps readers advance their understanding about the measures taken for the promotion of science and technology that are described in Part 3.

In Part 1, entitled "Japan's Scientific and Technological Capabilities: Japan Ten Years after the Enactment of the Science and Technology Basic Law and Its Future," we analyzed and introduced the recent status, achievements, and challenges of science and technology in Japan by making some comparisons with those of foreign countries, and indicated the future direction for the promotion of science and technology. In Part 2, we compared the science and technology activities in Japan and other major countries based on various data.

Introduction

Science and technology has generated new knowledge, such as discoveries of new principles, and has dramatically contributed to the development and progress of people's lives, the economy, and the society. Particularly in Japan, which lacks natural resources, technological innovations served as the key in achieving a remarkable recovery and high economic growth from the postwar devastation bringing material affluence to people's lives. In this process, Japan, which was making efforts to catch up with Europe and the United States, became one of the frontrunners as the world's second-largest economic power, and the time has come for Japan to demonstrate creativity and open the way to the future. Thus, the Japanese government enacted the Science and Technology Basic Law in 1995, and has implemented various measures for promoting science and technology according to the Science and Technology Basic Plan Phase 1 and Phase 2, in order to become an advanced science and technology-oriented nation.

On the other hand, social and public expectations for science and technology became more sophisticated and diverse, and new problems that need to be addressed such as global environmental issues have emerged.

Under such circumstances, international knowledge competition has intensified not only among western developed countries, but also among countries including China and the Republic of Korea. Therefore, Japan needs to further develop its "scientific and technological capabilities."

Dr. Shinichiro Tomonaga, the physicist who was the second Japanese Nobel Prize winner following Dr. Hideki Yukawa, said the following in an article contributed to *Kagaku* (Science) magazine, after referring to the difference in the research environment between Japan and the United States at the time: "It is wonderful that there are many brilliant scholars and ardent, competent young researchers also in Japan. These people have actually made remarkable accomplishments despite various adverse conditions. However, the scientific level of a country is defined not only by the research achievements of existing scholars, but also by taking into consideration everything that underlies and supports such achievements and serves as the foundation for future development. And with that in mind, the scientific level of Japan is far from satisfactory."

As indicated by Dr. Tomonaga, the scientific and technological capabilities of a country are not limited to numerical data, such as the current number of scientific papers, the frequency of their citation, and the number of Nobel Prize winners. Instead, they are considered to be more multi-dimensional, including the diverse research activities among industry, academia, and government, and their achievements/effects, the scientific and technological human resources carrying out these activities, the research infrastructure and the science and technology systems consisting of various elements such as the research environment and R&D funds, and potential that indicate future possibilities.

The Annual Report on Promotion of Science and Technology introduces the trends of a wide array of scientific and technological activities based on a specific theme every year, in Part 1. This year, which is the tenth year from the enactment of the Science and Technology Basic Law, the report regards "scientific and technological capabilities" to collectively cover the present scientific and technological capabilities of Japan and their level on a global scale, the achievements to date, and the future possibilities and potential, and it analyzes and introduces them from various angles and in a comprehensive manner.

In recent years, people's awareness of science and technology has been declining. The assumable reasons are that the latest science and technology are becoming more and more sophisticated and complicated and the fact that people are becoming less aware of science and technology since scientific and technological achievements have come to permeate very deeply among people. Therefore, in order to help readers concretely understand science and technology as well as its achievements, the report discusses them by focusing on the actual case examples, scientists/engineers, and research facilities as much as possible.

1.1 Contributions of Scientific and Technological Progress

Although the scientific and technological progress has made great contributions to society in Japan, we seem to be losing opportunities to realize or become aware of such contributions. Here is an example.

One of the items that have become rapidly diffused in recent years is the mobile phone. After digital services were launched in 1992 and the sale of mobile phones was liberalized, mobile phones quickly spread mainly among young people. Mobile phones used to weigh 750 g in 1987, but phone units that only weigh 230 g were released in 1991. Furthermore, those with a volume of 100 cc and weigh less than 100 g were placed on the market in 1996. With this, the reduction in weight and size seemed to have reached their limits. Nevertheless, mobile phones became even more compact and lightweight, and now there is even a model that weighs less than 70 g. In addition, mobile phones have become multi-functional. They not only serve as a phone, but also as an e-mailer, a camera, a video game machine, and even a music player or an electronic money wallet. Today, many people from children to the elderly would find it difficult to imagine life without a mobile phone.

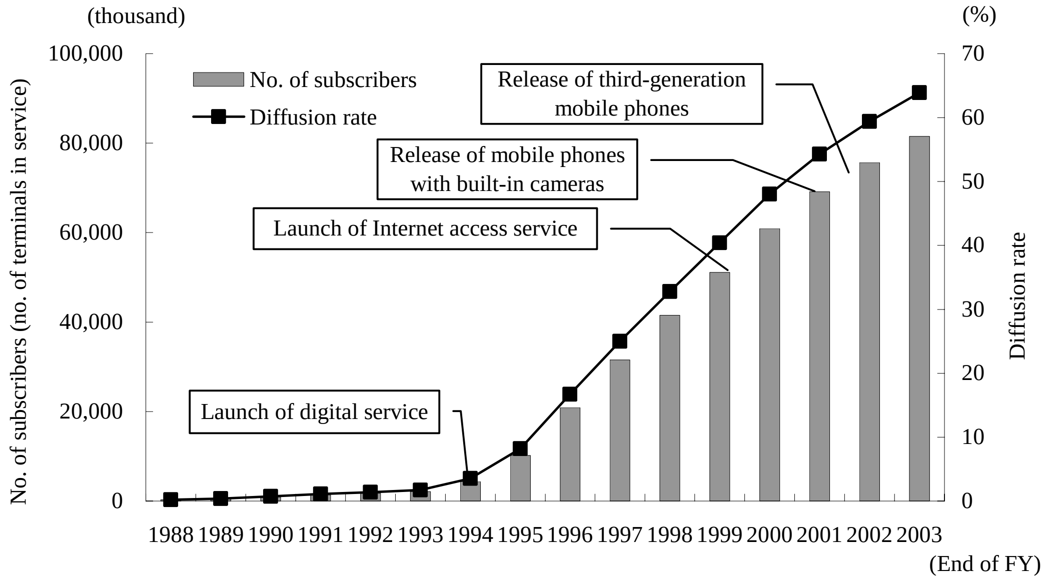


Figure 1-1-1 Number of Mobile Phone Subscribers

Source: Ministry of Internal Affairs and Communications, "Information on Subscribers of Cellular Telephone, Pager and PHS (Personal Handy-Phone System) in Japan," March 1, 2005.

It should be noted that such progress owes greatly to the contributions of Japan's original science and technology.

Today it is taken for granted that mobile phones come with color liquid crystal displays (LCDs), but LCDs for mobile phones were first commercialized in 1985 by a Japanese company.

Since a mobile phone LCD does not emit light by itself, it has a light source behind the LCD.

This is called a backlight. At present, many mobile phones use a light-emitting diode (LED) for the backlight. The white LED used for the backlight was invented at a Japanese university, and the technology seed was put to practical use by a Japanese company for the first time in the world. Japanese companies command the highest share ofthe worldwide LED market.

Meanwhile, the lithium ion battery, which is long-lasting and contributes to making mobile phones lightweight, was also commercialized for the first time in the world by a Japanese company in 1990.

The polymer battery, which is used as a backup battery, uses conductive plastic as the electrode.

Hideki Shirakawa won a Nobel Prize for the discovery of this conductive plastic in 2000.

In a foldable mobile phone, the main body with buttons and the part with the LCD are connected by a flexible substrate, which is flexible in itself. This substrate is made of a paper-like material made from synthetic fiber and an extremely thin beaten-copper. Conventionally, when the synthetic fiber was formed into a paper sheet, the fiber became tangled and could not be spread out uniformly. This problem was resolved by the technique developed through the making of traditional Japanese paper. As for beaten-copper, a Japanese company having the technology of making gold leaf that has been passed down since the Edo period commands a 40% share of the world market of beaten-copper for mobile phones.

Japanese science and technology is also applied to the electronic parts used in mobile phones. Capacitors are indispensable for electronic circuits, and a large number of multilayer chip ceramic capacitors, which are one type of capacitors, are used in mobile phones. They are tens to hundreds of derivative layers in between electrode layers pressed together and fired. The size is 1 mm×0.5 mm, and the height ranges from 1 mm to 2 mm. Japanese companies command 80% of the world market share for these multilayer chip ceramic capacitors, and one of these Japanese companies originates from a manufacturer of Kyoto’s Kiyomizu-yaki ceramics.

These are only a few of the science and technology achievements that are used in mobile phones. Accumulation of such scientific and technological progress results in the current lightweight and easy-to-use mobile phones.

Science and technology has generated new knowledge, such as discoveries of new principles, and has dramatically contributed to the development and progress of people’s lives, the economy, and the society. Chapter 1 overviews the achievements of the progress of science and technology in the 20th century by referring to the actual examples.

1.1.1 Creation and Use of Knowledge

1.1.1.1 Contributions of Science and Technology

A single mobile phone alone is packed with numerous cutting-edge scientific and technological accomplishments. In this manner, in the modern society, the scientific and technological knowledge and achievements are being used in our daily lives in various forms.

Science and technology has two functions: creating new knowledge such as elucidating unknown phenomena that surround us and discovering new laws and principles; and using the knowledge gained in the real world. Because these two functions interact and are hard to separate, and because scientific and technological achievements have already been permeated throughout our daily lives like the atmosphere itself, we have come to rarely realize them as scientific and technological achievements. However, science and technology has had various impacts and spillover effects in our daily lives in the process of their development. These impacts and spillover effects are reviewed below.

(**Intellectual**/cultural values of science and technology)

Science is an intellectual activity that started from intellectual curiosity for understanding natural phenomena, originating from the feelings of admiration and inspiration for nature and other things surrounding human beings. Scientific and technological achievements bring us new knowledge. Their accumulation expands the limits of people’s activities both in space and time, beyond the conventional concept of values. They can enlarge the possibilities of people’s activities and serve as the driving force for society from theviewpoints of culture and civilization.

In medieval times, when people believed the geocentric theory of Claudius Ptolemaeus, Nicolaus Copernicus advocated the heliocentric system (Copernican theory), and the theory came to be established by the efforts of Tycho Brahe, Johannes Kepler, and Galileo Galilei. Later, the idea was inherited by Isaac Newton’s law of gravitation and modern astrophysics represented by the Big Bang theory, and has influenced people’s views of the universe and the Earth in the various times.

John Dalton demonstrated the existence of atoms, which had been a philosophical concept until then, and this developed to Amedeo Avogadro’s molecular hypothesis. In addition, the discovery of atoms was accelerated by Dimitri Mendeleev’s periodic law, which had a large impact on the understanding of the composition of matter, i.e. that all matter is made up of a certain number of atoms.

Furthermore, the possible existence of even smaller elementary particles has been indicated. In this manner, our understanding of matter is likely to deepen even further in the future.

Charles Darwin's theory of evolution proposed an idea on the evolution of organisms, while the elucidation of genes, which started with Gregor Johann Mendel's law of heredity, hints at the answer to the mystery of organisms. Yet new views on organisms and senses of ethics are expected to develop in the 21st century, which is being called the "century of life science."

Today, as development of science and technology accelerates, their achievements are expected to influence people's values at an even faster pace and may dramatically change the paradigms of society.

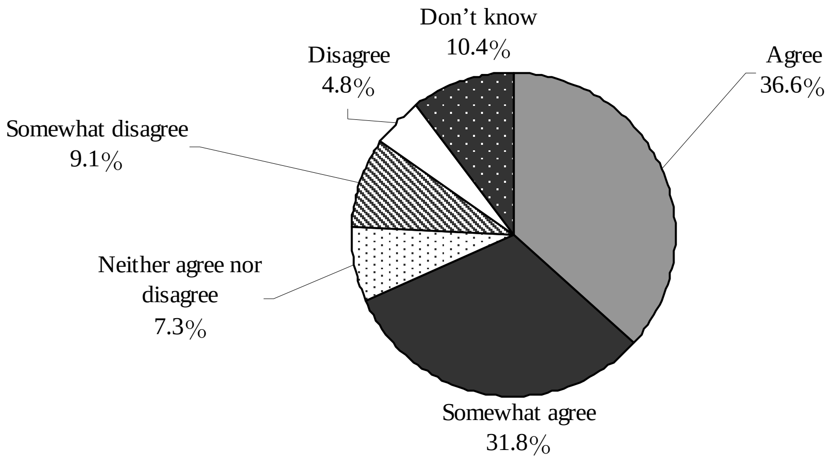


Figure 1-1-2 Scientific Research Is Essential in the Sense That It Brings New Knowledge to Humanity

Note: Graph shows the responses to the question, "Do you agree with the opinion that 'scientific research is essential in the sense that it brings new knowledge to humanity?'"
Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society (February 2004)"

[Column 1]

Albert Einstein: 50th Anniversary of Death, Centenary of Miracle Year

The year 2005 marks the centenary of Albert Einstein's release of his special theory of relativity in 1905. It is also the 50th anniversary of his death. The year 1905 is known as Einstein's "miracle year" because he published a series of important study results in that year.

In June 1905, Einstein released a paper entitled "On a Heuristic Point of View about the Creation and Conversion of Light," in which he denied the then prevailing theory that light was a wave. Einstein instead theorized that light consisted of particles and explained the photoelectric effect, by which metals emit electrons when illuminated by light. The solar cell, developed in the 1950s, is a device that uses the photoelectric effect to generate electricity.

In a dissertation published in July 1905 titled "On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat," Einstein postulated that the erratic movement of particles in fluids, known as "Brownian motion," was caused by molecules' random collisions in a fluid. This mathematic model is now known to be extremely useful in a variety of applications such as predicting the diffusion of fluids and gases and analyzing genetic functions and even stock market trends.

In September 1905, Einstein proposed the special theory of relativity in a dissertation titled "On the Electrodynamics of Moving Bodies" and said the speed of light remained constant, denying the then conventional view that time and space were absolutely constant. The theory of relativity affects actual life as, for example, receivers for global positioning systems adopted in car navigation systems reflect effects of the theory.

In November 1905, Einstein released another paper, named "Does the Inertia of a Body Depend upon its Energy Content?" and said, "The mass of a body is a measure of its energy content." Based on this theory, Einstein came up with the most famous equation in history—$E=mc^2$—in 1907. With this equation, it became apparent that material could be converted into energy, leading to nuclear power generation, which now covers one-third of power output in Japan.

As 2005 is the centenary of the miracle year, the general assembly of the United Nations decided that the U.N. Educational, Scientific and Cultural Organization (UNESCO) should plan activities to commemorate the "International Year of Physics" in cooperation with physical societies and groups throughout the world. In Japan, the Japan Committee for the World Year of Physics, set up jointly by related academic societies, has been undertaking various activities under the chairmanship of Akito Arima.

[Column 2]

Predictions for 20th Century

One may wonder how society will be 100 years from now. While it is impossible for humans to predict the future perfectly, there is no denying that science and technology will greatly affect the future of human beings.

On January 2 and 3, 1901, the Hochi Shimbun newspaper carried 23 "Predictions for the Future." The list is viewed with surprise and deep excitement because a substantial number of them, as mentioned below, have become realities.

Photo telephone	The telephone would have a device to show the image of a caller at the end of the line—the video phone.
Seven-day trip around the world	A trip around the world would take seven days at the end of the 20th century, down from 80 days at the end of the 19th century. People in civilized countries, whether men or women, would travel around the world once or more—an increase in the transfer of people and distribution of goods due to the development of aircraft and other high-speed means of transportation
Freedom from heat and cold	New equipment would be developed to supply air in an appropriate manner so as to adjust heat and cold. African development would be possible as a result—development of the air-conditioner.

- Other predictions that have become realities:

wireless telegraph and telephone; long-distance photography; plants and electricity; human voice reachable over a long distance; the world of electricity; speed of trains; in-town trains; age of automobiles; transport of electricity

- Predictions that have partially become realities

Convenient shopping	Consumers would be able to see remote goods and conclude purchase contracts by photo telephone and immediately receive them sent via underground steel pipe.

Irrigation of Sahara desert; warships and cannons in air; high-speed connection of trains; rise in height of people

- Predictions that have yet to materialize

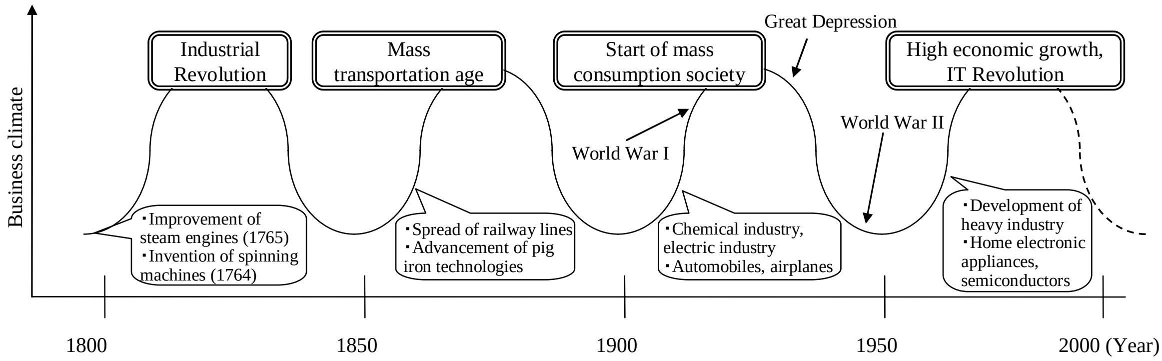
Prevention of typhoons	Advances in meteorological observation technology would make it possible to predict a natural disaster more than a month ahead of its occurrence. In the second half of the 20th century, shipwrecks and other marine perils would be able to be avoided by hitting a typhoon, the most fearful of natural disasters, with cannonballs to convert it into rain. Although earthquakes would be unavoidable, tremor-resistant houses and roads would be built.
Unlimited conversation between humans and animals	Studies on animal languages would advance, prompting elementary schools to have courses in them. Humans thus would be able to freely converse with dogs, cats and monkeys. Most positions of male and female servant would be occupied by dogs, which would run errands for people.

Extinction of wild animals; extinction of mosquitoes and fleas; advances in medical technique; abolishment of kindergartens

(Creating economic values by science and technology)

The rapid progress of science and technology from the end of the 19th century to the beginning of the 20th century gave rise to electrical industries, chemical industries, automobiles, and airplanes, and economic activities expanded due to the emergence of these new industries. After World War II, Japan saw economic development brought about by the diffusion of home electrical appliances and development of the petrochemical industry, followed by economic growth driven by the information and communications technology (ICT) revolution led by the semiconductor industry, which began from around 1985 and lasted until the 1990s.

In either case, creation of new industries based on innovative science and technology brought about significant and long-lasting economic effects. Science and technology has acted as a driving force for economic development through innovation.



In the 1920s, a Russian economist, Nikolai D. Kondratieff (1892-1938), announced a theory that the business climate has a cycle of about 50 to 60 years. He mentioned that this cycle is mainly caused by technological innovation, war, and large-scale development. The graph indicates that a long time is required from occurrence of technological innovations until they produce effects on the market.

Figure 1-1-3 Relationship Between Business Cycles and Technological Innovation

Source: Produced by MEXT.

(Achievement of social and public values)

Scientific and technological progress has brought wealth to society mainly in developed countries. Therefore, there are great expectations for science and technology to contribute to further development of the whole of mankind.

On the other hand, as can be seen in global environment issues, the worldwide diffusion of the Internet, the terrorist attacks in the United States in September 2001, and the bioethical and infection issues, the "lights" and "shadows" of scientific and technological development are spreading widely, and are becoming more closely related to social issues, such as economy, diplomacy, security, health and welfare, energy, environment, disaster prevention, and urban problems. For example, environmental problems such as pollution existed in the past, but they were only problems specific to limited areas. However, discovery of ozone holes prompted the whole of mankind to recognize that the global environment is in a critical situation.

Science and technology is a promising means for recognizing and foreseeing problems that face mankind and for identifying their solutions, so it is expected to provide knowledge that can be shared by all mankind

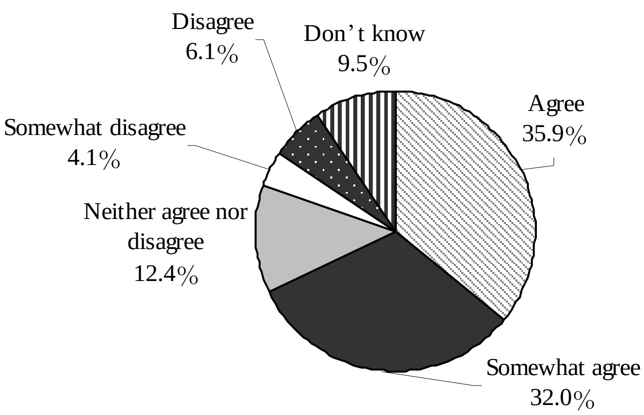


Figure 1-1-4 High Scientific and Technological Standards Are Needed toEnsure Security

Note: Graph shows the responses to the question, "Do you agree with the opinion that 'high scientific and research

standards are essential for ensuring security in your daily life and the general security of the nation?'"
Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society (February 2004)"

1.1.1.2 Scientific and Technological Progress in the 20th Century

(Turning dreams into reality)

In the 20th century, which is referred to as a "century of science," science and technology made significant contributions to the development of human activity. The desire to make our lives more affluent and convenient (social demand) had supported the remarkable development of science and technology. In developed countries, the science and technology in the 20th century was viewed as something that could turn our dreams into reality.

Science and technology in the 20th century dawned with quantum theory and the theory of relativity. Modern physics rapidly enhanced our understanding on the structure of matter from elementary particles to space. With quantum mechanics, which enabled development of atomic power and semiconductors, mankind acquired great strength.

Genetic research achieved remarkable progress with the finding of the double helix structure of DNA. We were surprised and at the same time fascinated by the mysteries of life to learn that the number of genes of a human was about 22,000, far less than what had been predicted in the past and not so different from that of a fruit fly, which is about 20,000.

In the field of medicine, development and diffusion of preventive, diagnostic, and treatment techniques, including antibiotics, vaccines, and X-ray, enabled treatment of various diseases, and in combination with improved living environment, considerably prolonged the average life expectancy in many countries.

In the middle of the 20th century, mankind looked at the Earth from space and landed on the moon. When people saw the space shuttle flying to and fro in outer space and building a space station under international cooperation, people raised hopes that the era of space exploration would begin and that human activity would come to expand into space.

As electronic equipment such as telephones, televisions, and computers developed and transportation means such as cars and airplanes made progress, people and goods came to move easily around the world, and developed countries acquired materially affluent and convenient lifestyles.

It is not too much to say that changes that mankind has never experienced before were brought about by science and technology over the past 100 years. Science and technology significantly changed modern civilization, contributed to dramatically improving human welfare and convenience in life, and noticeablyexpanded the scope of human activity over the past 100 years.

("Lights" and "shadows")

When the scope of human activity expanded with the development of science and technology in the 20th century, not only "lights," such as affluence and convenience in life, but also "shadows" started to emerge.

The enlarged human activity has come to involve mass production and mass consumption of goods, mass disposal, and heavy energy consumption, and is about to go beyond what the Earth can tolerate. Such concerns as depletion of resources, the global warming issue, and destruction of the natural ecology are casting "shadows" over the basis of survival and sustainable development of mankind.

Meanwhile, in the area of life science, which is expected to have a large impact on people's value judgment, it is necessary to examine concurrently the achievements made through scientific and technological progress, such as genetic engineering and cloning, and the ethical questions involved.

Moreover, there is a risk that scientific and technological development will widen the economic gaps between developed countries and developing countries, and have an influence on the world order.

The 20th century was a century where science and technology became more and more involved with society as they achieved development, and the "shadows" of scientific and technological developpment began to emerge on a global scale.

Table 1-1-5 Development of Science and Technology in the 20th Century

	Inventions and discoveries related to science and technology	Events in society surrounding science and technology
1901	･First Nobel Prize * Shibasaburo Kitasato (Japan) nominated as a Nobel Prize candidate for his research into the tetanus bacillus ･Invention and patenting of a method for manufacture of adrenaline (Japan: Jokichi Takamine) ･Success in wireless transmission across Atlantic Ocean (Italy: Guglielmo Marconi)	
1902	･Discovery of Z-term for latitude variation (Japan: Hisashi Kimura)	
1903	･Proposal of Saturnian model for the atom (Japan: Hantaro Nagaoka) ･First manned flight of powered aircraft (U.S.: Wright brothers)	
1904	･Invention of diode vacuum tube (U.K.: John Fleming)	･Russo-Japanese War
1905	･A “miracle year” for physics; photovoltaic effect; theoretical analysis of Brownian motion; special theory of relativity (Switzerland: Albert Einstein)	
1907	･Invention of triode vacuum tube (U.S.: Lee de Forest)	
1908	･Establishment of ammonia synthesis (Germany) ･Patenting of a method for manufacturing a seasoning mainly composed of monosodium glutamate (Japan: Kikunae Ikeda)	･First sale of Model T Ford (U.S.)
1910	･Discovery of Vitamin B1 (Oryzanin) (Japan: Umetaro Suzuki)	
1911	･Success in cultivation of syphilis pathogen (Japan (Hideyo Noguchi) ･Discovery of atomic nucleus (U.K.: Ernest Rutherford) ･Discovery of superconductivity phenomenon (Netherlands: HK Onnes)	
1913		･Mass production of Ford automobiles (U.S.)
1914		･World War I (until 1918)
1915	･Artificial inducement of cancer tumor (Japan: Katsusaburo Yamagiwa, Koichi Ichikawa) ･General theory of relativity (Germany: Albert Einstein) ･Theory of continental drift (Germany: Alfred Wegener) ･Invention and patenting of Japanese typewriter (Japan: Kyota Sugimoto)	
1917	･Invention of KS steel (Japan: Kotaro Honda)	･Establishment of Institute of Physical and Chemical Research (RIKEN) (Japan)
1920		･World's first radio broadcast (U.S.)
1921	･Discovery of insulin (Canada: Frederick Banting, Charles Best)	
1922	･Proposal of expanding universe model (Russia: Aleksandr Friedmann)	
1925	･Invention of Yagi antenna (Japan: Hidetsugu Yagi)	
1926	･Proposal of wave equation (Austria: Erwin Schrodinger) ･Launch of first liquid-fueled rocket (U.S.: Robert Goddard) ･Success in Braun tube reception of electronic signals (Japan: Kenjiro Takayanagi)	
1927	･Proposal of uncertainty principle (Germany: Werner Heisenberg)	･Japan’s first subway opens for operation
1929	･Discovery of penicillin (U.K.: Alexander Fleming) ･Observation of expanding universe (U.S.: Edwin Hubble) ･Invention and patenting of cable phototelegraphic transmission method (Japan: Yasujiro Niwa)	

	Inventions and discoveries related to science and technology	Events in society surrounding science and technology
1932	・Invention and patenting of MK magnetic steel (Japan: Tokuhichi Mishima)	
1935	・Proposal of mehon theory (Japan: Hideki Yukawa)	
	・Isolation of crystal structure in tobacco mosaic virus (U.S.: Wendell M. Stanley)	
	・Invention of nylon synthetic fiber (U.S.: Wallace Carothers)	
1936	・Theoretical computer model (U.K.: Alan Turing)	
1937	・Development of jet engine (U.K.: Frank Whittle, Germany: Hans von Ohain)	
1938	・Discovery of uranium fission (Germany: Otto Hahn, Fritz Strassman)	
1939	・Discovery of DDT insecticide (Switzerland: Paul Mueller)	・World War II (until 1945)
		・First flight of jet aircraft (Germany)
1941		・First commercial television broadcasts (U.S.)
1942	・Success in nuclear fission chain reaction (U.S.: Enrico Fermi, et al)	・Manufacture of V-2 rocket (Germany: Werner von Braun)
1944	・Proof of DNA gene structure (U.S.: Oswald Avery)	
	・Discovery of streptomycin (U.S.: Selman Waxman)	
1945		・Manufacture of atomic bomb (U.S.)
		・Bush Report (U.S.: Vannevar Bush)
1946	・Development of ENIAC electronic computer (U.S.: John Mauchly, Presper Eckert)	
	・Big Bang theory (U.S.: George Gamow)	
	・Development of transistor (U.S.: William Shockley, John Bardeen, Walter Brattain)	
1949	・Hideki Yukawa wins Nobel Prize for Physics	
1951		・First nuclear power generation (U.S.)
1953	・Elucidation of DNA double helix (U.S.: James Watson, U.K.: Francis Crick)	・Start of color television broadcasting (Japan)
1954	・Discovery of interferon (virus inhibition factor) (Japan: Yasuichi Nagano, Yasuhiko Kojima)	
		・World's first kidney transplant (U.S.)
1955		・World's first commercialization of transistor radio (Japan)
Around 1955		・Pollution becomes a societal problem (Japan)
1957		・First criticality in Japanese nuclear reactor
		・Launch of Sputnik artificial satellite (U.S.S.R.)
1959	・Invention of integrated circuit (IC) (U.S.: Jack Kilby)	
1960	・First success in laser firing (U.S.: Ted Maiman)	
1961		・First manned space flight (U.S.S.R.: Yuri Gagarin)
1963	・Proposal of theory of sea-floor spreading (U.K.: Fred Vine, Drummond Mathews)	
1964	・Proposal of Quark Model (U.S.: Murray Gell-Mann, George Zweig)	・Tokai Shinkansen commences operations (Japan)
1965	・Observation of universe background radiation (U.S.: Arno Penzias, Robert Wilson)	
	・Shinichiro Tomonaga wins Nobel Prize for Physics	
1966		・Start of commercial nuclear power generation (Japan)
1967	・Plate tectonics theory (U.K.: Dan McKenzie, U.S.: Jason Morgan, et al.)	・Promulgation of Basic Law for Environmental
		・First heart transplant operation (South Africa: Christiaan Barnard)
1969	・Proposal of superlattice (Japan: Reona Esaki)	・Apollo 11 lands on the moon (U.S.)
1970		・Japan World Exposition (Osaka)
		・Launch of Ohsumi, Japan's first artificial satellite
Around 1973		・Oil shock (Japan)
1973	・Establishment of gene recombinant technology (U.S.: Stanley Cohen, Herbert Boyer)	・Release of microcomputer in kit form (U.S.)
	・Reona Esaki wins Nobel Prize for Physics	
1974	・Indication that chlorofluorocarbon may be depleting ozone layer (U.S.: Sherwood Rowland, Mario Molina)	
1977		・Release of world's first personal computer (U.S.)
		・Release of Japan's first personal computer (Japan)
1978		・First in vitro insemination infant born (U.K.)
1979		・Three Mile Island nuclear power plant accident (U.S.)
1981	・Kenichi Fukui wins Nobel Prize for Chemistry	・First flight of the space shuttle (U.S.)
1982		・Release of world's first CD player (Japan)
1983	・Discovery of AIDS virus (France: Luc Montagnier, U.S.: Robert Gallo)	
1984	・Discovery of fullerenes (U.K.: Harold Kroto, et al)	
Around 1985	・Discovery of the ozone hole (Japan, U.K., U.S.)	
1985		・International Science and Technology Exposition
1986	・Discovery of high-temperature superconductivity (Switzerland)	・Chernobyl nuclear power plant accident (U.S.S.R.)
		・Space Station Mir commences operations (U.S.S.R.)
1987	・Susumu Tonegawa wins Nobel Prize for Physiology or Medicine	・Start of mobile phone services (Japan)
1989		・End of Cold War

	Inventions and discoveries related to science and technology	Events in society surrounding science and technology
1991	・Discovery of carbon nanotubes (Japan: Sumio Iijima)	
1992		・Earth Summit
Around 1993		・Announcement of Information Superhighway concept (U.S.)
		・Explosive growth of Internet
1994	・Confirmation of top quark (U.S.: Fermi National Accelerator Laboratory)	・Launch of H-II rocket (Japan)
1995		・Great Hanshin Earthquake (Japan)
		・Enactment of the Science and Technology Basic Law (Japan)
1996	・Birth of Dolly the cloned sheep (U.K.)	
1997		・Promulgation of Organ Transplant Law (Japan)
1998	・Confirmation of mass in neutrino (Japan: Super Kamiokande)	・Assembly of International Space Station commences (Japan, U.S., EU, Canada, Russia)
1999		・World Conference on Science (Budapest)
		・Test observation of Subaru Telescope starts (Japan)
		・Japan's first organ transplant from brain-dead donor
		・Criticality accident at uranium processing plant (Japan)
2000	・Hideki Shirakawa wins Nobel Prize for Chemistry	・Enactment of Law concerning Regulation relating to Human Cloning Techniques and Other Similar Techniques (Japan)
2001	・Ryoji Noyori wins Nobel Prize for Chemistry	・September 11, 2001 terrorist attacks (U.S.)
		・Launch of H-II A rocket (Japan)
2002	・Masatoshi Koshiba wins Nobel Prize for Physics	・Johannesburg Summit
	・Koichi Tanaka wins Nobel Prize for Chemistry	
2003	・Sequencing of human genome completed (Japan, U.S., Europe)	
2004		・Great Sumatra Earthquake and Indian Ocean Tsunami
2005		・Entry into force of Kyoto Protocol
		・2005 World Exposition (Aichi)

Source: Produced by MEXT

1.1.1.3 Relationship between Japan's Modernization and Science and Technology

A large part of Japan's current science and technology originates from those that had been actively imported from Western Europe in order to promptly achieve the "wealth and military strength" and "encouragement of new industries" advocated by the Meiji government. No other country outside those of Western Europe achieved modernization from the second half of the 19th century to the beginning of the 20th century. This rapid modernization owed partly to the fact that favorable social infrastructure had been available. For example, the literacy rate and people's average basic abilities were high and the level of traditional arts and crafts was also high already in the Edo period.

There is an opinion that because Japan made it a national policy to catch up with Western Europe, it adopted science and technology by primarily focusing on their practical use, and consequently failed to sufficiently acquire the scientific spirit. However, it is a fact that science and technology led Japan's modernization to a success in a short period of time. Furthermore, these efforts and achievements of predecessors have been passed down to the present day through human resources development and technological tradition at research institutes, such as universities, and companies, and they support Japan's scientific and technological capabilities.

[Column 3]

Pioneers of Japan's Modern Science and Technology

The history of modern Japanese science and technology got off to a full-fledged start under the leadership of foreign teachers invited by the government of the Meiji era (1868-1912) and Japanese generations that worked to implant modern science and technology in Japan by learning from them or studying abroad. Following their leadership, Japanese researchers began to produce creative world-level study results in the middle of the Meiji era.

While Japan was little known in the European and U.S. science worlds at that time, there were nevertheless Japanese scientists and engineers who made world-class achievements for the first time in Japan. The following three persons are typical of them.

Shibasaburo Kitasato undertook studies on the tetanus bacillus under Robert Koch in Germany and successfully grew the bacillus in pure culture in 1889. He also discovered the toxin and antibody of the tetanus bacillus in 1890, paving the way for immune serum therapy. Based on Kitasato's discovery, the specific treatment of infectious diseases was established. After returning to Japan, Kitasato discovered the Yersinia pestis in 1894. With those achievements, Kitasato became the first Japanese physician known worldwide. In particular, the discovery of immune serum therapy against the tetanus bacillus is highly credited for leading Emil Adolf von Behring to receive the first Noble Prize in Physiology or Medicine for his discovery of immune serum therapy against diphtheria.

Before returning to Japan, Kitasato received invitations from many countries to continue his studies. But he declined all of them and contributed to improvements in medical science in Japan by founding the Institute of Infectious Diseases and the Kitasato Institute. Many of Kitasato's descendents made world-class achievements. Among them were Kiyoshi Shiga, who discovered the shigella bacillus, and Sahachiro Hata, who developed Salvarsan, an agent for the treatment of syphilis.

Jokichi Takamine settled in the United States in 1890 and devised a method of mass-producing and refining the diastase, which has a highly saccharifying capacity, by implanting mould fungi, called koji, on the rhytidome of wheat. He filed with the U.S. government for related patents in 1894 and let a U.S. drug maker release a digestive under the name Takadiastase in 1897. In 1901, Takamine succeeded in isolating the hormone adrenaline in pure crystalline form from bovine glands. While adrenaline is effective in increasing blood pressure and arresting hemorrhage, Takamine was the first in the world to extract the hormone as a purified substance and thus contributed greatly to the subsequent development of neuroscience and endocrinology.

Takamine also worked to promote friendship between Japan and the United States and proposed and contributed to the establishment of the Institute of Physical and Chemical Research, known as RIKEN, in Japan. Both Takadiastase and adrenaline have been widely used throughout the world for more than a century. Making a huge fortune with income from patents on them, Takamine was the first Japanese person to establish a research and development-oriented venture business.

Hantaro Nagaoka was known worldwide as a leading scholar in the field of magnetostriction. He was the first Japanese physicist recognized in the world. As an example of his fame, he was invited to the International Physics Conference in Paris in 1900 to report on his experiments on magnetostriction.

Nagaoka drew international attention in 1903 when he announced the "Saturnian" model of the atom, in which he postulated that electrons revolved around an atomic nucleus. Nagaoka's concept was proved correct in 1911 through experiments conducted by British physicist Ernest Rutherford.

Japan's modern physics stemmed from Nagoka's wide-ranging studies, which included experimental physics, mathematical physics and geophysics. Assuming such key posts as president of the Osaka Imperial University and of the Japan Academy, Nagaoka made a great deal of contribution to the administration of science and technology in Japan.

As an episode probably seen only among pioneers in any field, Nagaoka, when he was a student at the department of science at the University of Tokyo, wondered whether scientific creativity was inherent in the Japanese and thus took a year off to study the oriental history of science in a bid to find an answer to the question troubling him.

The pictures of the ten great inventors on a poster for "Invention Day"

Sakichi Toyoda (1867-1930) Wooden handloom; Type-G automatic loom
Kokichi Mikimoto (1858-1954) Cultured pearls
Jokichi Takamine (1854-1922) Taka-diastase; adrenaline
Kikunae Ikeda (1864-1936) Sodium glutamate
Umetaro Suzuki (1874-1943) Vitamin B1; vitamin A
Kyota Sugimoto (1882-1972) Japanese typewriter
Kotaro Honda (1870-1954) KS steel; new KS steel
Hidetsugu Yagi (1886-1976) Yagi antenna
Yasujiro Niwa (1893-1975) Phototelegraphic method
Tokushichi Mishima (1893-1975) MK magnetic steel

* The ten inventors were selected by the Japan Patent Office (JPO) in 1985 in commemoration of the 100th anniversary of the industrial property system.

Figure 1-1-6 Ten Great Japanese Inventors

[Column 4]

Comics and Science Fiction Novels That Foster Dreams about Scientific Technologies

Evolution of Robots

There are many people who became completely absorbed in imaginary future worlds by reading comics and science-fiction novels in their childhood. Robots appeared frequently in the future worlds. The word “robots” was coined by Czech science-fiction novelist Karel Capek in 1920. But in Japan, the word became popular by characters such as “Astro Boy” in animations and comics. Moreover, animation and comics have also greatly inspired the progress of the study about robots in Japan.

The future world that Osamu Tezuka described in his “Astro Boy” comics released soon after the end of World War II was supposed to be the world at the beginning of the 21st century, where robots resembling people lived the same lives as people, occasionally exercising much higher abilities than people, and playing an active role in the fight for justice. Undoubtedly, many children at the time dreamed that some day in the future robots like Astro Boy would come into actual existence. Unfortunately, such robots as Astro Boy have not yet materialized because we have not yet developed the science and technology to produce them even though we live in the 21st century. How much has such a dream come true?

You can see the most recent results in the study of robots at the 2005 World Exposition held in Aichi, Japan. Robots that can walk with two legs such as Astro Boy are exhibited, among which there is a biped robot that walks three kilometers per hour. In the Tsukuba Science Expo held twenty years ago, only one biped robot with two legs and a waist was exhibited, and it took ten minutes for it to walk even one step forward. Since then, robots have steadily progressed. In addition to biped robots, many robots that have a wide variety of functions are developed and exhibited at the Aichi Expo.

Some science and technology, which was once described as being part of an imaginary future world where robots such as Astro Boy would flourish, has now materialized, including mobile phones, small-sized computers, large-sized passenger planes, and elevated expressways.

Science and technology will realize our dreams, but at the same time, our imagination and dreams that appear in novels and comics are a driving force for the development of science and technology.

1.1.2 Relevance of Science and Technology in the Transformation and Development of People’s Lives, the Economy, and the Society

After World War II, Japanese people’s lives improved significantly and Japan achieved high economic growth thanks to the contributions of science and technology. This section overviews such influence of science and technology based on data. At the same time, it also introduces applications of science and technology to addressing social problems that have surfaced as “negative” products of scientific and technological progress in recent years.

1.1.2.1 Improvements in People’s Lives

Currently, many scientific and technological achievements are used in our daily lives and are making our lives more convenient. In addition, the concept of distance and time has changed along with the development of science and technology, and dramatically transformed our lifestyles. Furthermore, science and technology also contributes to maintaining and recovering health, which serves as the basis of our daily lives.

(Better convenience)

Scientific and technological achievements that are familiar to us include home electrical appliances. The development and diffusion of various products including fully automatic washing machines, microwave ovens, video tape recorders (VTRs), air con ditioners, and toilet seats with a warm-water bidet function (Figure 1-1-7) have brought convenience to life and made our living environment more pleasant.

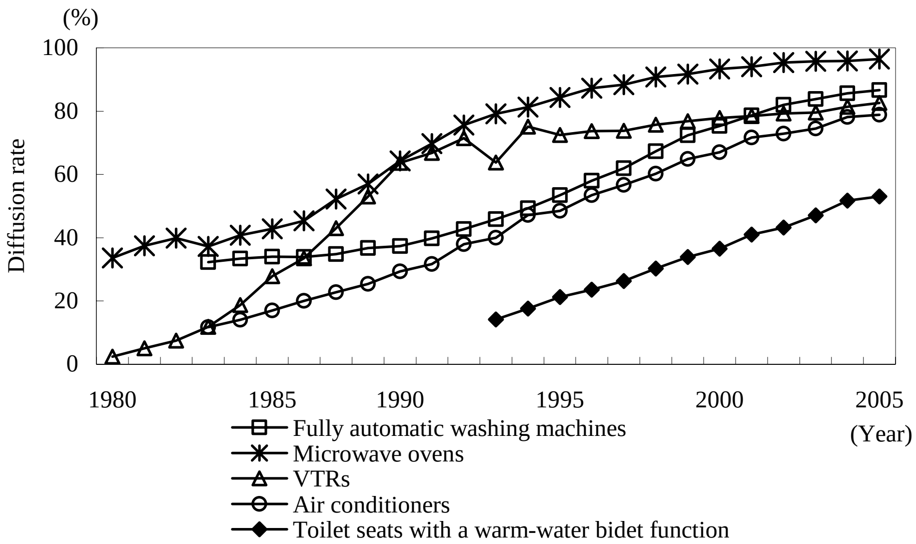


Figure 1-1-7 Diffusion Rate of Home Electrical Appliances

Source: Cabinet Office, “Consumer Confidence Survey”

The frequency of calling or sending e-mail by mobile phones to communicate with other people considerably increased compared to the previous year, indicating that mobile phones have become the central information and communications means in place of postal mail and fixed-line telephones (Figure 1-1-8). Mobile phones made it easier for people to communicate with one another regardless of their locations.

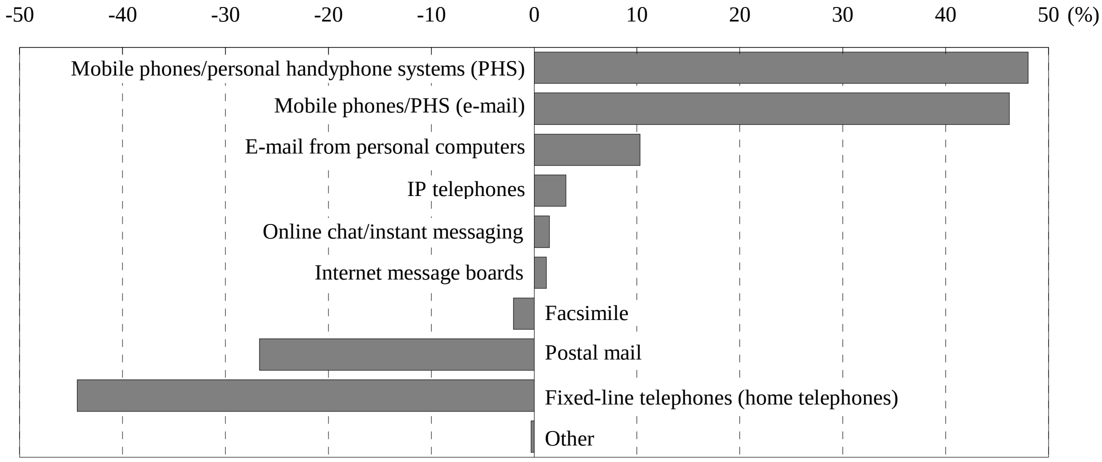


Figure 1-1-8 Changes in Communication Means Compared to Previous Year

Note: Values were derived by deducting the percentage of respondents who answered "less frequently used" from the percentage of respondents who answered "more frequently used."
Source: Ministry of Internal Affairs and Communications (MIC), "Survey on People's Lives in a Ubiquitous Network Society" (March 2004)

(Changes in lifestyles)

In 1956, when the Tokaido Line became fully electrified, it took seven hours and thirty minutes by limited express train from Tokyo to Osaka. However, in 1964, the Tokaido Shinkansen, which boasted a top speed of 210 km per hour—the world's fastest speed at the time—began operation and shortened the time required for traveling from Tokyo to Shin-Osaka to four hours. The emergence of the Shinkansen allowed people to take day trips to areas along the Tokaido Line, and had a considerable impact on people's social lifestyles and economic activities. Since then, many technologies have been applied to the Shinkansen; for example, the axle load was reduced from the original 14 tons to 11 tons through the introduction of aluminum train bodies. As a result, the current Shinkansen achieves a top speed of 270 km per hour, and travels from Tokyo to Shin-Osaka in a mere two hours and thirty minutes (Figure 1-1-9).

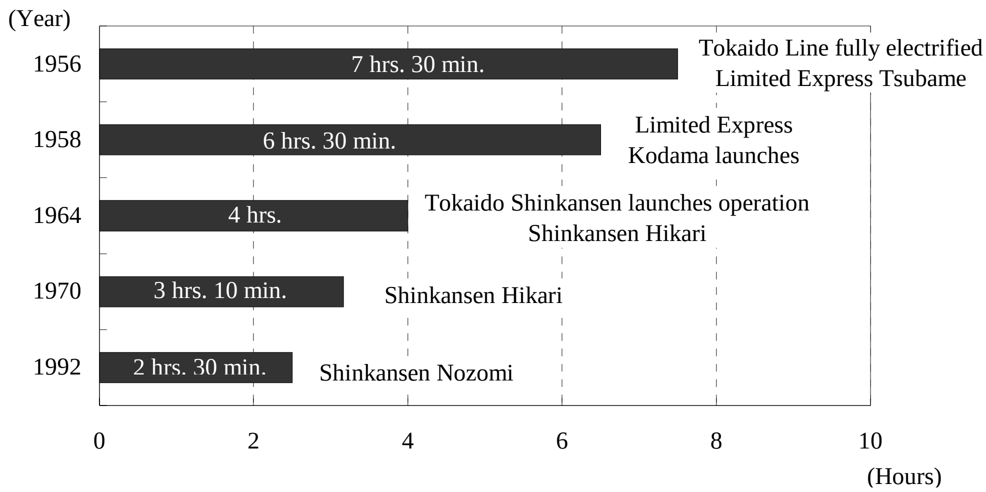


Figure 1-1-9 Travel Time from Tokyo to Shin-Osaka (514.5 km)

Source: Produced by MEXT based on the Website of the Railway Technical Research Institute

Japan's first commercial Internet access service was commenced in 1992. After that, the Internet rapidly spread to people in various segments including companies and general homes, and brought dramatic changes to the methods of information gathering and communication. In schools also, the percentage of public schools connected to the Internet reached 99.8% in fiscal 2003. These schools provide education using information and communications technologies, such as using online information as teaching materials (Figure 1-1-10).

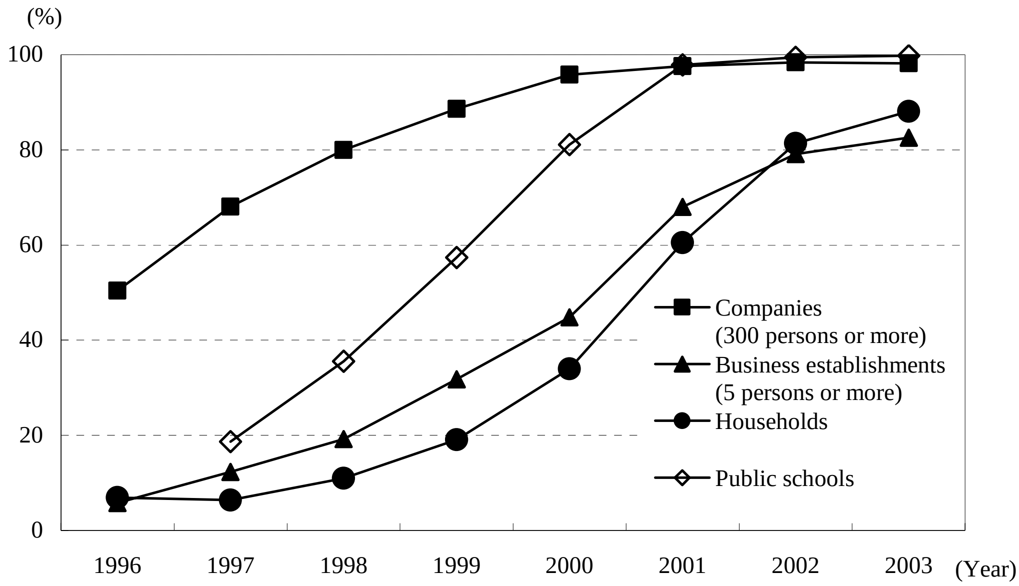


Figure 1-1-10 Internet Diffusion Rates of Households, Companies, Business Establishments, and Public Schools

Notes: Diffusion rate for households indicates the percentage of households where member(s) accesses the Internet via PCs or mobile phones for private purposes "at home/other."
Diffusion rate for companies indicates the percentage of companies where "the entire company"or "part of the offices or divisions" accesses the Internet.
Diffusion rate for business establishments indicates the percentage of business establishments that access the Internet.
Data on the diffusion rate for public schools are only available for 1997 onward.
Source: MIC, "Communications Usage Trend Survey"; MEXT, "Survey Results on Actual Condition of Information Education at Schools"

(Maintenance/recovery of health)

Medical care developed dramatically in the 20th century. Many lives have been saved and life expectancy has been prolonged thanks to the discovery of vaccines and antibiotics, development of various new pharmaceuticals, the progress of medical technologies, the early discovery of diseases through health examinations, and the development of medical equipment used for diagnosis and surgical operations. In particular, Japan has one of the highest longevity rates in the world, and there are signs that the average life expectancy will become even longer in the future (Figure 1-1-11).

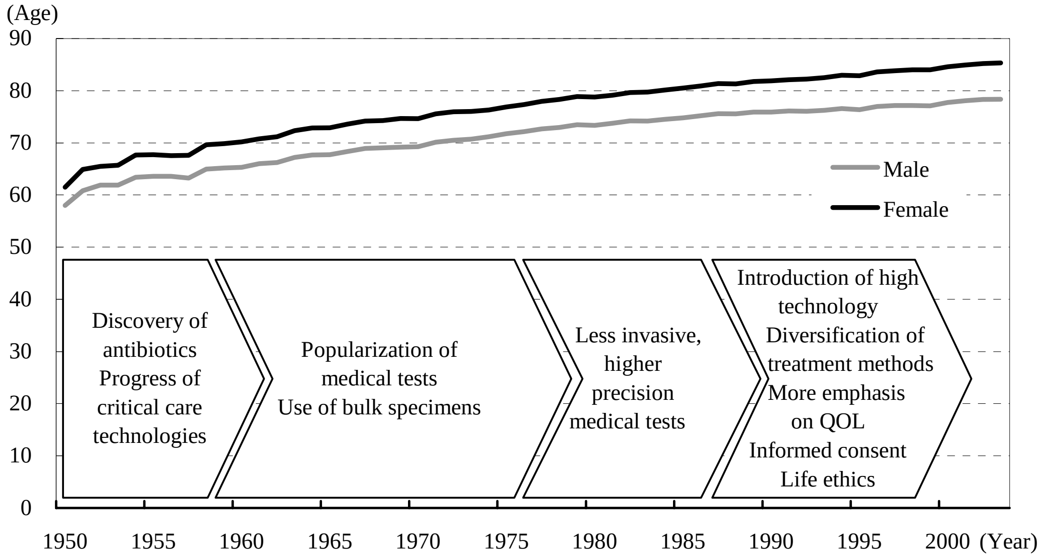


Figure 1-1-11 Development of Medical Technologies and Average Life Expectancy in Japan

Source: Produced by MEXT based on Ministry of Health, Labour and Welfare (MHLW), "Complete Life Tables," "Abridged Life Tables" and Institute of Biomedical Engineering, Tokyo Women's Medical University ed., "21 Seiki Wo Kirihiraku Sentan Iryō" (State-of-the-art medical care for leading the way in the 21st century) (October 1999).

The World Health Organization (WHO) defines, "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." In the modern society, there is risk of suffering from lifestyle-related diseases such as hyperlipemia, hypertension, diabetes, and obesity due to overeating, insufficient exercise, smoking, and drinking alcohol. In particular, obesity is a risk factor that may trigger yet other lifestyle-related diseases, so easy-to-use body fat scales for home use, drinks that help burn body fat, and fat foods that do not easily form fat deposits were developed in order to control body fat.

1.1.2.2 Economic Development

After World War II, Japan did not merely achieve economic revival, but developed significantly through the subsequent high economic growth. The cause for the economic growth can be indicated by the relationship among three elements: labor, capital, and total factor productivity (TFP). The TFP is said to mainly involve technological progress and improvements in human resources. Looking at the past 30 years, although capital investment largely accounted for the economic development in the first half of the 1970s, the increase in the TFP contributed significantly to the subsequent economic growth, particularly in the second half of the 1980s (Figure 1-1-12). Japan's economic growth has owed greatly to an increase in TFP, that is technological innovations and the like, in addition to quantitative expansion of capital.

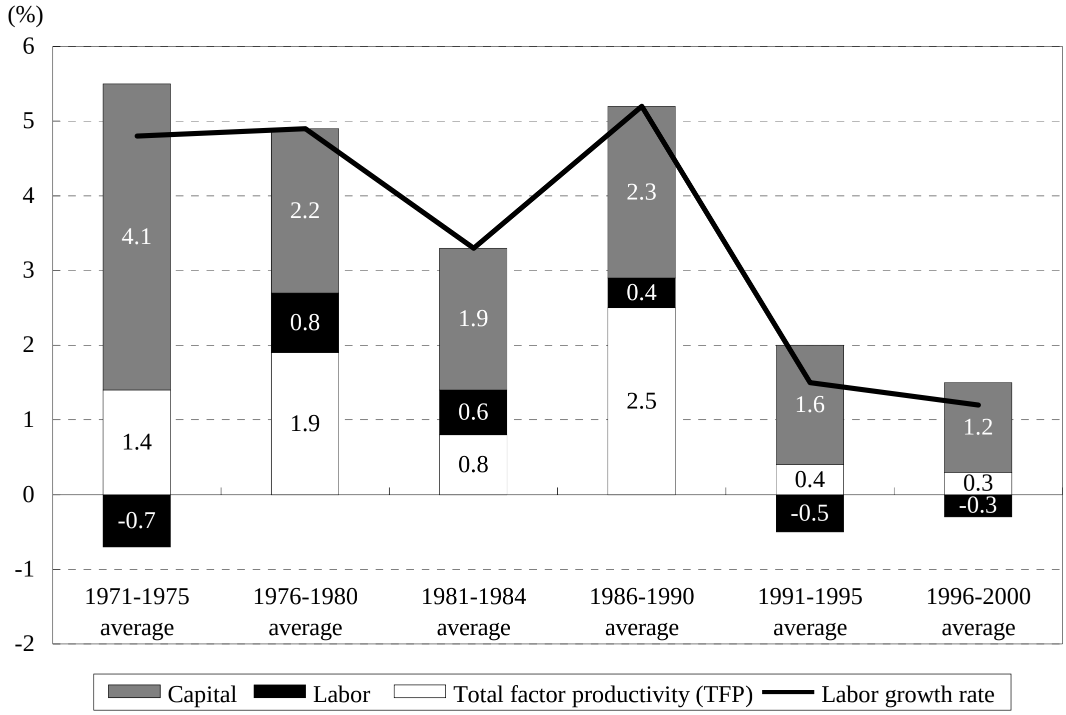


Figure 1-1-12 Contributions of Technological Innovations to Economic Development

Notes: 1. TFP increase rate = (real growth rate of value-added production) - (capital share x capital stock growth rate) - (labor share x labor input growth rate)

2. The simple averages of production growth and contributions of the respective elements to the production growth were obtained for each period.
The data for 1985 was deleted because there would be a gap based on the market entry of Nippon Telegraph and Telephone Corporation (NTT).

3. The average values from 1996 through 2000 were obtained by MEXT in accordance with the estimation method indicated in "Economic Survey of Japan FY 1997."

Source: Economic Planning Agency, "Economic Survey of Japan FY 1997."

1.1.2.3 Addressing Social Issues

As seen in the environmental problems and bioethical issues, science and technology also serves as a cause of threat to the survival of mankind and a cause of concern for people. Effective use of science and technology is also expected for building a safe and secure society, such as addressing such "shadows" of scientific and technological development, taking measures to alleviate damage from natural disasters, and preventing terrorism.

(Environmental problems)

Global warming caused by greenhouse gases such as CO_2 has become a major problem. About 20% of Japan's CO_2 emissions are attributable to the transportation sector, of which 90% are emitted from cars. In order to reduce CO_2 emissions, the fuel efficiency of gasoline-fueled cars was improved by about 18% from 1997 to 2002 (Figure 1-1-13) through various kinds of technological development, such as making the engines and the power transmission systems more efficient, reducing the weight of the vehicle, and reducing the air resistance. In addition, hybrid cars, which efficiently combine the power of the engine and other power such as electricity, were developed, and cars that boast about twice the mileage of gasoline-fueled cars appeared. In this manner, efforts are being made to reduce the environmental loads by saving resources through improvement of fuel consumption, by curbing CO_2 emissions, and by cleaning emissions.

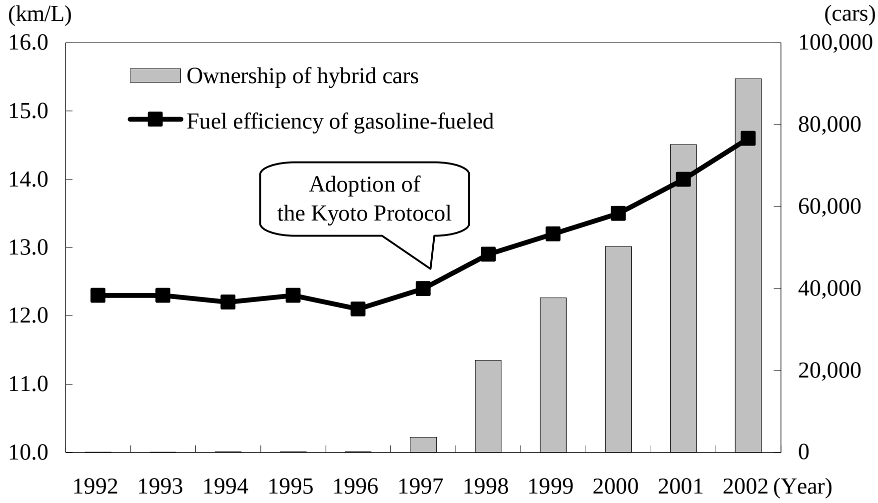


Figure 1-1-13 Fuel Efficiency of Gasoline-Fueled Cars and Ownership of Hybrid Cars

Sources: Ministry of Land, Infrastructure and Transport, "List of Automobile Fuel Efficiency" (March 2005); Japan Automobile Research Institute.

In Japan, energy consumption at home has been increasing. Therefore, new technologies have been introduced to many home electrical appliances to reduce their energy use. For example, when comparing an electric refrigerator, which uses a lot of energy, in 1981 and 2001, the average rated volume nearly doubled over the 20 years, but the annual power consumption per 1 liter of volume has been drastically cut to less than one-third due to technological innovations including a significant improvement in insulation efficiency and use of an inverter-controlled compressor (Figure 1-1-14).

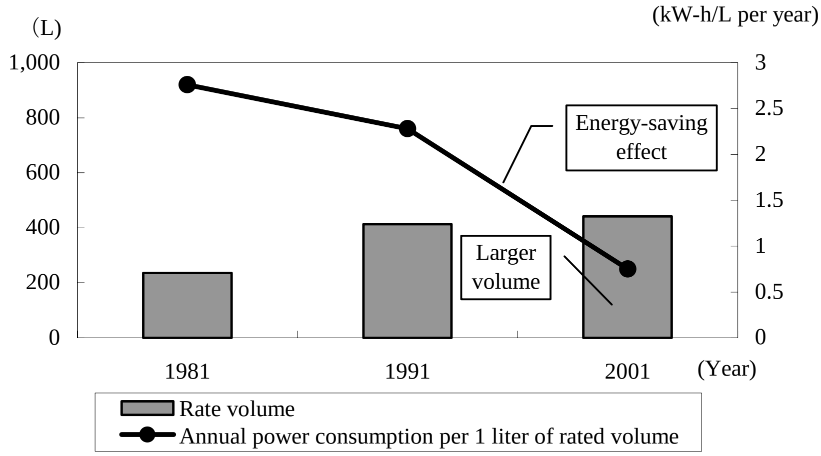


Figure 1-1-14 Energy-Saving Performance of Refrigerator-Freezers

Source: Surveyed by the Japan Electrical Manufacturers' Association (JEMA)

As an entire nation, Japan maintains the lowest level of primary energy consumption per GDP among the major developed countries (Figure 1-1-15). This suggests that Japan, which has scarce energy resources and depends largely on imports, is achieving high productivity based on technologies for using energy efficiently.

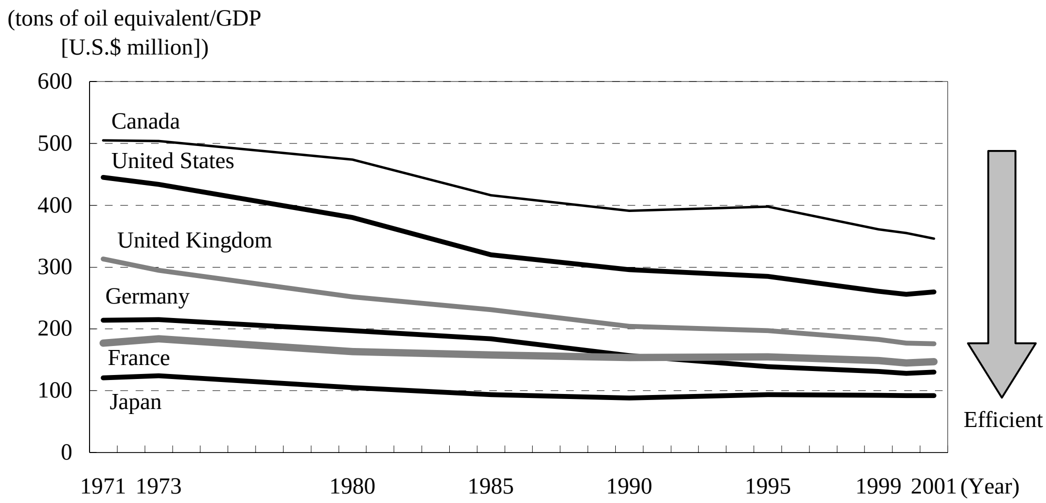


Figure 1-1-15 Primary Energy Consumption per GDP

Source: OECD, "Energy Balances of OECD Countries"

(Science and technology for safety and security)

People have come to face various risks and threats as social systems became more and more sophisticated and complicated. According to a questionnaire survey implemented by the Study Group on Science and Technology Policy for a Safe and Secure Society, more than 75% of the respondents answered that they "feel concern" or "feel slight concern" about crimes, traffic accidents, and air/water pollutions (Figure 1-1-16). Science and technology is also expected to contribute toward eliminating such concerns and achieving safe and secure living and society.

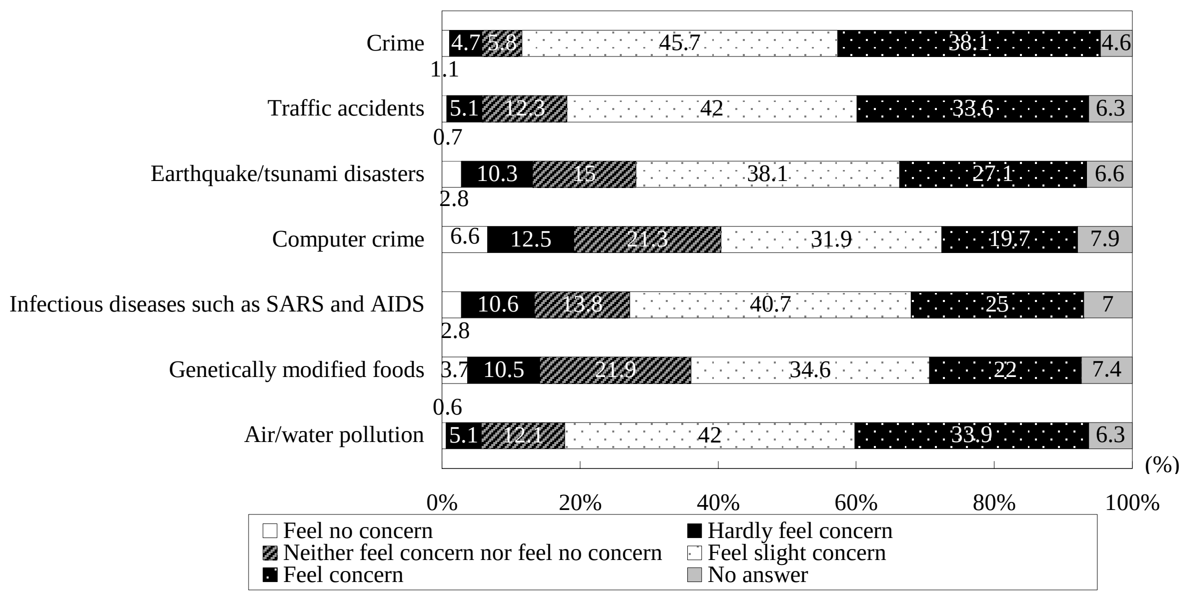


Figure 1-1-16 Degree of Concerns about Threats to Safety

Note: Values are the result of a questionnaire survey conducted on 3,600 citizens by postal mail (no. of valid responses: 1,476).
Source: Extracted from the results of a questionnaire survey conducted by the Study Group on Science and Technology Policy for a Safe and Secure Society (February 2004).

[Column 5]

Key Words for Future Science and Technology Considerate to the Planet and Comfortable for Human Beings: Love the Planet

The main task for all members of the earth in the 21st century is to seek the establishment of sustainable symbiosis of all lives on the planet from the perspective of the whole world. A new challenge has already begun regarding how science and technology can contribute to solving problems emerging on a global scale that human beings are expected to face in the future.

With "Nature's Wisdom" as the main theme, the 2005 World Exposition (Abridged name: Expo 2005 Aichi; Nickname: "Love the Earth") is held with the participation of many countries and multinational organizations. As a comprehensive and international exposition, this Expo is being held in Japan for the first time in 35 years, since the Osaka Expo in 1970, and it is also the first world exposition of the 21st century.

State-of-the art science and technology is displayed to show how science and technology is used to make the recycling-oriented society and to put it into practice for the purpose of the establishment of sustainable development of the society, which is a major issue of the 21st century.

The "Bio Lung" is built at the center of the exposition site. It is a green-painted wall, 150 meters long and 15 meters high, covered with flowers and plants. This facility functions as the lung of the site, reducing the environmental burden by inhaling carbon dioxide and exhaling oxygen by taking advantage of the power of plants, and to improve the living environments in the surrounding area by lowering the temperature during the summer time.

At the food courts, where visitors can enjoy foods from all over the world, environmentally friendly biomass tableware made of recyclable organic materials (biomass) such as plants are used. They are decomposed to water and carbon dioxide by microorganisms in the ground after being dumped, which helps effectively reduce waste and create a post-petroleum society.

Visitors can also experience a next-generation environmentally conscious transport system for moving around inside the site.

As for electricity supply, atomic energy generated at the Mihama Nuclear Power Plant was used for Osaka Expo. But in the case of the Aichi Expo, "New Energy Power Plants" such as photovoltaic power plants and fuel cell power plants located in several places within the site are planned to supply sufficient electricity to meet the expected demand of 2,200KW of electricity of the Japan Pavilion and others in the Nagakute area.

In February 2005, just before the opening of the Aichi Expo, the Kyoto Protocol finally went into effect, eight years after the adoption of the treaty.

It is unclear how the weather will change in the future because of the impact of various environmental problems. But in the past, serious changes in the weather that could destroy human life have occurred many times. Modern civilization has finally taken the first step to seriously considering how to tackle environmental problems and resultant changes in the weather.

The Japan Pavilion Nagakute The Japan Pavilion Nagakute (left) is covered by a bamboo basket. It is 90 meters long, 70 meters wide and 19 meters high. At the Japan Pavilion Nagakute, the steel sheet roof is used for taking advantage of the effectiveness of heat radiation caused by the super hydrophilic photocatalytic property, which is an achievement of Japan's original basic research. Water flows down from the upper side of the roof, evaporates on the surface, and deprives heat from the roof (i.e., the heat of vaporization), which is an achievement of Japan's original basic research. Water flows down from the upper side of the roof, evaporates on the surface, and deprives heat from the roof (i.e., the heat of vaporization), which cools the roof and then lowers the temperature inside the pavilion. This reduces the air-conditioning load. Waste water disposed within the pavilion is zoned and reused for this purpose. Moreover, active oxygen is created on the roof because of ultraviolet rays, which decompose organic matter on the roof. And, as decomposed materials are washed away by rain, the roof remains clean.

[Column 6]

Ten Years after the Great Hanshin Earthquake

Fatalities numbering 11,000, total disaster victims coming to 7 million, among which 4.6 million live in evacuation houses, and a total amount of economic damage of 112 trillion yen, the equivalent of the national budget for one year and three months (of which direct damage is 67 trillion yen)—these are the estimated damage figures if an earthquake of the same magnitude as the Great Hanshin earthquake (magnitude 7.3) hit the Tokyo metropolitan area at present. (These figures are quoted from the materials of the Earthquake Measure Experts Research Committee about Inland Earthquakes in Metropolitan Areas, by the Central Disaster Prevention Council. Estimation is made based on the assumption that the earthquake source is in the northern part of Tokyo Bay.)

In the early morning of January 17, 1995, the “Southern Hyogo earthquake” struck, with a magnitude of 7.3 and a source at the Nojima Fault. This earthquake is the first big inland earthquake that has hit a major city of an advanced nation in modern history. The earthquake was later renamed the Great Hanshin earthquake.

The Great Hanshin earthquake caused the greatest human and physical damage in the postwar period. The number of the people killed or missing came to 6,436, a total of 250,000 houses were destroyed, and the direct economic damage reached ten trillion yen. In addition to building damage, the transportation network such as the Hanshin Superhighway, Japan Railways lines, private railways and harbors, and the lifeline network including the water, electricity and gas systems suffered destructive damage, which revealed the vulnerability of the functions and social infrastructure of modern cities.

After the earthquake, the Office to Promote the Research and Study of Earthquake was established, and full-scale joint efforts by the government, private companies and academia were launched to work out measures to prevent and reduce disasters. The Japan Meteorological Agency, universities, the National Research Institute for Earth Science and Disaster Prevention, the Building Research Institute, and private companies and others are engaged in efforts to establish the network of earthquake observation, to explore the mechanism of earthquake occurrence by using simulation models, to develop seismic isolation and damping technologies for buildings and other structures, and to develop robots for disaster relief.

Moreover, on the tenth anniversary of the Great Hanshin earthquake in January 2005, a real size three-dimensional full-scale earthquake destruction testing facility called “E-Defense,” the largest of its kind in the world, was constructed at a site next to the Miki Earthquake Disaster Memorial Park in Miki City, Hyogo. This facility is equipped with the world’s largest shaking table, which is 15 meters long and 20 meters wide, and can recreate an earthquake of the same size as the Great Hanshin earthquake. It also has shakers, fourteen of which can move structures vertically and ten of which can move them horizontally. The testing facility can explore how a building is destroyed, how much a building is destroyed and why a building is destroyed, by shaking the building with a weight of 1,200 tons at maximum from three directions and eventually destroying it. By increasing the strength of buildings, human casualties would become more serious when buildings collapse, because people would be buried under the bricks. Researchers have been striving to develop construction design methods to minimize human casualties, by allowing a building to be partially destroyed under strong vibrations.

Natural disasters cannot be prevented even if modern technologies are applied. But science and technology are expected to play an important role in minimizing disaster damage, securing the safety of people who suffer disasters and rescuing disaster victims as quickly as possible. In this field, Japan is expected to make an intellectual contribution.

1.2 Japan's Scientific and Technological Capabilities and Their Level

As a comprehensive framework for Japan's scientific and technological policy, the Science and Technology Basic Law was enacted in 1995, and the "Science and Technology Basic Plan" was formulated as a five-year plan based on this basic law (first period: from 1996; second period: from 2001). The current Second Basic Plan encompasses expansion of government investment in R&D, strategic priority setting, and reform of the science and technology system for increasing Japan's scientific and technological capabilities.

Accumulation of such policies and resource investment is expected to bring about "creation of new knowledge," "creation of vitality based on the knowledge," and "creation of an affluent society based on the knowledge" in Japan as a result.

This chapter overviews the scientific and technological achievements in Japan in recent years, people who are making these achievements, the Science and Technology Basic Law, and the First and Second Science and Technology Basic Plans based on the basic law. Lastly, it clarifies Japan's scientific and technological level through comparisons with other countries.

1.2.1 Japan's Scientific and Technological Achievements

1.2.1.1 Scientific and Technological Achievements and Spillover Effects

Japan's scientific and technological achievements cover extensive fields, so it is difficult to overview all of them. Nevertheless, "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" ("Study for Evaluating the Achievements of the S&T Basic Plans in Japan"(NISTEP Report, no. 89, March 2005)) compiled by the National Institute of Science and Technology Policy analyzes case examples in the eight fields specified in the Second Science and Technology Basic Plan and cites examples of effects that have been already generated over the past ten years or so, as shown in Table 1-2-1.

This section looks at the achievements and spillover effects of science and technology mainly based on case examples in the four priority fields and the other four fields that were taken up in the above report.

(1) Economic effects

Economic effects include "creating or expanding markets and employment," "reducing costs," "reducing economic risks," and "enhancing international competitiveness."

(Creating or expanding markets and employment)

The development of new technologies through R&D and subsequent technological progress have, when applied to products and services, an effect of creating or expanding the markets of these products and services, as well as creating or expanding related employment. Based on a creative research achievement of a Japanese researcher, the high-intensity LED was commercialized for the first time by a Japanese company in 1994. Today, Japanese companies command an 80% share of the world market for high-intensity LED. The world market size for overall high-intensity LED exceeded 100 billion yen in 2003, and is expected to grow further in the future. Examples of this type of effects are listed in Table 1-2-2.

Table 1-2-1 Examples of the Effects Generated by Science and Technology

Category	Type of effects	Examples of specific effects
Economic effects	Creating/expanding markets (employment)	- Creating new product/service markets - Expanding related markets - Giving rise to venture companies
	Reducing costs	- Shortening the R&D period, reducing test production costs - Improving efficiency of physical distribution, reducing inventory costs - Reducing energy costs, reducing costs for environmental measures
	Reducing economic risks	- Averting business risks - Preventing/reducing damage from disasters - Preventing a decline in product prices
	Enhancing international competitiveness	- Contributing to technological progress through scientific research - Enhancing international competitiveness through infrastructure development - Enhancing international competitiveness through pioneering efforts
Social effects	Addressing environmental problems	- Reducing greenhouse gas emissions - Preventing air pollution (dioxin, SOx, NOx, particulate matter) - Preventing water/soil pollution (PCB, lead, cadmium), reducing waste
	Addressing energy/resource problems	- Saving energy - Thermal/material recycling - Improving energy security
	Addressing the aging of the population	- Facilitating social participation of the elderly and the disabled - Reducing the burden of nursing care on society - Achieving a society of healthy longevity
	Improving social infrastructure/disaster prevention measures	- Improving the physical disaster prevention measures of structures - Preventing disasters in advance or reducing damage through information transmission - Improving the safety and reliability of social infrastructure, reducing traffic accidents
	Other	- Making international contributions - Influencing culture and policies
Effects on people's lives	Securing the lives /livelihoods of the people	- Reducing loss of lives at times of disasters - Overcoming deadly diseases
	Maintaining/ recovering people's health	- Preventing deterioration of the living environment (air, water, soil, noise, vibration) - Improving therapeutic effects to combat diseases
	Improving convenience /comfort for the people	- Reducing the burden on household budgets - Increasing convenience through reducing the size and weight of electronic equipment - Facilitating access to various services
	Changing people's awareness/lifestyles	- Increasing energy-saving/recycling awareness - Improving disaster-prevention awareness - Changing lifestyles through altering the concept of distance and time

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

Table 1-2-2 Examples of Creating or Expanding the Domestic Market and Employment

Type of effects	Case example	Field	Effects
Creating a market	Processing technology using lasers	Manufacturing	Processing equipment market: approx. 300 billion yen → approx. 600 billion yen (2010)
	Home photovoltaic power generation systems	Energy	Photovoltaic power generation system market: approx. 150 billion yen (the highest in the world) → approx. 400 billion yen (2010)
	Technology to increase the density and extend the life of lithium batteries	Nanotechnology/ materials	Put to practical use ahead of the rest of the world Lithium-ion secondary battery market: 250 billion yen
Expanding related markets through development of systematization technologies	Intelligent transport systems (ITS) (car navigation, VICS, ETC)	Information and communications	Related markets: approx. 881.4 billion yen → approx. 7 trillion yen (2015) Employment creation: 1.07 million persons (2015)
Creating/expanding related markets through development of elemental technologies	Photocatalytic materials	Nanotechnology/ materials	Related markets: approx. 40 billion yen

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(Reducing costs)

The developed technologies not only have economic effect as goods or services, but also have the effect of improving efficiency or reducing costs for the individual users or society as a whole through use of the products or services applying those technologies.

The technology for local weather forecasting has made progress, and it is used for cutting costs through reduction of inventory in a wide range of business types in which sales are easily affected by weather, such as the energy industry and convenience stores. In addition, the introduction of intelligent transport systems (ITS) (car navigation, VICS, ETC) has contributed to improving traffic efficiency and reducing traffic congestion. It is expected to reduce social costs by about 1 trillion yen through the easing of congestion and other effects.

(Reducing economic risks)

The developed technologies cannot only be comprehended in economic terms; they also have the effect of reducing economic risks such as reducing opportunity losses and stabilizing the market.

Development of a testing method to predict the possibility of carcinogenicity or long-term toxicity of chemical substances on the human body made it possible to discover such hazardous chemical substances in advance. It has had the effect of preventing the recurrence of damage caused by chemical substances, such as the Kanemi oil poisoning and Minamata disease, and reducing the business risks of the related companies.

(Enhancing international competitiveness)

The developed technologies enhance the international competitiveness of the industries that use those technologies through various routes.

Such base technologies as the "Earth Simulator" and "SPring-8" have promoted scientific research and contributed to the progress of diverse technologies. In addition, pioneering efforts were made ahead of the rest of the world in developing technologies to produce and use alternatives to chlorofluorocarbon (CFC) and halon, which are ozone-friendly and have a minimum impact on global warming, and in spreading the use of home photovoltaic power generation systems. Due to these efforts, the air-conditioner industry and the photovoltaic power generation industry respectively took measures to meet the emission regulations earlier than the relevant industries in other countries, so their international competitiveness was strengthened.

[Column 7]

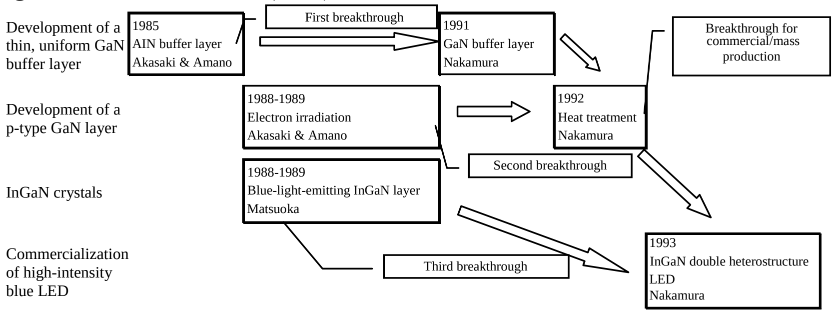
Researchers Devoted to the Study of Gallium NitrideSearch for Blue Light Emitting Diode

Recently, traffic signals that use light emitting diodes (LED) are installed at every corner and junction, so that drivers can easily identify the colors of signals even in strong light. This improvement in traffic signals owes greatly to the Japanese researcher who discovered the blue LED.

The blue LED was tested for the first time in 1971 in the United States by using gallium nitride. For the MIS-type LED that uses gallium nitride, the then Ministry of International Trade and Industry (MITI) conducted research under the Blue Light Emitting Devices Development Project for three years from 1975, and Japanese companies made sample shipments of flip-chip LEDs in 1980. But in making a single crystal of gallium nitride, its surface tends to become uneven or even cracked. As it was difficult to produce p-type semiconductors, which are indispensable for diodes, researchers tried continuously to test other materials such as zinc selenide, silicon carbide and so on.

At the time, there were some Japanese researchers who continued to focus on gallium nitride.

Technological Progress of Gallium Nitride (GaN) Blue LED



Source: Surveyed by MEXT

Then Nagoya University professor Isamu Akasaki (currently a professor at Meijo University), who spearheaded the sample shipment of metal–insulator–silicon (MIS) LED using gallium nitride while working for a private company, and Meijo University professor Hiroshi Amano, who was a graduate student at the time, succeeded in 1985 in making a high quality gallium nitride crystal by a low temperature buffer layer technique that used aluminum nitride as the buffer layer. This was the first breakthrough in the development. Then, they were jointly commissioned along with other private companies for four years from 1987 to develop "gallium nitride blue LED production technology" by the Research Development Corporation of Japan (currently Japan Science and Technology Agency). In 1988, they discovered that they could make a p-type semiconductor by applying an electron beam to gallium nitride blended with magnesium. Though emitting ultraviolet light, a pn junction LED with gallium nitride was made for the fist time. This was the second breakthrough in the development.

Gallium nitride emits ultraviolet light by itself. Tohoku University professor Takashi Matsuoka, who worked at NTT's Atsugi R&D Center at the time, considered indium gallium nitride (InGaN) to be the best material to emit blue light. And he succeeded in making a single crystal of it in 1988. This was the third breakthrough.

Around 1991, Shuji Nakamura, who worked for Nichia Corporation at the time, and is currently a professor at the University of California, Santa Barbara, succeeded in making a uniform crystal by using gallium nitride as the buffer layer, and discovered that a p-type semiconductor could be made through heat treatment of a crystal. This was the breakthrough for its commercialization and mass-production. In 1992, he developed the high-intensity blue LED by using a gallium nitride layer mixed with indium, which created a new market.

The use of the blue LED has spread from electric lights illuminating towns, traffic signals, large-sized screens, and it is now expected that the white LED derived from blue LED will replace white lamps and fluorescent bulbs.

The global market size of the gallium nitride LED in 2003 was estimated at over 100 billion yen, of which three Japanese companies occupy more than 80% of the total market share. Professor Akasaki and other researchers had received an accumulated amount of 3.6 billion yen as license fees as of 2003.

We should be proud that Japan has these researchers who took on the challenge of this difficult subject and succeeded in commercialization of the blue LED through their original approaches.

[Column 8]

ITS (Car Navigation, VICS, ETC etc.)
Aiming for Resolution of Road Transport Problems

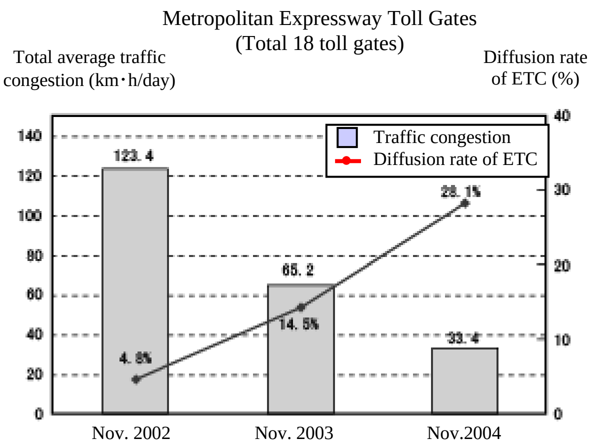
Intelligent Transport Systems (ITS) are systems that seek to resolve road transportproblems such as traffic congestion, traffic accidents, environment deterioration caused by traffic and so on by combining people, roads and cars in an integrated system by making use of the state-of-art communication technology.

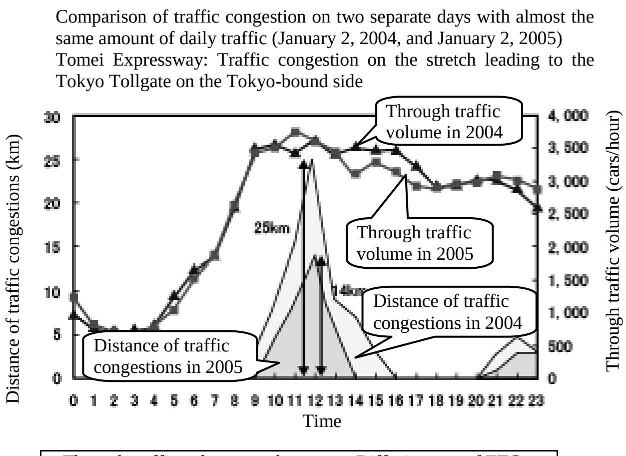
ITS in Japan have been promoted by four government ministries or agencies—the National Police Agency, the Ministry of Internal Affairs and Communications, and the Ministry of Economy, Trade and Industry, the Ministry of Land, Infrastructure and Transport—and extra-governmental organizations of the four ministries or agencies, such as ITS Japan, which represents the private sector. Since the formulation of the “Overall Plan regarding Promotion of Intelligent Transport Systems” by five related ministries in 1996, joint efforts were made by government organizations, universities and private companies to develop the systems and put them into practice in various fields. Among the elementary technologies, car navigation, the Vehicle Information and Communication System (VICS), Electronic Toll Collection (ETC) and others are already in practical use.

Car navigation was first invented by a Japanese company in 1981. Since then, new types of car navigation that use CD-ROM, DVD-ROM and hard discs have been put on the market in quick succession and their functions have been expanding in line with the development of large capacity storage. According to the Japan Automobile Research Institute, the accumulated number of shipments of car navigation systems is estimated to reach 25 million units at the end of 2005.

The VICS launched a service enabling drivers to acquire road traffic information, such as information on congestion and traffic control, in real time while driving. According to a survey conducted by the VICS Center, the total number of in-vehicle VICS units shipped exceeded 10 million in July 2003.

ETC is a system for collecting toll charges from cars without stopping them, by using radio communication for connecting ETC machines installed in cars to antennas located at toll booths. According to the Organization for Road System Enhancement, the accumulated number of cars that are equipped with ETC devices exceeded 5 million from the launch of the service in March 2001 to January 2005. Cars equipped with ETC devices account for 25.6% of the combined traffic volume of Japan Highway Public Corporation, the Metropolitan Expressway Public Corporation, the Hanshin Expressway Public Corporation, and the Honshu-Shikoku Bridge Authority for the period from December 24 to 30, 2004.





Through traffic volume per day	Diffusion rate of ETC
1/2/2004 ⇒ 59,800 cars/day	(approx. 15%)
1/2/2005 ⇒ 59,100 cars/day	(approx. 28%)

Source: Ministry of Land, Infrastructure and Transport, press release, “Diffusion rate of ETC exceeds 30%: About the recent diffusion rate of ETC,” February 8, 2005

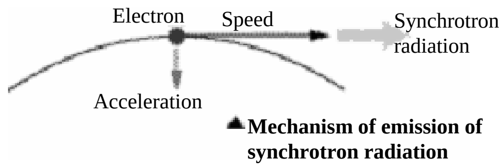
Since the 1990s, R&D for promotion of ITS has been implemented in Japan, the United States, and Europe. Japan leads the world in terms of R&D and system diffusion of individual elemental technologies constituting ITS, such as car navigation, VICS, and ETC.

[Column 9]

High-Power Synchrotron Radiation Technology (SPring-8)
Most Effective X-ray Generator in the World, 100 Million Times Brighter Than Conventional Generators

When the direction of an electron running straight at the almost same speed as that of light is changed by a material such as a magnet, electromagnetic waves are radiated. This wave is called synchrotron radiation.

As high-power synchrotron radiation technology is a basic technology, it is difficult to measure its direct economic effect. But there are several success cases of the application of synchrotron radiation. The duration of the use of catalytic agents for gas emission is extended by solving related problems by the application of synchrotron radiation and improvement in the lifetime of lithium-ion batteries is also made by clarifying the problems causing their degradation by the application of synchrotron radiation. Analyses of properties of minor components by using synchrotron radiation are applied to solve archaeological mysteries such as the Kofun Period geometrically-shaped convex copper mirror with a design of intertwined gods and beasts, as well as criminal investigations and so on.



Mechanism of emission of synchrotron radiation

Source: Japan Synchrotron Radiation Research Institute "Summary of SPring-8"

The higher the energy of an electron is, the brighter the synchrotron radiation that is generated and the better the directional characteristics of that radiation. And the greater the energy of an electron is and the greater the change of direction of movement that is made, the shorter the waves of the lights contained (e.g. X-rays) in the synchrotron radiation. As the brightness (luminance) of synchrotron radiation is very high with a wide range of wavelengths from X-rays to infrared radiation, detailed analyses of the kind, structure and properties of materials can be made by using synchrotron radiation.

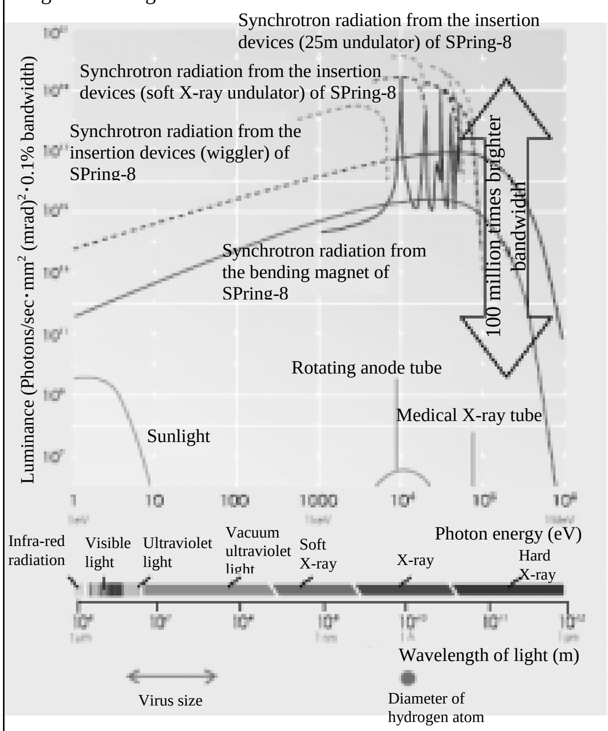
R&D on high-power synchrotron radiation generators has been undertaken by universities and public research institutes since the 1960s.

Now it is time for large third-generation synchrotron radiation facilities. SPring-8, which was jointly constructed by the Japan Atomic Energy Research Institute and the Institute of Physical and Chemical Research (RIKEN), is the most sophisticated experimental facility in the world. There are only two other facilities in the world that are of the same size and capacity as SPring-8: APS of the U.S. Department of Energy and ESRF, the joint facility of eighteen European countries.

Among the 48 beamlines—the experiment facilities that extract the synchrotron radiation—two shared-use beams and four exclusive-use beams are also made available for private use. As one thousand and several hundred researchers visit SPring-8 every year because of it boasting the highest performance in the world, it also contributes to international cooperation.

SPring-8 has already yielded the above-mentioned research results, and it is also expected to be applied further for industrial use.

Brightness of light source



Source: Japan Synchrotron Radiation Research Institute "Summary of Spring-8"

(2) Social effects

Social effects include "addressing environmental problems," "addressing energy/resource problems," "addressing the aging of the population," and "improving social infrastructure/disaster prevention measures."

(Addressing environmental problems)

Science and technology has the effect of adderssing global environmental problems such as global warming and ozone depletion, as well as the effect of preventing air, water, and soil pollution and reducing waste.

As for technologies that have the effect of reducing greenhouse gas emissions, which cause global warming, CO_2 emissions are reduced by home photovoltaic power generation systems, and the greenhouse effect is reduced while internationally organized prevention of depletion of the ozone layer is also achieved by development of technologies to produce and use alternatives to chlorofluorocarbon (CFC) and halon, which are ozone-friendly and have a minimum impact on global warming.

(Addressing energy/resource problems)

Japan relies on imports for a large part of its energy and mineral resources. Therefore, by using them efficiently, Japan can achieve security in terms of energy and mineral resources.

Home photovoltaic power generation systems can be considered as domestic energy, since they recover the energy used for their manufacture in one year and a half to two years, and produce 10 to 13 times the energy used for their manufacture over the subsequent 10 years.

(Addressing the aging of the population)

Society will become more active by improving the medical technologies for the elderly, the disabled, and patients with various diseases. The achievements in the field of life science, such as cancer research, have lead to improving the therapeutic effects to combat diseases and increasing the possibility for a complete cure, and further effects are hoped for in the future.

(Improving social infrastructure/disaster prevention measures)

With regard to technologies for improving social infrastructure and disaster prevention measures, the technology to simulate the effects of earthquake motion on the behavior of structures has increased the safety of structures including roads, bridges, buildings, and houses, while development of a design method that enables early restoration at times of disasters has contributed to improving disaster prevention measures. In addition, development of the ITS is hoped to have such effects as reducing traffic accidents.

(Other social impacts)

SPring-8 had the effect of raising Japan's international status in the area of science and technology for possessing the world's highest performance facility, while it also made a cultural contribution to solving archeological mysteries with its analysis function and was applied to investigation of criminal offenses. Furthermore, the Earth Simulator had an impact on U.S. supercomputer R&D policy by achieving the world's fastest computation speed.

[Column 10]

The Earth Simulator (ES)
The Ultrafast Parallel Computer

Since 1997, the Earth Simulator (ES) has been developed in collaboration of the former Japan Marine Science and Technology Center, the former National Space Development Agency of Japan, and the Japan Atomic Energy Research Center, to create the world’s fastest supercomputer. The ES has been operated by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) since March 2002. It is one of the greatest ultrafast parallel computer systems in the world. The ES aims to predict and investigate global phenomena including global warming, environmental changes, abnormal weather and tectonic movements, utilizing its highly precise simulation capabilities.

The ES recorded the world’s best computing performance at 35.86 TFLOPS at the performance evaluation by the LINear equations software PACKage (LINPACK). The performance was approximately five times better compared to other supercomputers at the time. Consequently, it occupied first place in the world supercomputer performance TOP500 ranking, and did not yield it for approximately two and a half years until a supercomputer made in the United States took over first place in November 2004. For its research achievements utilizing the high performance of the ES, the JAMSTEC won the Gordon Bell Prize for three consecutive years from 2002, as well as the 21st Century Achievement Award in 2003.

Supercomputers including the ES were mostly utilized in scientific fields at first, but they are also expected to be applied in industrial areas such as the simulation of vehicular safety in collisions.

The U.S. Department of Energy listed supercomputers as the second-most important large-scale research equipment or facilities that should be developed in its report published in 2003. Additionally, in November 2004, the “Department of Energy High-End Computing Revitalization Act of 2004” was approved at the U.S. Congress.

Supercomputer competition between the United States and Japan has been becoming more and more intense.

(3) Effects on people’s lives

Effects on people’s lives include “securing the lives/livelihoods of the people,” “maintaining/ restoring people’s health,” “improving convenience/comfort for people,” and “changing people’s awareness/lifestyles.”

(Securing the lives/livelihoods of the people)

With respect to securing the lives/livelihoods of the people, progress in the technology for local weather forecasting and advancement of the technology to simulate the effects of earthquake motion on the behavior of structures have the effect of reducing damages based on better disaster prevention measures. The development of observation technology using satellites made it possible to gain a precise understanding of the status of damage at times of disasters, and contributed to speeding up recovery operations. Meanwhile, development of the helical CT technology—an effective means for early detection of lung cancer—enabled early discovery of lung cancer, which had been hard to discover and often advanced to the terminal stage.

(Maintaining/restoring people’s health)

In terms of maintaining/restoring people’s health, science and technology has the effect of preventing deterioration of the living environment and the effect of improving therapeutic effects to combat diseases. With regard to prevention of deterioration of the living environment, the development of photocatalysts and development of technologies to appropriately dispose of discarded cars and home electrical appliances have the effect of preventing air, water, and soil pollution as well as deterioration of the living environment. Improvement of therapeutic effects to combat diseases includes increasing the possibility of completely curing cancer through progress in cancer research.

[Column 11]

HIMAC (Heavy Ion Medical Accelerator in Chiba) Utilized for Cancer Therapy

From fiscal 1984 to 1993, the former Ministry of Education, the former Ministry of Health and Welfare, and the former Science and Technology Agency collaboratively promoted the "10-year Strategy for Cancer Control." Subsequently, since fiscal 1994, the three government offices have conducted the joint project "New 10-year Strategy for Cancer Control." Based on this strategy, many researchers belonging to universities, public research institutes and hospitals have worked closely together to carry out pioneering research, utilizing advanced technologies, and have achieved internationally distinguished results.

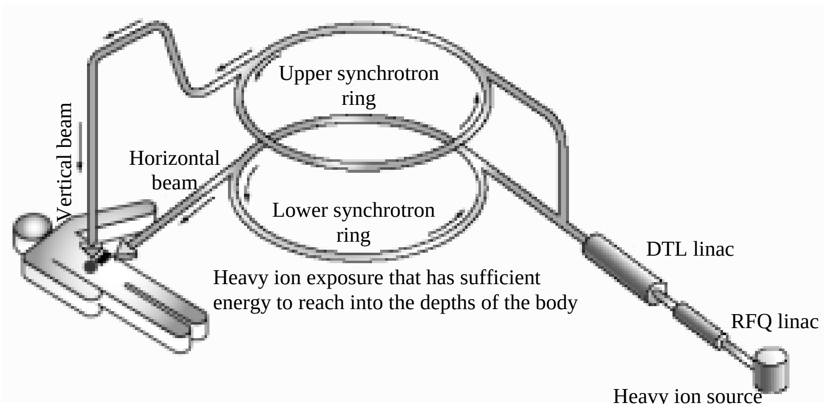
The Research Center for Charged Particle Therapy of the National Institute of Radiological Sciences (NIRS) has been conducting R&D utilizing the Heavy Ion Medical Accelerator in Chiba (HIMAC), which was established for the first time in Japan based on the "10-year Strategy for Cancer Control."

The HIMAC accelerates the heavy ions whose atomic number is 2 or more, e.g. proton and carbon ions, for exposure therapy for cancer focuses that are to be removed. Those heavy ions have the merit of reaching into the depths of the body, not diffusing like a shower. Consequently, the HIMAC can destroy cancer cells at some depth in the body, unlike X-rays, which harm healthy organs in front of or in the region of the cancer cells. It is expected that the HIMAC will be able to cure advanced cancers that exist very deep in the body and that were hard to remove in the past. Also, with the introduction of the HIMAC, the recurrence rate of cancer is estimated to drop sharply.

This is the tenth anniversary of the HIMAC, which was launched in 1994 as a project of the "10-year Strategy for Cancer Control." To date, the HIMAC has treated more than 2,000 cancer patients, proving the strong effectiveness of heavy ion beam therapy for cancer. In October 2003, the Ministry of Health, Labour and Welfare approved the HIMAC as a highly advanced medical technology, which was an important step for its diffusion as a therapy for the people.

The establishment and operation of a heavy ion medical accelerator for cancer therapy currently requires a large investment. For its diffusion as a therapy for the people, however, this cost should be decreased. In order to achieve such cost reduction, the optimization of the design for downsizing and R&D of parameter technologies are being conducted.

Conceptual illustration of heavy ion medical accelerator for cancer therapy



Source: NIRS, "Heavy ion beam: the novel ace for radiological therapy"

(Improving convenience/comfort for people)

With respect to improving convenience/comfort for people, science and technology has the effect of reducing financial burdens, such as reducing electricity charges due to the spread of home photovoltaic power generation systems and lowering recycling costs due to development of technologies to appropriately dispose of discarded cars and home electrical appliances.

Science and technology also has the effect of increasing convenience, such as easy access to various services through ITS, and the effect of increasing aesthetic appearances and comfort, such as antifouling tiles and antifog vehicle mirrors through the development of photocatalysts.

[Column 12]

Photocatalysis
Stain-proofing by UV Radiation

A photocatalyst is defined as a "substance that accelerates chemical reactions by receiving UV radiation, without changing itself." Because of its immutability, a photocatalyst can be used semi-permanently. In about 1968, Kenichi Honda (honorary professor at the University of Tokyo) and Akira Fujishima (the same) discovered the photoelectrochemical decomposition of water in UV radiation by using TiO2 and a platinum electrode. Their amazing discovery was presented to the world in *Nature* magazine in 1972. The photocatalytic effect of TiO2 was named the "Honda-Fujishima effect," after the discoverers.

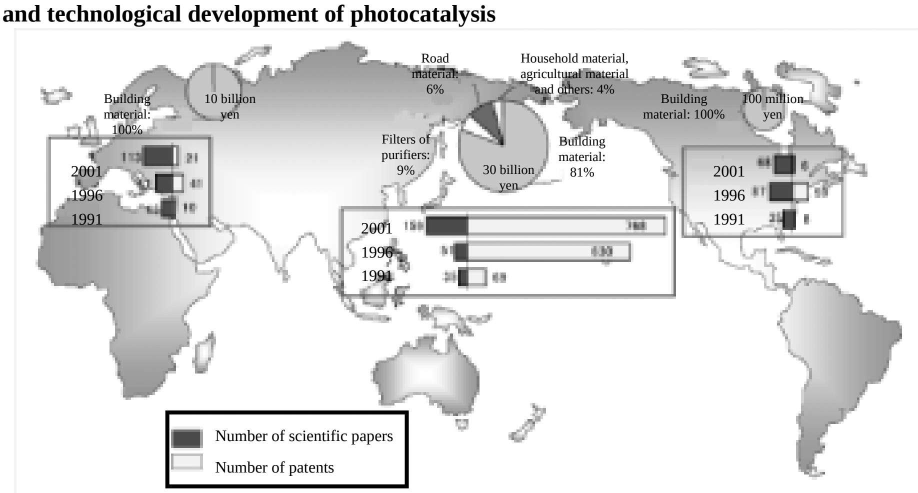
About 1968 The "Honda-Fukushima effect" was discovered.	⇨	1990 Academia and industry cooperatively start studies on practical photocatalytic systems.	⇨	1994 Photo-assisted superhydrophilicity discovered in the cooperative studies.

In the beginning, it was expected that the photocatalytic system could be used for hydrogen composition technologies, but this was not disseminated. Later around 1990, the academic world and industry cooperatively started studies on TiO2 coating on various materials for stain-resistance, preventing bacteria and deodorization. Research groups supervised by Akira Fujishima and Kazuhito Hashimoto (professor) at the University of Tokyo lead the project, in collaboration with many businesses. It took several years to put photocatalytically-coated products on the market. The products have been gradually improved, in areas such as controllability of photocatalytic reaction, endurance and cost performance.

Additionally, in 1994, the collaborative study group of researchers at the University of Tokyo and businesses discovered the photo-assisted superhydrophilicity of photocatalysis, or in other words, that a surface coated with a photocatalytic product becomes highly hydrophilic on receiving UV radiation. Superhydrophilicity had not been common at all until the study group introduced it in *Nature* magazine in 1997. It contains the possibility of practical use in many fields. The self-cleaning effect, which is a combination of the oxidativity and superhydrophilicity of photocatalysis, has been already applied to building tiles, glass, and vehicles' sideview mirrors. The photocatalysis market is expected to expand dramatically in the future.

The following diagram compares Japan, the United States and Europe in terms of market scale (in 2002) and the number of patents and scientific papers (in 1991, 1996 and 2001) related to photocatalysis. It is clear that Japan is overwhelmingly the world leader in every aspect of the photocatalytic sphere.

Market scale and technological development of photocatalysis



Note: Figures for market scale are estimations for 2002. For 2003, the scale of the Japanese market is estimated at approximately 40 billion yen, the European market at 15 billion yen, and the U.S. market at 2.3 billion yen.

Estimation of market scale is based on the data provided by the Photocatalytic Products Forum.

Source: Japan Patent Office, "Research Report on Patent Application Trends: Photocatalysis (F.Y. 2003)."

(Changing people's awareness/lifestyles)

With regard to changing people's awareness, energy-saving awareness increased with the diffusion of home photovoltaic power generation systems, and recycling awareness increased with the spread of technologies for appropriately disposing of discarded cars and home electrical appliances. Furthermore, realization of ITS made it easier for users to make travel plans and changed their lifestyles through easing traffic congestion and providing appropriate information.

(4) Contributions of public R&D and support to scientific and technological progress

Contributions of public R&D and support to scientific and technological progress and achievement of results can largely be divided into two: direct contributions such as investment in R&D and indirect contributions such as procurement and development of research infrastructure. Direct contributions include public R&D and support on basic research and those implemented in line with the development and trend of technologies. Indirect contributions include public R&D and support on base technologies and technical infrastructure and contributions for tackling problems in coordination with policies other than R&D policy.

Table 1-2-3 evaluates the extent of such contributions of public R&D and support for some case examples from these perspectives. It suggests that indirect contributions such as procurement and development research infrastructure are also important as a role of the public sector.

(Public R&D and support on basic research)

The importance of public R&D and support on basic research is obvious from the contributions made by national universities in discovery of the phenomena and elucidation of the principles with regard to water decomposition by photocatalysts, decomposition of organic matter, and super-hydrophilc property. Various basic research conducted at public research institutes, such as universities, provide essential technology seeds for achieving results or produce unexpected results through continuance of diverse research. Through accumulation of scientific knowledge, they contribute to technological progress and the achievement of results.

(Public R&D and support in line with the development and trend of technologies)

Public R&D and support in line with the development and trend of technologies are also important. This type of R&D and support include the shortening of the period for achieving results by shifting to focused research or national projects in a timely manner according to the technological progress, and implementation of public R&D or support by clarifying the positioning and the aim of the technological development in each phase until the achievement of the effects, based on a long-term national vision. Examples of the latter include promotion of diffusion of home photovoltaic power generation systems in accordance with the Sunshine Plan and the New Sunshine Plan based on a 30-year long-term vision.

(Public R&D and support on base technologies and technical infrastructure)

Public R&D and support on base technologies and technical infrastructure may not be obvious as direct contributions, but the lack of such R&D and support may have made achievement of results difficult or reduced their effects. R&D and business activities by diverse users including the private sector become possible through standardization and development of databases by public research institutes. In addition, SPring-8, a sophisticated radiation facility boasting the world's most powerful radiation, has been developed by public investment as a facility for common use by industry, academia, and government, and it has been used for leading-edge research, such as analyses, in a wide array of scientific domains and for the measuring technologies and material technologies in industries.

Table 1-2-3 Case Examples of Public R&D and Support

(Contribution: large ○; moderate △)

		Public R&D and support on basic research	Public R&D and support in line with the development and trend of technologies	Public R&D and support on base technologies and technical infrastructure	Tackling problems in coordination with other policies
Life sciences	Helical CT technology effective for early detection of lung cancer	–	△	–	–
	Base sequence determination technologies for detecting individuals' gene polymorphism and their application (diagnosis and tailor-made medicine)	△	○	○	–
Information and telecommunications	High-speed parallel computers (Earth Simulator)	–	△	○	○
	ITS (car navigation, VICS, ETC)	–	△	○	○
Environment	Technologies to produce and use alternatives to CFC and halon, which are ozone-friendly and have a minimum impact on global warming	△	△	○	○
	Technologies to elucidate the impact of endocrine disrupting chemicals on the human body and living organisms	○	–	–	–
Nanotechnology and materials	Technologies to make higher-density, longer-life lithium batteries	–	–	–	–
	Photocatalytic materials	○	○	–	–
Energy	Home photovoltaic power generation systems	△	○	△	○
	Technologies to produce liquid fuels from natural gas and use them (GTL, DME)	△	△	–	–
Manufacturing	Technologies to appropriately dispose of discarded cars and home electrical appliances	–	△	–	○
	Processing technologies using lasers	△	○	△	–
Infrastructure	Technology for local weather forecasting	○	–	○	△
	Technology to simulate the effects of earthquake motion on the behavior of structures	○	–	○	△
Frontier	Satellite remote sensing technologies (technologies for analyzing and using data)	△	–	△	–
	High-power radiation technologies (SPring-8)	△	–	○	–

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(Tackling problems in coordination with other policies)

Problems have been tackled through coordination with policies other than R&D policy. For example, R&D was promoted as a result of deregulation or the introduction of regulations as represented by the home photovoltaic power generation systems, where grid connection allowing reverse power flow was also made possible besides technological development. Also, continuous technological development became possible through government procurement as represented by parallel computers with a high computing speed. In addition, early markets emerged due to the introduction of subsidy systems.

[Column 13]

Home Photovoltaic Power Generation Systems
Clean Energy

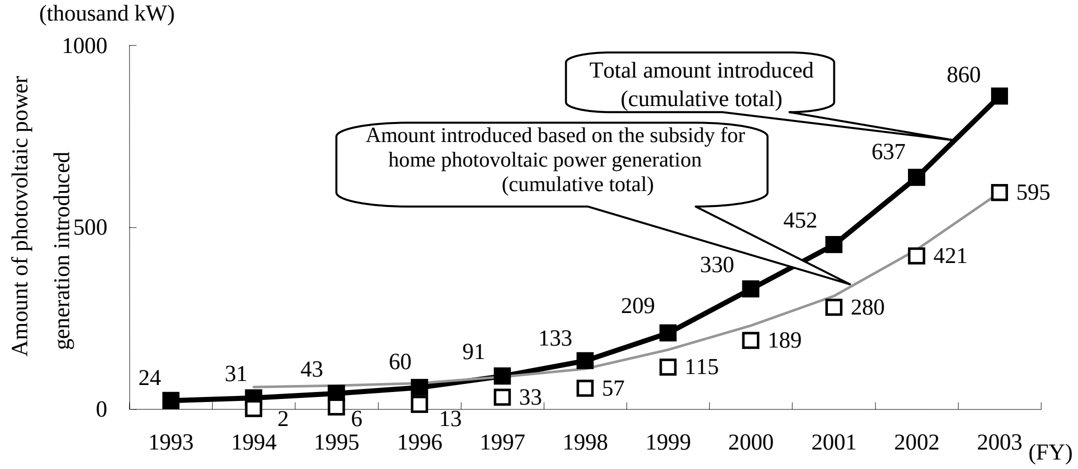
The bright sun on a clear day is an inexhaustible and semi-permanent source of energy. It is estimated that the total energy expended by the human race in an entire year is equivalent to the solar energy the earth receives in just 30 minutes. Additionally, the photovoltaic power generation system is clean, with no discharge of either greenhouse gasses or waste during the generation process.

Since 1999, Japan has been the world's foremost producer of solar cells. Nearly half of all cells produced in the world in 2003 were produced in Japan.

In the Sunshine Plan started in 1974, the home photovoltaic power generation system was treated as an important technology. Large-scale R&D was conducted jointly among industry, academia and government. The subsidy project for home photovoltaic power generation systems was taken over by the New Sunshine Plan since 1993, as well as by individual projects conducted by the New Energy and Industrial Technology Development Organization (NEDO).

One of the major factors behind the successful diffusion of the photovoltaic power generation systems was that the Japanese government promoted the projects with a long-term vision for 30 years, with the target set for the year 2000. The technologies for the mutual service system were developed on the assumption of the power generation systems being distributed among individual households. The system enables consumers to sell surplus energy to power companies, as well as to buy energy from power companies when it is insufficient. Other effective factors include the deregulation that approves the service of photovoltaic power generation system for individual households, and the establishment of the initial photovoltaic power generation system market supported with the subsidies for its establishment. It was a prominent example of policies not directly related to R&D (e.g. deregulation and subsidies) effectively promoting R&D.

Number of photovoltaic power generation systems installed



Source: METI, "New Vision of Energy Industry" (June 2004). The "total number of installations of photovoltaic generation systems subject to the subsidy project" for 2003 was surveyed by METI.

(Need for contributions of public R&D and support)

In the "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" ("Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)) compiled by NISTEP, a questionnaire survey was conducted on 2,154 researchers and technology users (persons responsible for the planning division or the market research division in companies). The survey results indicate how the samples saw the contributions of public R&D and support in various fields to date and the future need for such contributions (Figure 1-2-4).

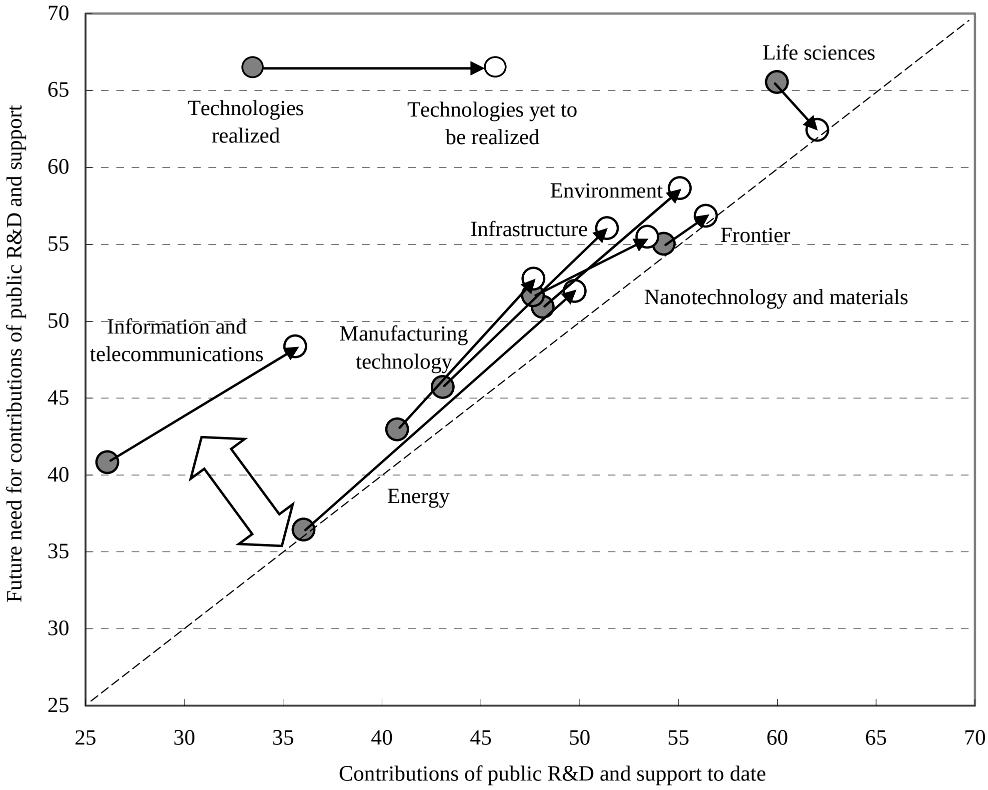


Figure 1-2-4 Contributions of Public R&D and Support in Various Fields to Date and the Future Need for Such Contributions

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

Looking by field, the respondents considered that large contributions have been made with respect to technologies realized (those that have been realized within the past 10 years or so and are already producing effects) in the fields of life sciences and frontier, followed by nanotechnology and materials, environment, infrastructure, and manufacturing technology. The respondents regarded that small contributions have been made to date in the fields of energy and information and telecommunications. On the other hand, looking at technologies yet to be realized (those that are likely to be realized and produce effects in the coming 10 years or so), the respondents viewed that larger contributions would be made in all fields compared to the contributions made for the technologies realized. The expected degree of contributions for technologies yet to be realized was particularly larger than that for technologies realized in the fields of information and telecommunications, energy, manufacturing technology, and infrastructure.

The same degree of contributions is generally being sought in the future, but an ever-larger degree of contributions of public R&D and support is being sought in the information and telecommunications field.

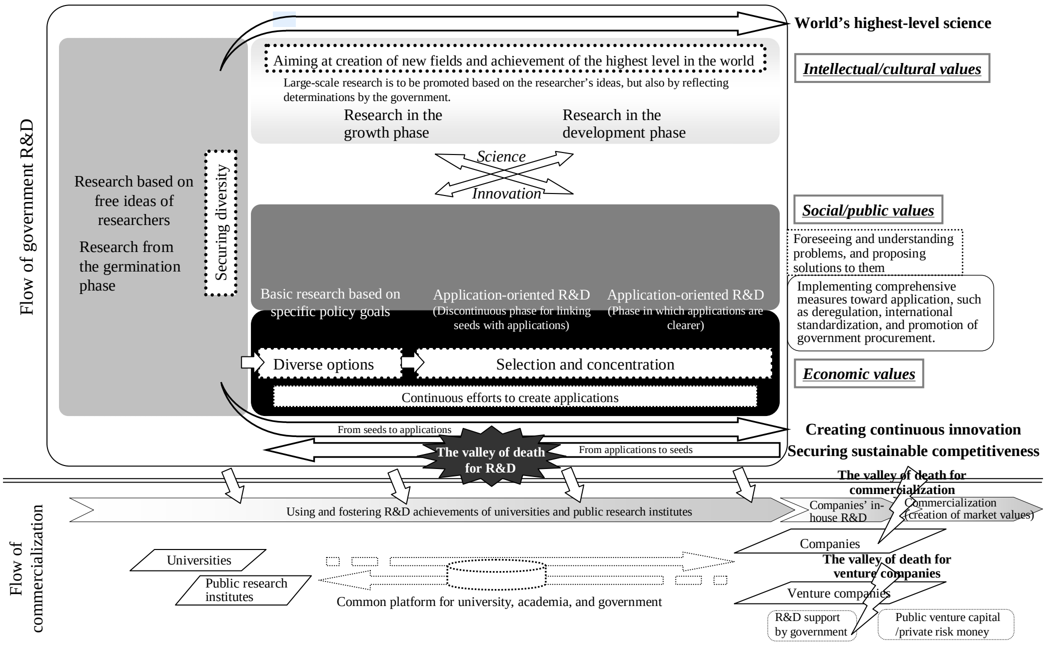


Figure 1-2-5 Development of Science and Creation of Continuous Innovation

Support for R&D should be provided in accordance with the development phase and the characteristics of the R&D. This figure overviews the concept where research based on free ideas of researchers lead to development of science and creation of continuous innovation toward generation of various values.

Source: Produced from materials of the Special Committee on Science and Technology Basic Plan, Council for Science and Technology, MEXT.

1.2.1.2 Turning Dreams into Reality by Science and Technology

Sometimes mankind encounters a phenomenon that overturns the conventional common knowledge of science and technology, and finds a new truth. Also, it devises a new verification measure, and discovers a new phenomenon by using that measure. Such efforts lead to new discoveries and inventions, and further to the progress of mankind and realization of dreams. This kind of progress has been driven by researchers' insatiable intellectual curiosity.

In 2000, Hideki Shirakawa, Professor Emeritus at the University of Tsukuba, and two other professors were awarded the Nobel Prize in Chemistry for the "discovery and development of conductive polymers." At the end of the 1970s, they made a unique discovery that polymers (plastics), which had been believed not to conduct electricity, sometimes indicated conductivity. Addition of this discovery to the original properties of plastics—being lighter, more flexible, more workable, and lower material costs than metal—broadened the possibilities for application areas, and later developed conductive polymers into an important research domain for chemists and physicists. This field also became important in practical use. For example, in industrial use, conductive polymers are being used or being developed to be used as polymer batteries, condensers, various electron devices, and light emitting elements. In Professor Shirakawa's research, a pioneering discovery was made from among down-to-earth research, and it vividly indicates that the continuation of basic research generates a significant achievement.

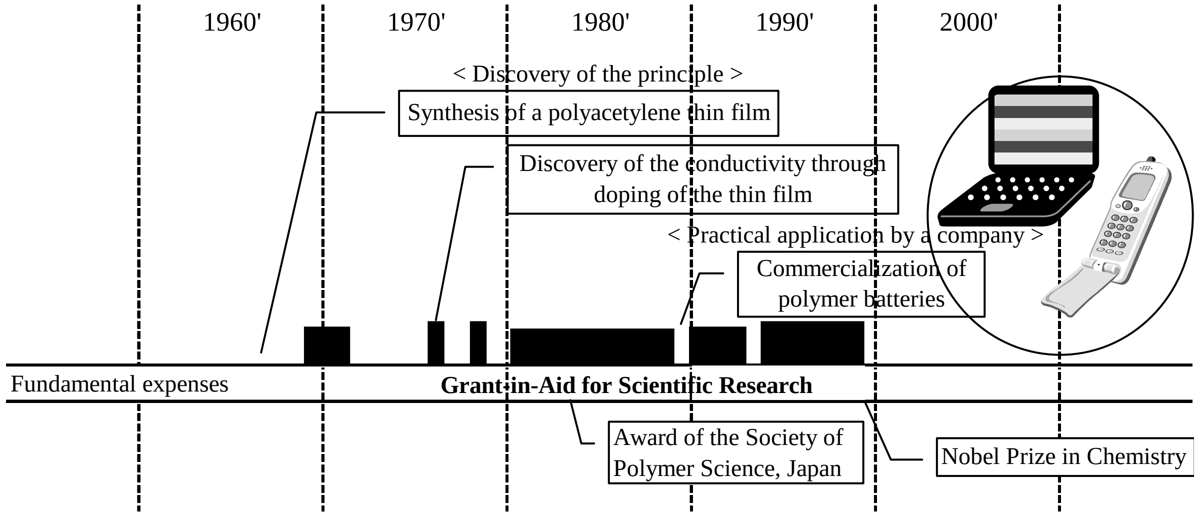


Figure 1-2-6 Achievements of Hideki Shirakawa and Public Support

Source: Surveyed by MEXT

In 2001, Ryoji Noyori, President of RIKEN, Japan, and U.S. chemists were awarded the Nobel Prize in Chemistry for their "work on chirally catalysed hydrogenation reactions." The term "chiral" originates from a Greek word for the "palm," and it refers to molecules that are in a mirror-image relation, just like the palms of the left and the right hands. These molecules are called enantiomers, and ever since they were discovered by Louis Pasteur, it had been a dream of mankind to develop a method to selectively synthesize one of these two. This was because many pharmaceuticals had enantiomers having different functions from each other. There were cases where one of the enantiomers was an excellent drug, but the other was a deadly poison. Noyori discovered a hydrogenation catalyst that synthesizes only one of the two enantiomers with high selectivity from among compounds that have various double bonds. The achievement of this long-term catalyst research, which germinated from around 1965 is today widely used in industrial production of pharmaceuticals, menthols, and other items.

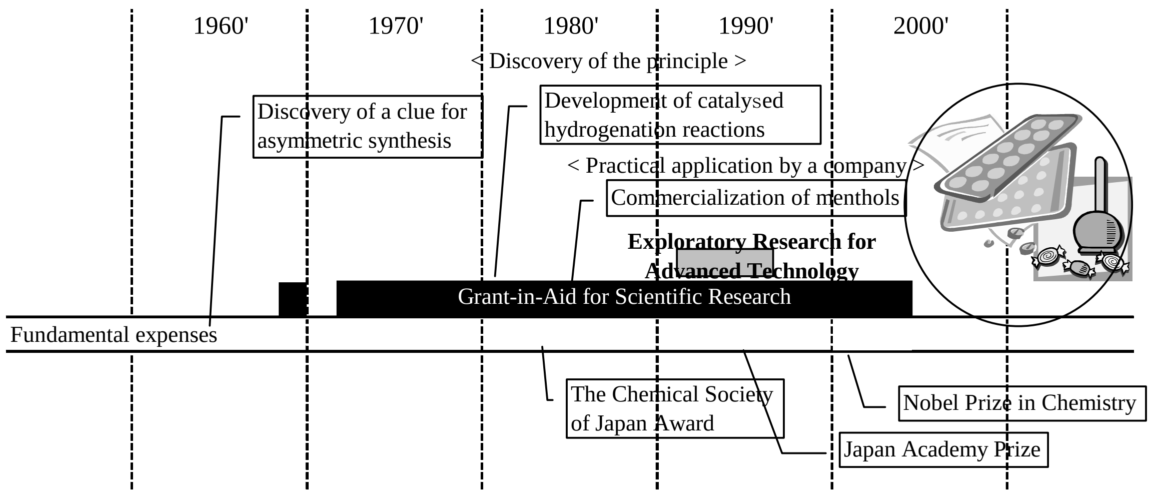


Figure 1-2-7 Achievements of Ryoji Noyori and Public Support

Source: Surveyed by MEXT

In 2002, Masatoshi Koshiba, Emeritus Professor at the University of Tokyo, was awarded the Nobel Prize in Physics "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos." He was highly commended for succeeding in detecting neutrinos from a faraway supernova explosion by using a gigantic detector called the Kamiokande, underpinning the theories on the mechanism of a supernova explosion caused by a gravitational collapse and the stellar evolution, and opening up a new research field called neutrino astronomy.

Also in 2002, Koichi Tanaka, fellow at Shimadzu Corp., was awarded the Nobel Prize in Chemistry "for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules." He developed the "soft laser desorption" technique in which proteins are crystallized by being mixed with a matrix (a mixture of multiple chemical substances) and are bombarded with laser pulses. This method, which conducts ionization without breaking up the protein molecule structure, made analysis of biological macromolecules possible.

Name	Category	Year
Hideki Yukawa	Physics	1949
Shinichiro Tomonaga	Physics	1965
Leo Esaki	Physics	1973
Kenichi Fukui	Chemistry	1981
Susumu Tonegawa	Medicine	1987
Hideki Shirakawa	Chemistry	2000
Ryoji Noyori	Chemistry	2001
Masatoshi Koshiba	Physics	2002
Koichi Tanaka	Chemistry	2002

Figure 1-2-8 Japanese Nobel Prize Winners (Natural Sciences)

Source: Surveyed by MEXT

The prize-winning by these persons of merit demonstrates to the world the high research standard of Japanese researchers, and is a great pride and encouragement not only for Japanese researchers, but for the entire nation.

(1) Unexpected achievements brought about by scientific and technological progress

Hideki Shirakawa, Professor Emeritus at the University of Tsukuba, is said to have made the achievement by, instead of considering an experiment with erroneous blending of catalysts as a mere mistake, continuing with the research by focusing on its outcome. Masatoshi Koshiba, Professor Emeritus at the University of Tokyo, also succeeded in detecting neutrinos by installing the Kamiokande for observing the process of proton decay, and encountering a supernova explosion. Furthermore, Koichi Tanaka, a fellow at Shimadzu Corp., is said to have discovered the clue for the formula that won the prize by mixing an erroneous chemical into the sample but continuing with the experiment.

In the realm of science and technology, an unexpected coincidence or a slight mistake often leads to a historic discovery. However, a coincidence is not sufficient to make such a historic discovery, but as Louis Pasteur said "chance favors only the prepared mind." Likewise, researchers' daily efforts and their insights based on those efforts are essential for turning a "coincidence" into a "discovery."

This also applies to scientific and technological achievements. There have been cases where effects that had not been intended in the basic research phase were achieved or came to be expected in the course of subsequent research (Figure 1-2-9).

Technology	Unexpected effects
Photocatalytic materials	They were originally intended for producing hydrogen, but due to their super hydrophilic property and the function to break down organic matter, they are used for antifouling/defogging and for air purification.
Base sequence determination technologies for detecting individuals' gene polymorphism and their application (diagnosis and tailor-made medicine)	They were intended for life-saving treatment against genetic diseases in the basic research phase, but there are hopes for realization of their application to tailor-made medicine.
Processing technologies using lasers	The laser light source for nuclear fusion research was applied to the light source for industrial laser processing machines.
Carbon nanotube device technologies	They were originally intended for mere structural materials, but there are growing expectations for their application as electronic devices.
Hydrogen storing alloy	In 1990, a nickel-metal-hydride battery was put to practical use by using a hydrogen storing alloy as the negative-electrode material.
System for disaster prevention before the arrival of seismic motion based on a nationwide seismic detection network	Basic research for earthquake prediction and installation of seismometers contributed to the system for taking disaster prevention measures before the arrival of the seismic motion.

Figure 1-2-9 Science and Technology which Produced or Is Likely to Produce Unexpected Effects in the Basic Research Phase

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(2) Time required from invention or discovery of a technology seed until achievement of results

Scientific and technological progress has had a large impact on the economy, society, and people's lives in diverse forms. However, the progress of individual science and technology does not immediately bear results, but has a considerable impact on the economy, society, and people's lives only when it is combined with other science and technology or when goods/services using the science and technology are diffused in society.

Scientific discoveries may be required but not sufficient for making innovations that have economic effects. The road from making a scientific discovery to achieving economic effects is long and tough. Only after accumulation of many people's failures and frustrations on top of a scientific invention does a new product appears on a market, and when it is accepted by the market, the innovation is complete. It is extremely difficult to predict the time required until the completion of this process. However, it is certain that no innovation will occur without action, and Japan will not develop if it leaves innovations to the efforts of others.

For example, the National Institute of Science and Technology Policy surveyed the time required from invention or discovery of a technology seed until its practical application regarding technologies for which the time of invention or discovery of the technology seed, the time of its practical application, and the time of achievement of results were relatively clear, including future prospects. As a result, it found that the time was very long and varying, ranging from about 10 to 40 years (Figure 1-2-10).

Technology	Period until practical application	1960 1970 1980 1990 2000 2010 2020 2030	Details of invention/discovery and practical application
Helical CT technology effective for early detection of lung cancer	Approx. 10 years		1982: Private company acquires a patent for helical CT (Japan) 1990: Helical CT put to practical use (Japan)
Vertical magnetic recording technology (for hard disk drives)	Approx. 30 years		1976: University invents the vertical magnetic recording technology (Japan) 2005: Hard disk using the vertical magnetic recording technology put to practical use (Japan)
Technologies to make higher-density, longer-life lithium batteries	Approx. 10 years		1979: Lithium cobaltate developed as a positive-electrode material (U.K.) 1991: Lithium battery using lithium cobaltate as the positive electrode put to practical use (Japan)
Photocatalystic materials	Approx. 30 years		1967: Photodecomposition of water discovered (Japan) 1994: Tiles and building materials using photocatalysts commercialized (Japan)
Home photovoltaic power generation systems	Approx. 40 years		1954: Solar battery created by Bell Labs (U.S.) 1994: Monitor users for home photovoltaic power generation systems invited from the public (Japan)
Processing technologies using laser	Approx. 20 years		1960: Theodore Maiman succeeds in ruby laser oscillation (U.S.) 1980s: Application of laser to processing technologies makes progress (Japan)

: From invention/discovery of technology seed to practical application

Figure 1-2-10 Period from Invention/Discovery of Technology Seeds Until Their Practical Application

Source:NISTEP, “Study for Evaluating the Achievements of the S&T Basic Plans in Japan” (NISTEP Report, no. 89, March 2005)

(3) Pursuing dreams

In order to promote science and technology, it is also important to arouse people’s intellectual curiosity and inquisitiveness so that the entire people increase their interest in and understanding of science and technology, and that the youth, who will lead in the next generation, can hold dreams and hopes in science and technology and develop science and technology oriented minds.

The outstanding performance of Japanese athletes at the Athens 2004 Olympic Games is still fresh in our minds, and the efforts and talents of each athlete deserve praise. Kosuke Kitajima is said to have carried out effective training and improved his swimming method based on scientific analyses at the Japan Institute of Sports Sciences (JISS). It has become necessary to scientifically analyze sports in order to compete for world records.

[Column 14]

Athens Olympic Games and Sports Science

Kosuke Kitajima's Brilliant Achievement Supported by Science and Manufacturing Technologies

Japanese swimmer Kosuke Kitajima won gold medals in the 100-meter and 200-meter breaststroke at the Athens Olympic Games in August 2004. He also broke the Olympic record in the 200-meter event. Although you might not know it, Kitajima's brilliant achievement was considerably supported by Japanese technology.

Kitajima was supported in his training in the aspect of sports medicine and science by the Japan Institute of Sports Sciences (JISS), which was established in 2001. JISS is the core institute for sports medicine, science and information in Japan. It is equipped with MRI, motion analyzers, video editing and analysis devices and facilities, and an altitude training room that can simulate the low-oxygen conditions at altitudes about 1,800 - 3,000 meters above sea level. Making good use of its leading facilities and devices, JISS provides a support system to athletes using objective digital information, converted from the subjective and emotional analogue information traditionally given by sports coaches.

To scientifically investigate inefficiencies in Kitajima's swimming, a group of specialists mainly composed of JISS staff examined the velocity curve (graphic data) of his swimming style filmed underwater. They thoroughly analyzed his stroke and kick. They also provided Kitajima with data beneficial for planning his altitude training schedule, showing the effects of hypoxic training based on physiological data on blood and blood lactic acid consistency. The data on Kitajima's diving angle proved that his starting posture was not perfect compared to other top swimmers in the world, and contained some room for improvement. Based on the data, Kitajima and his coaches made efforts to shorten his time over the first 15 meters, which is regarded as the first critical part of a race. Their efforts contributed greatly to Kitajima breaking the Olympic record.

Japan's excellence in manufacturing technologies also contributed to Kitajima's victory. To create the swimsuit Kitajima wore, a special-effects manufacturer gave support by creating a soft mannequin of Kitajima based on the 3-D measurements of his body. Much importance is placed onto how swimsuits fit, because if they do not fit perfectly, water will penetrate into the spaces between the swimsuit and body, creating resistance while swimmers are racing. Additionally, based on the analysis of water flow computation, various efforts were made to create a swimsuit with the least possible resistance under water, using a surface similar to sharkskin and stitches that are not resistant to water flow. It was a swimsuit made especially for Kitajima to wear at the Athens Olympic Games.

At the Athens Olympic Games, Kitajima successfully won two gold medals, which in the past seemed a mere dream for Japanese swimmers. Other Japanese athletes also had great success at the Olympics. The total number of medals won by Japanese athletes was 37, the highest number ever won by the Japanese team. Part of the amazing achievement by Kitajima and other Japanese athletes at the Athens Olympic Games was down to the contribution of Japan's technological excellence.

Have you ever gazed at a starry sky and wondered what the universe looks like and how it all started? By increasing such intellectual curiosity and inquiring mind, people can acquire the willingness to learn independently and the ability to learn on their own initiative, and as a result, they can develop scientific ways of thinking and looking at things.

Thirteen astronomic observatories gather from 11 countries around the world at the summit of Mauna Kea on the island of Hawaii, and compete their observation results. Japan also has the "Subaru" Observatory, which boasts the world's largest single-mirror reflecting telescope with a primary mirror diameter of 8.2 m, on Mauna Kea. A joint research group of the University of Tokyo, the National Astronomical Observatory of Japan, and other institutes announced in February 2005 that they had discovered a young cluster of galaxy in the universe of 12.7 billion years ago by using the Subaru Telescope. This means looking at the universe in its very early stages since the National Aeronautics and Space Administration (NASA) has estimated the age of the universe to be 13.7 billion years.

When the universe was formed, matter (protons, neutrons, and electrons) and antimatter (antiprotons, antineutrons, and antielectrons) had supposedly existed in the same amount. However, antiprotons, etc. cannot be found under natural conditions in the actual world. The KEK B Factory of the High Energy Accelerator Research Organization (KEK) is attempting to solve this mystery, and has empirically proved that the Kobayashi-Masukawa theory, which theoretically predicted the differences between matter and antimatter, is correct.

When thinking about these large research facilities, we tend to look solely at the research achievements made at these facilities, but we must not forget the science and technology required for building these large research facilities as well. The primary mirror of the Subaru Telescope has a diameter of 8.2 m, but it is only 20 cm thick, so the mirror would bend if no measurement were taken. Thus, the mirror has 261 actuators (shafts of which vertical movement is controllable) at the back to detect the bent of the lens with an accuracy of 0.01% and compensate the mirror surface by moving the actuators. Meanwhile, the rotating part of the dome, which is 20 m in diameter and weighs approximately 2,000 tons, is moved to make a round in six minutes. These are achievements of Japanese science and technology.

Achievements could also be made by using the Kamiokande because a Japanese company created a gigantic photomultiplier with a diameter of 50 cm.

Such large facilities and equipment used there could not have been created without Japan's science and technology, and this indicates the high scientific and technological level of Japan.

People will always aspire to reach new frontiers. The frontiers that exist today are the universe and the deep sea. In Japan, the Japan Agency for Marine-Earth Science and Technology owns the "Shinkai 6500," which is a manned research submarine that can dive to depths of 6,500 meters, "Deep Tow," which is a towing-type, deep-sea exploration system that can investigate the sea at a depth of about 4,000 meters, and "Dolphin 3K," which is an unmanned exploration vehicle with a self-navigation capacity that can dive to depths of 3,300 meters. The latter two have made achievements, such as investigating the Russian tanker "Nakhodka," which sank off the Oki Islands in Shimane Prefecture in 1997, as well as discovering the main engine of the first-stage rocket of "H-II Launch Vehicle No. 8," which fell into the waters close to the Ogasawara Islands in December 1999 and contributing to ascertaining the causes of the accident. As for their original task, which is deep sea investigation, they have discovered a large number of unknown creatures around "hydrothermal vents" where water heated by magma under the seabed spurts out like hot springs.

In the area of space, H-IIA Rocket No. 7 with Multifunctional Transport Satellite-1R (MSTA-T-1R) onboard successfully lifted off from the Tanegashima Space Center on February 26, 2005. The satellite has been named "Himawari 6" and will be used for weather monitoring and air-traffic control. Not only such practical use, but also the presence of Japanese astronauts working internationally in the challenging arena of manned space activities in cooperation with U.S. astronauts gives strength to many Japanese people, and such activities as the "Space Educational Program" in which astronauts in space give a direct lecture to young people on the Earth contribute to increasing people's awareness of science and technology.

[Column 15]

50 Years of Rocket Development in Japan

The pioneer of rocket development in Japan was Hideo Itokawa (Professor at the University of Tokyo), who started developing the “pencil” rocket when the ban on aerospace exploration was removed after World War II, and succeeded in an experiment on its horizontal launch in 1955. Various developments and experiments on rockets followed that, and finally in 1970, the Japanese first satellite “Osumi” was successfully launched by the L-4S, which was propelled by solid fuel. By the success of the L-4S, Japan became the fourth country where a satellite was launched with its domestic aerospace technologies. Japanese technologies of solid-fueled rockets for scientific uses were improved and taken over to the “M” series, reaching at the world-highest standard when the current M-V was developed.

The development of launchers for satellites with practical purposes was, on the other hand, not so smooth for Japanese scientists. They had to import U.S. technologies before developing their own technologies. It was 1994 when the test rocket H-II No.1, the first large-scale rocket completely developed in Japan, was successfully launched. The H-II series was improved and the H-II A, the base rocket for Japanese satellites with competence in the world market, was developed.

Although the launching of the H-II A had been suspended for more than a year because of the failure of Launcher No. 6, it was restarted on February 2005. The H-II A No.7 successfully launched MTSAT-1R (Himawari No. 6).

Fifty years ago, the 23-centimeter “pencil” rocket developed by Itokawa gave dreams and hope to young scientists in those days. Now the 53-meter H-II A is a symbol of the big results and capacity of Japanese technologies, which are brought about by 50 years of intellectual work and technical efforts by prominent scientists and engineers. Current rocket science technologies have given dreams and hopes to many scientists and youngsters in Japan, similar to the way the pencil rocket did 50 years ago.

1.2.2 Leaders of Future Science and Technology and Their Roles

The basis for scientific and technological activities is diverse human resources. The fostering and securing of such human resources have become an important issue common to various countries.

Due to the rapid declining of birthrate and aging of the population, Japan needs to make stronger efforts in the future to secure the quantity and quality of human resources such as researchers and engineers, and develop people's understanding of and interest in science and technology, including those of children.

This section looks at the current status and challenges concerning such diverse human resources for science and technology and their roles as well as activities for enhancing people's understanding.

1.2.2.1 Importance of Fostering/Securing Scientific and Technological Human Resources

(Worldwide competition for acquiring human resources)

In the "knowledge-based society" of the 21st century, the basis for all kinds of activities will be "people" who create and use knowledge. In particular, quality and quantity of "human resources" will be important for promoting and encouraging scientific and technological activities. Therefore, efforts for securing scientific and technological human resources have been strengthened in countries around the world.

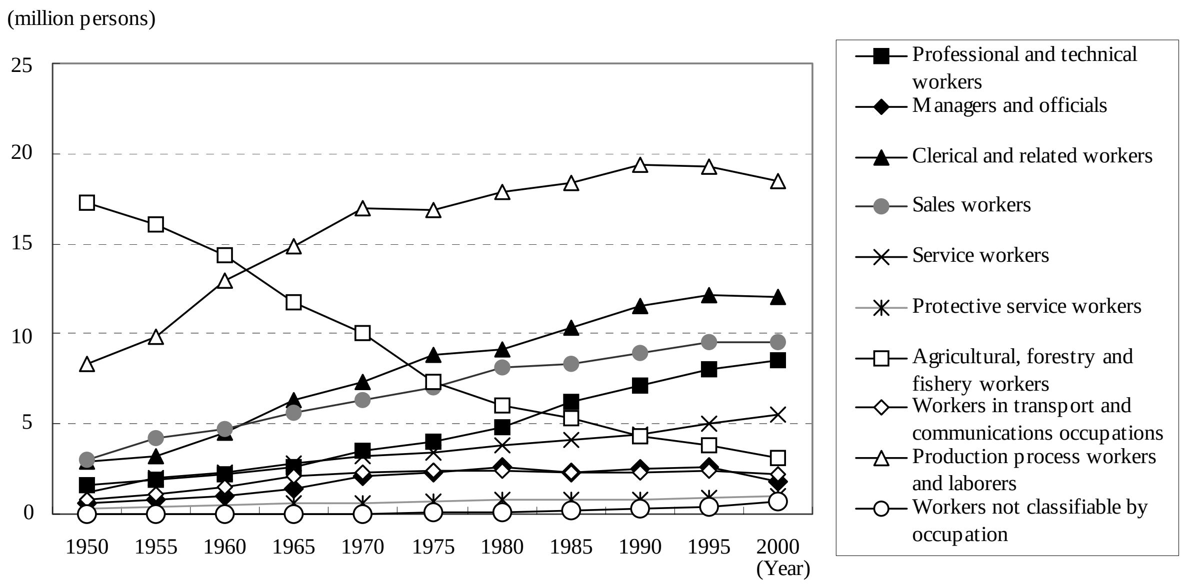
For example, human resources programs have been formulated in France and China. Also, because of the trend of globalization, cross-border competition for acquiring human resources with advanced skills and knowledge has intensified and some countries have taken measures to retain human resources or encourage their return from other countries due to a sense of a brain drain crisis (see Chapter 2 Section 4). "Innovate America" (commonly known as the "Palmisano Report") released by the U.S. Council on Competitiveness in December 2004 also mentioned "talent" as the first of the three recommendations for promoting the innovation policy. In addition, at the Meeting of the OECD Committee for Scientific and Technological Policy (CSTP) at Ministerial Level, "Improving the development and mobility of human resources in science and technology" was taken up as a theme, and discussions were made on issues including the brain drain, securing quantity and improving quality with respect to human resources development, support for students to pursue science and technology studies starting from elementary education, and expanding the participation of women.

Also in higher education, international competition among universities has intensified, for example in establishment of branch schools overseas, due to the increased international mobility of human resources such as exchanges of students and teachers, as well as movement of experts between countries.

In this manner, the fostering and securing of scientific and technological human resources has become an important challenge not only for developed countries, but also for rapidly developing Asian countries.

(Impacts of the declining birthrate and aging of the population in Japan)

Domestically, Japan's scientific and technological human resources have been constantly growing in terms of the number of "those engaged in specialized/technical jobs" and their proportion in all employees has also been increasing (Figure 1-2-11). The total number of researchers and the proportion of researchers in the working population have been growing as well (Figure 1-2-12).



Proportion of professional and technical workers to all workers	4.3	4.8	5.0	5.5	6.6	7.6	8.7	10.6	11.6	12.5	13.5

Figure 1-2-11 Number of Workers by Occupational Classification

Source: Statistics Bureau, MIC, "Population Census"

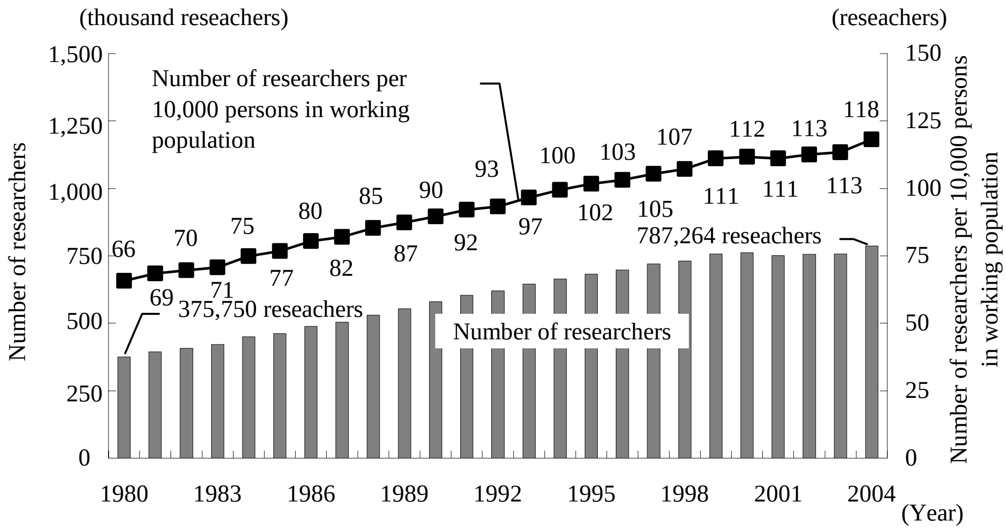


Figure 1-2-12 Number of Researchers per 10,000 Persons in Working Population

Notes: 1. Number of researchers includes those in social sciences and humanities.
2. Number of researchers is the value as of April 1, but that in or before 2001 is the value as of March 31. Working population is the value as of October 1.

Source: Statistics Bureau, MIC, "Survey of Research and Development," "Labor Force Survey."

However, according to the “Survey on Research Activities of Private Businesses” in fiscal 2004, shortage of talents, particularly R&D staff, R&D leaders, and intellectual property-related staff, was being perceived in companies engaged in R&D, especially in the fields of manufacturing technology, information and communications, nanotechnology, and materials (Figure 1-2-13).

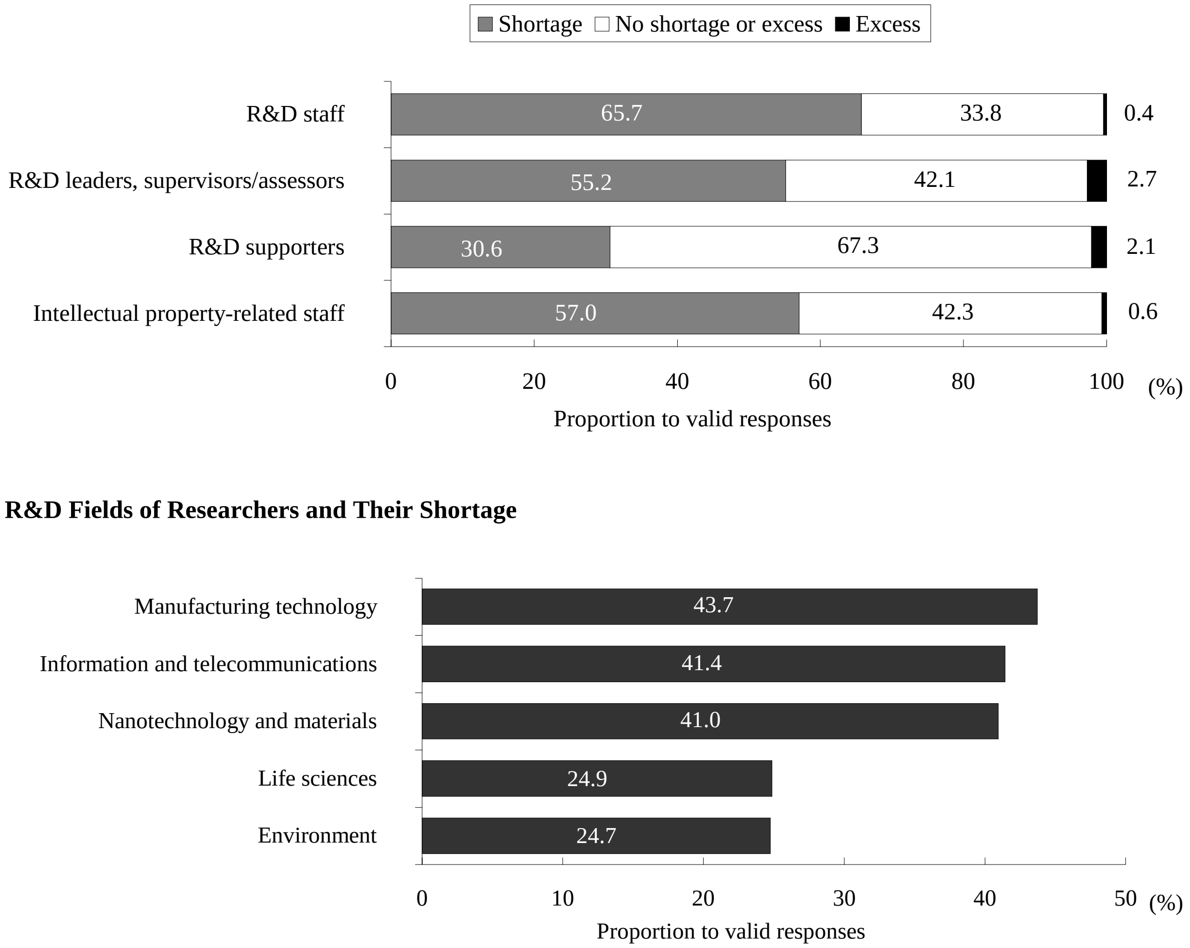


Figure 1-2-13 Shortage and Excess of Scientific and Technological Human Resources

Source: MEXT, “Survey on Research Activities of Private Companies (FY 2004)”

Furthermore, the declining birthrate and aging of the population are accelerating in Japan at an unparalleled pace in the world, so the working-age population began to decline after peaking in 1995, and the proportion of middle-aged and older people in those engaged in specialized/technical jobs has been increasing. There are concerns about the predicted lack of successors of manufacturing engineeers and technicians, the difficulty of passing down technologies and expertise, and the outflow of technologies to Asian countries in line with the mass retirement of the “baby boomers” of the first postwar baby boom (the Year 2007 Problem) (Figure 1-2-14). Under such circumstances, there is a risk of being unable to secure sufficient supply of talented researchers and engineers for meeting the demand in the future, depending on the future industrial structure. There is an estimation that the number of researchers and engineers will be short by more than one million persons in the next 25 years.

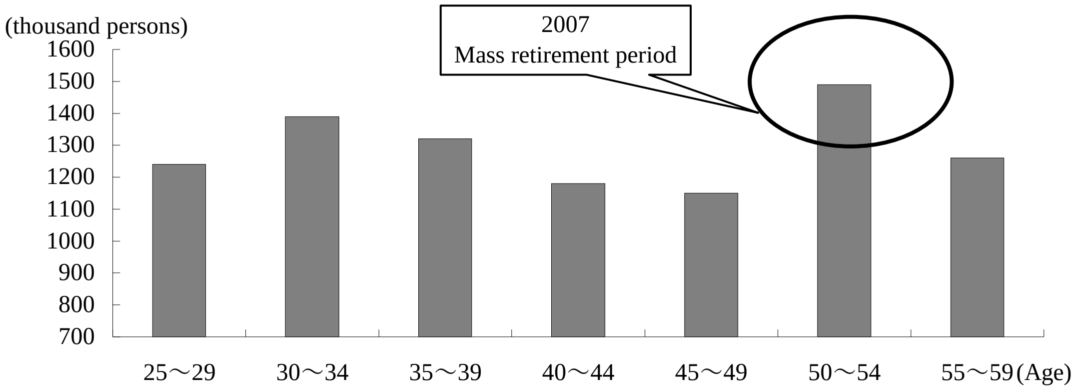


Figure 1-2-14 Number of Employees in the Manufacturing Industry by Age Group (2003)

Source: Statistics Bureau, Ministry of Internal Affairs and Communications, "Labor Force Survey (2003)"

In the field of science and technology, not only measures for increasing the quantity of human resources, but rather, measures for raising their quality would be important, such as increasing their creativity. A decline in vitality of younger generations may lead to a decline in scientific and technological potential. Since Japan will become a society with a declining population in the future, it will be important to attract talented human resources to the field of science and technology, and develop an environment where they can fully demonstrate their abilities.

Therefore, there is a need to implement comprehensive policies for developing and securing human resources by designing integrated measures for elementary and secondary education, undergraduate schools, graduate schools, and working people, while considering life cycles.

1.2.2.2 Diverse Human Resources Involved in Science and Technology

(Human resources involved in science and technology)

Today, the relations between science and technology and society are becoming closer and more diverse. Scientific and technological activities are carried out by people having diverse roles, such as those who create new knowledge (researchers), those who use achievements of knowledge in commercialization or services (engineers, technicians), those who engage in management (e.g., management of technology [MOT]), those who promote coordination between industry, academia and government in intellectual property-related projects or the like, and those who bridge between science and technology and the general public (science communicators) (Figure 1-2-15).

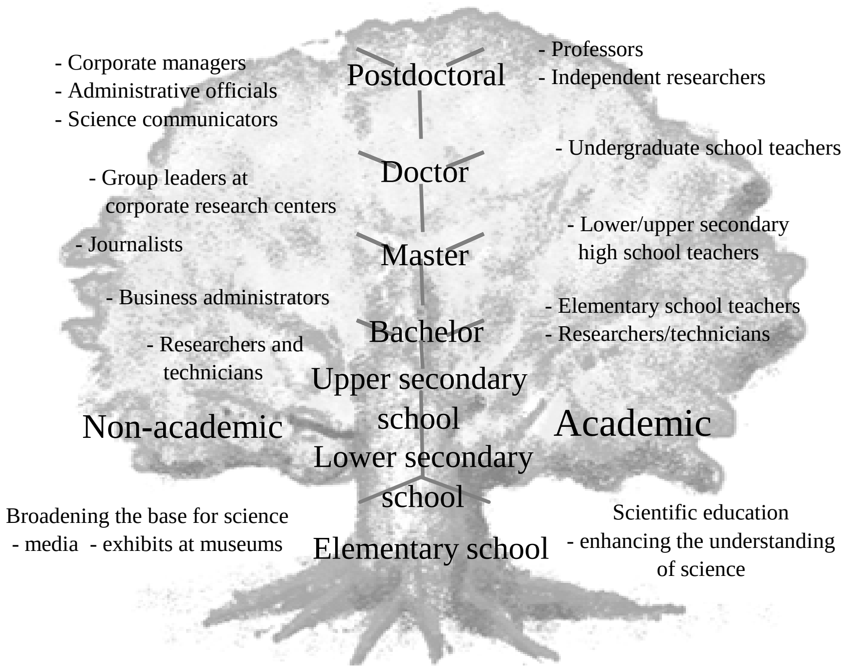


Figure 1-2-15 Example Career Paths of Scientific and Technological Human Resources

Source: Produced by MEXT based on the report of the Conference on International Training and Support of Young Researchers in the Natural Science Field (November 29-30, 2001 [France: Strasbourg]).

Conventionally, emphasis had been placed on measures for further raising the peak of knowledge creation (researchers). However, there will be a need to also focus on use of knowledge and establishment of the foundation for such use (broadening the base for science) in the future. Incidentally, according to NISTEP's analysis based on a questionnaire survey, about one-third of those with a doctor's degree in the United States get a job at profit-making companies, and conduct activities in wide-ranging fields including non-academic jobs. On the other hand, only about 17% of those with a doctor's degree in Japan get a job at profit-making companies, which is about half the percentage of those that do in the United States.

(Development of researchers and engineers)

Higher educational institutions such as universities and graduate schools are core research institutes that play a lead role in Japan's basic research as well as institutions for developing scientific and technological human resources such as researchers and engineers.

In Japan, graduate schools mainly focused on development of researchers and university instructors at the time when the graduate school system was established. However, in response to the growing needs for development of human resources for advanced, specialized jobs backed by rapid technological innovation as well as the sophistication and increased intricacy of society and economy, the professional graduate school system was established in fiscal 1999 and the professional school system was established in fiscal 2003. Due to the establishment of such systems and an increase in the number of graduate schools, the numbers of persons enrolled at, graduated from, and hired after graduating from graduate schools for natural science have been increasing every year.

However, a shortage of such human resources has been perceived by private companies for some job types and fields, while the problem of quality has also been pointed out. For example, when working researchers were asked about the qualities and abilities sought in an ideal researcher, many mentioned creativity, knowledge in the areaof expertise, the ability to set research themes, and an inquiring mind. However, while they highly evaluated young researchers as having knowledge in the area of expertise and cooperativeness, they made low evaluation of young researchers' creativity and ability to set research themes (FY 2002 "Survey of the State of Japan's Research Activities") (Figure 1-2-16). Meanwhile, private companies seek universities and graduate schools to develop the ability to think and extensive knowledge/interests of students, indicating that "the thinking power should be developed rather than providing knowledge" and "the method of the entrance examination should be changed from evaluation of the amount of knowledge to multidimensional evaluation of the ability to think, interests, and talent" (FY 2004 "Survey on Research Activities of Private Businesses") (Figure 1-2-17).

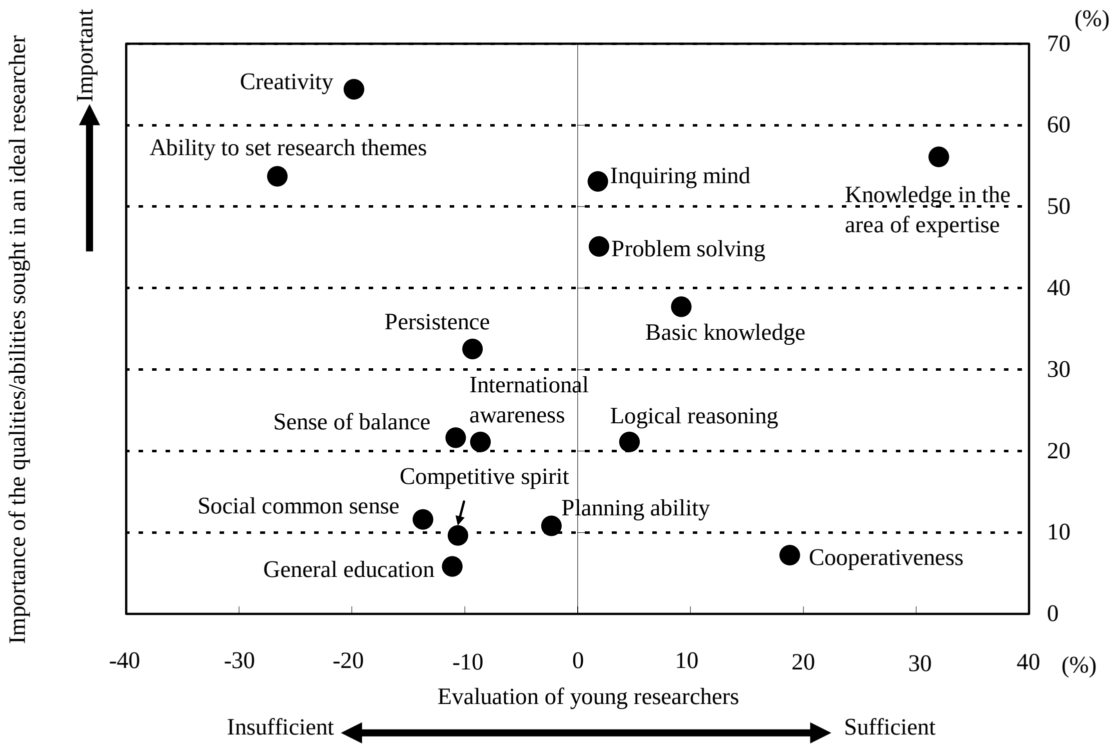


Figure 1-2-16 Importance of the Abilities Sought in an Ideal Researcher and Evaluation of Young Researchers

Source: Produced by NISTEP based on MEXT, "Survey of the State of Japan's Research Activities (FY 2002)"

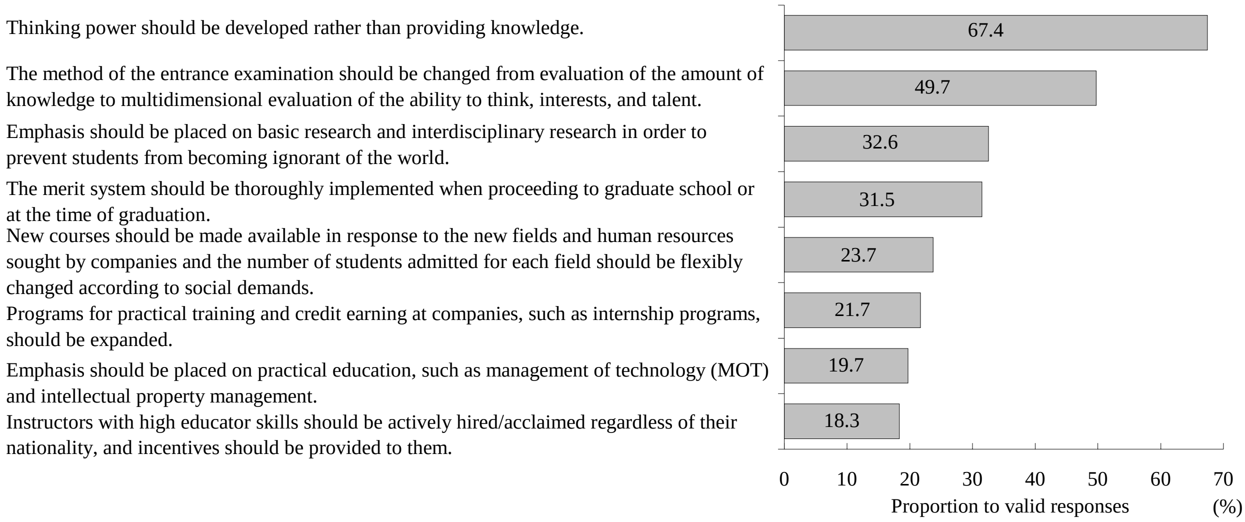


Figure 1-2-17 Matters Sought from Universities and Graduate Schools

Source: MEXT, "The Survey on Research Activities of Private Businesses (FY 2004)"

Accordingly, from the viewpoint of upgrading the abilities and qualities of researchers, there is a need to improve the educational content and methods at graduate schools, mainly those of doctorate courses, while also considering social needs.

Many engineers and technicians supporting Japan's manufacturing field have graduated from specialized upper secondary schools such as industrial high schools, special training colleges, colleges of technology, junior colleges, and universities. In order to foster creative, high-quality engineers and technicians with an ethical sense, it is necessary to promote practical education at these institutions as well as make efforts to implement coordination between industry, academia and government in human resources development, such as internship programs, and to cultivate students' outlook on careers.

Furthermore, due to the increased intricacy of scientific and technological activities, there are demands for persons who engage in management, so an increasing number of educational institutions are providing educational programs on management of technology (MOT). In addition, in order to use the scientific and technological achievements for economic activities, there is a need to develop and secure wide-ranging human resources including, coordinators of coordination between industry, academia and government, those with an expert eye who can discover technology seeds and match them with companies, those engaged in intellectual property affairs, and those who support start-ups.

(Allowing female and non-Japanese workers to demonstrate their abilities)

Due to the declining birthrate and aging of the population, there is a need to increase individuals' abilities and productivity as well as to develop an environment in which diverse human resources can show good performance according to their abilities.

Firstly, the number of female researchers and their proportion have been gradually increasing (Figure 1-2-18), but the level is low compared to the proportion of females among school graduates (such as among those who earned a bachelor's, master's, or doctor's degree), the proportion of females in all employees (more than 40%), and the situation in other countries.

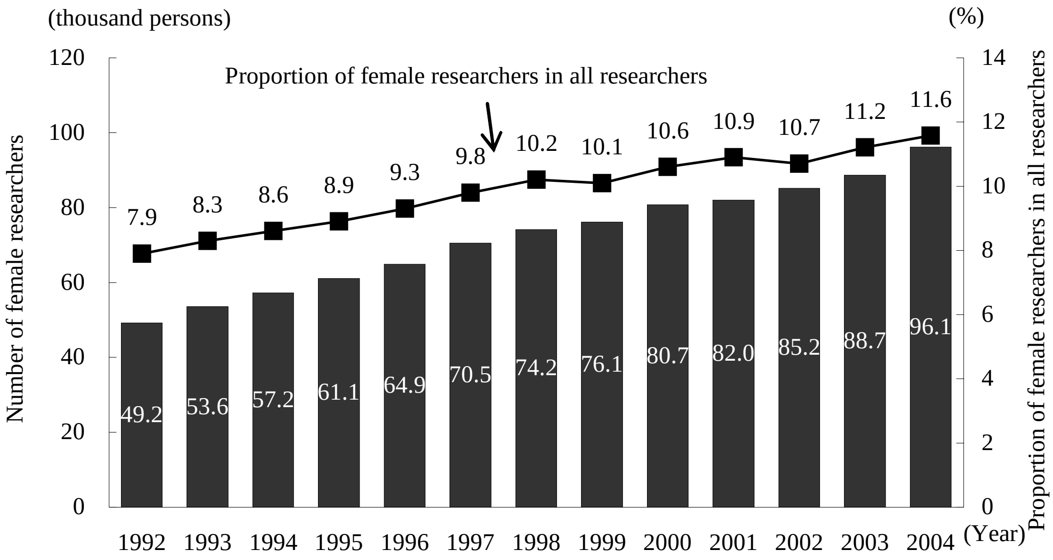


Figure 1-2-18 Proportion of Female Researchers in All Researchers

Note: Values are the number/proportion of female researchers including those in social sciences and humanities as of March 31 (as of April 1 for values up to 2001).

Source: Statistics Bureau, MIC "Survey of Research and Development"

Looking by sector, the proportion of female researchers in 2004 was relatively high for universities at 20.4% and the proportion has been gradually increasing, but that for companies was low at 6.6% and the proportion has remained at the same low level for the past several years.

The reasons include insufficient preparations to accept female workers particularly at private companies, and the problems of childbearing and childraising. It has been pointed out that it is tough to continue being engaged in R&D work.

According to the "Survey on Research Activities of Private Businesses" in fiscal 2004, the most companies stated "there are few or no applicants" as the reason for lack of increase in the proportion of female researchers, followed by "the company does not make special effort to increase the number of female researchers" (Figure 1-2-19). With regard to measures for encouraging female researchers to demonstrate their abilities, about 70% of the companies had taken some kind of measures, mainly in the area of providing systems for taking leave and allowing flexible working hours and working modes. As for measures to be implemented in the future, some companies, though still not so large in number, mentioned about setting numerical targets for female executives and researchers, in addition to expanding the fields and job categories for employing female workers. Thus, even more active measures are expected in the future (Figure 1-2-20).

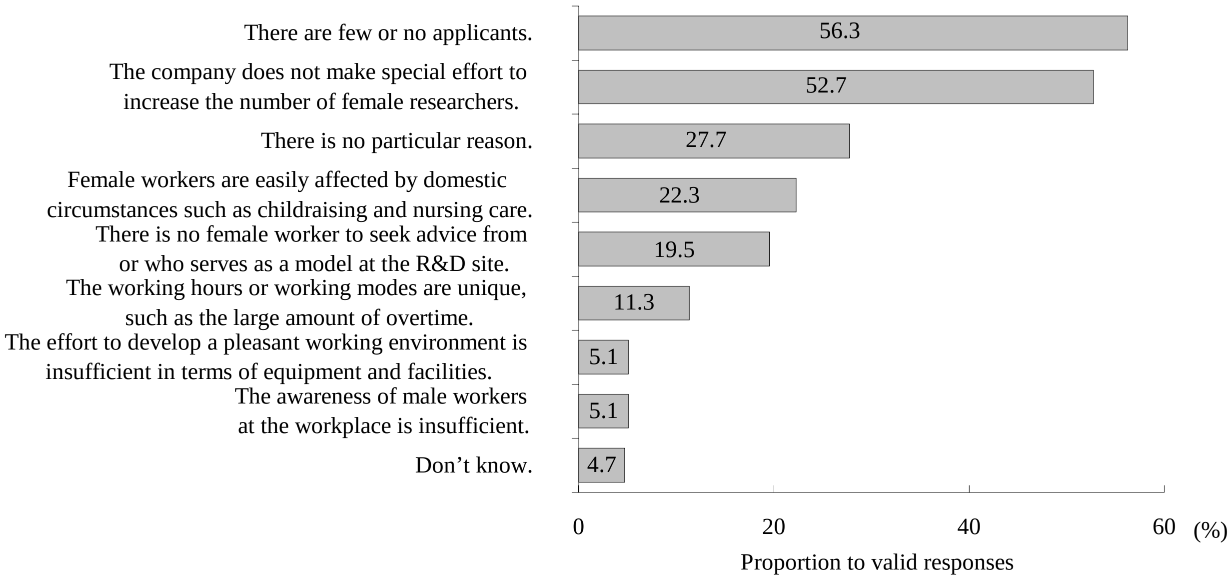


Figure 1-2-19 Reasons for Lack of Increase in the Proportion of Female Researchers

Source: MEXT, “Survey on Research Activities of Private Businesses (FY 2004)”

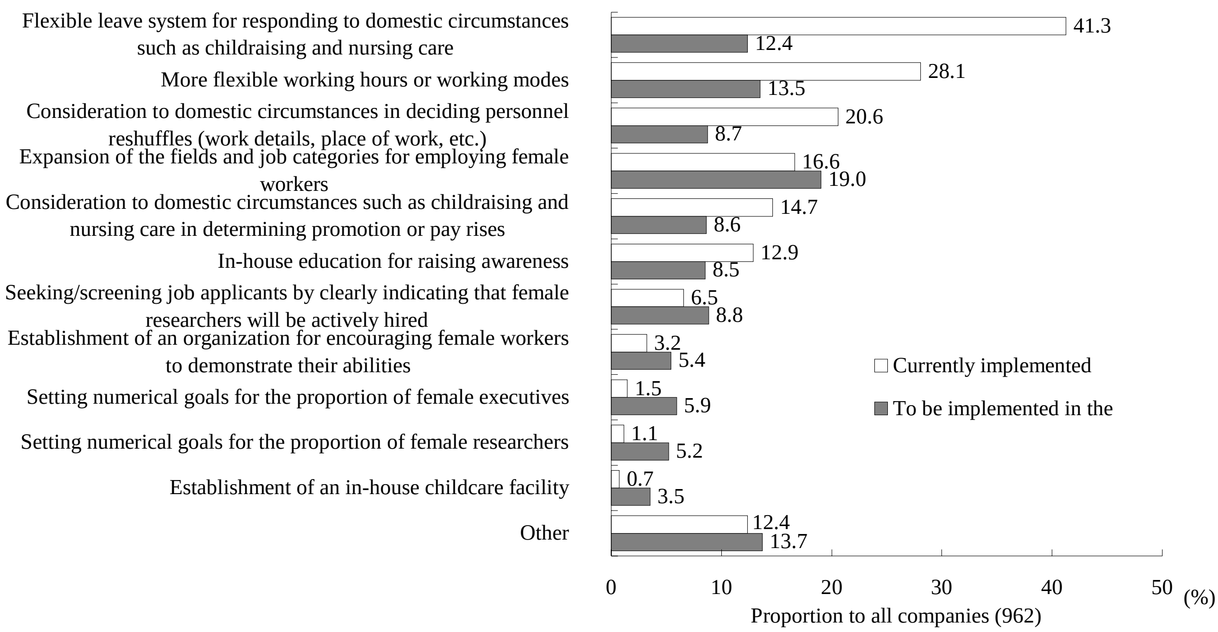


Figure 1-2-20 Specific Measures for Encouraging Female Researchers to Demonstrate Their Abilities

Source: MEXT, “Survey on Research Activities of Private Companies (FY 2004)”

Next, the number of non-Japanese researchers and their proportion have also been gradually increasing in recent years (Figure 1-2-21), but the influx of people engaged in technological/research work has been declining. Moreover, according to the “Survey on Research Activities of Private Businesses,” the number of newly hired non-Japanese researchers has hardly changed for the past five years.

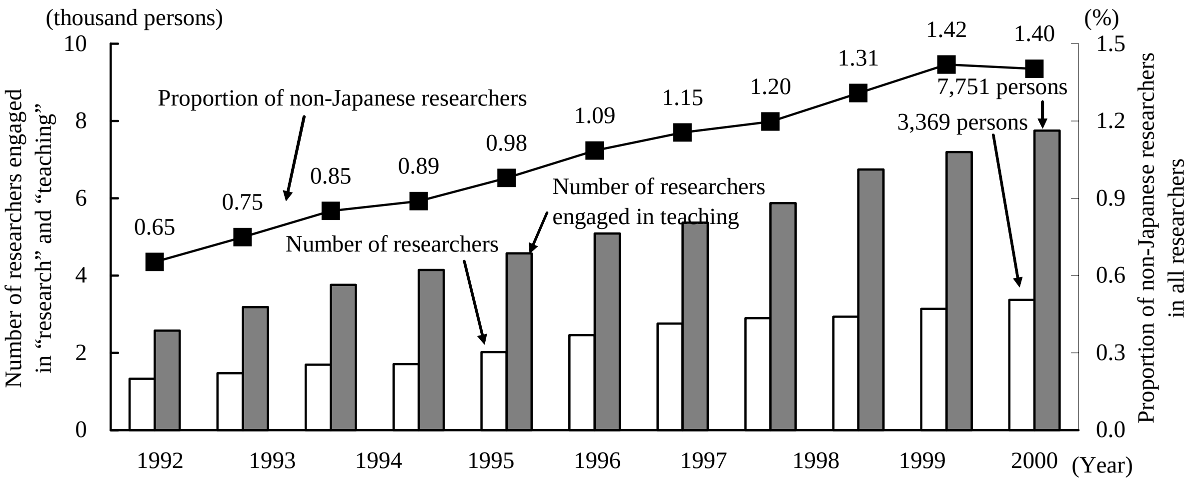


Figure 1-2-21 Number of Non-Japanese Researchers and Their Proportion in All Researchers

Source: NISTEP, "Science and Technology Indicators" (FY 2004)

Some of the reasons mentioned were communication problems, such as language problems, and the uncertainty of maintaining the employment contract. However, presence of talented non-Japanese researchers is important for intellectually stimulating Japan's research society, which tends to be regarded as being closed, and for building an international network. Therefore, measures should be taken to establish an environment that facilitates their stay and settlement in Japan.

Comprehensive measures will be required, also including use of elderly human resources and expansion of reeducation programs for workers.

(Improvement of treatment for scientific and technological human resources)

When comparing the average wage for jobs related to science and technology between Japan and the United States, a higher wage than average is paid for most jobs that require specialized skills or knowledge both in Japan and in the United States. In Japan, however, the payment is not particularly high for most jobs related to science and technology, except for "aircraft pilots" and "doctors." In contrast, a high wage corresponding to professional ability is paid for technological jobs in the United States (FY 2002 "Annual Report on Promotion of Science and Technology")

Meanwhile, according to a survey on private companies that engage in R&D, most companies (67.3%) mentioned that there is no difference in average wage between researchers and other workers, while a larger percentage of companies (49.4%) provided the same or almost the same starting salary to those with a doctor's degree as for those with a bachelor's or master's degree than companies (45.8%) that paid more to those with a doctor's degree (FY 2002 "Survey on Research Activities of Private Companies").

This indicates that, in Japan, technological workers who tend to have received long years of education with rich curriculums do not enjoy a particularly good wage. Although treatment of workers cannot be measured merely by their wages, which only indicate one economic aspect, it will be desirable to guarantee treatment that matches the advanced knowledge, skills, and ability in securing excellent scientific and technological human resources and allowing them to demonstrate their potential.

1.2.2.3 Fostering Understanding of and Interest in Science and Technology

(Scientific and technological literacy)

In order for society to appropriately determine what is ideal science and technology and to take necessary measures, the level of scientific and technological literacy of the people becomes important.

People enjoy scientific and technological achievements in various forms. In the future, however, it is hoped that they will participate in forming policies of the national or local government instead of merely being one-sided beneficiaries. This is because the relation between science and technology and society is becoming closer and more intricate, and individuals have come to be inevitably involved in both the "positive" and "negative" effects of scientific and technological development, as well as because enormous amounts of national expenditure (tax) are directed to science and technology.

However, cutting-edge science and technology has become more and more sophisticated and complicated—becoming something like a black box—scientific and technological achievements have penetrated so deeply into people's lives that they often go unnoticed, and Japan has attained economic affluence in general. Due to these reasons, people's awareness of science and technology has lowered compared to the previous survey. The decline was particularly notable for younger generations under age 30 (Figure 1-2-22).

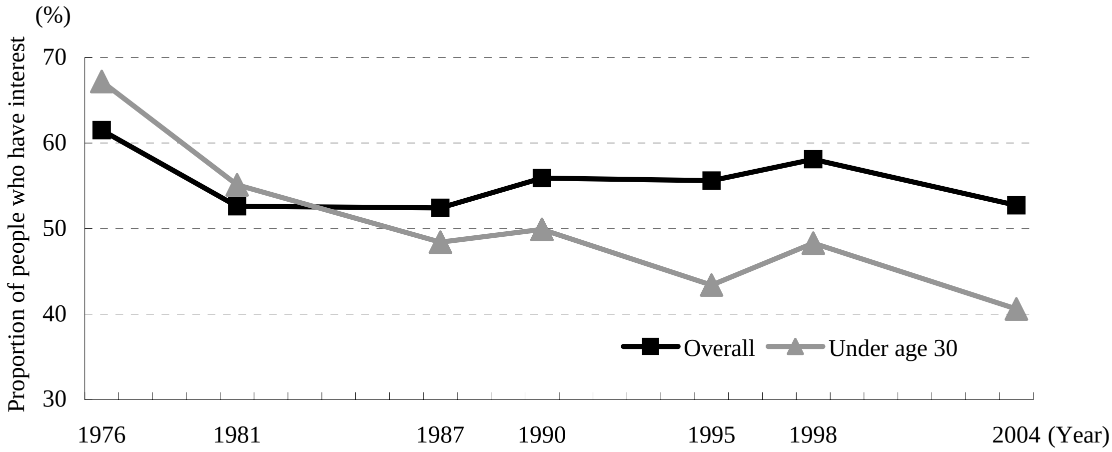


Figure 1-2-22 Interest in News and Topics of Science and Technology

Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society."

According to a survey that internationally compared the degree of understanding of basic scientific and technological concepts of adults aged 18 or over, Japan ranked low among the surveyed countries.

People's loss of interest in science and technology may invite a decline in the intellectual level of Japan as a whole, a decrease in the number of young people wanting to pursue a career related to science and technology, as well as diminishing of scientific and technological human resources.

The survey results show that adults' interest in science and technology is affected by whether they liked or disliked science when they were children. Therefore, in order to raise adults' scientific and technological literacy, it will be beneficial to increase schoolchildren's interest in science and technology as well to implement wide-ranging measures such as encouraging them to acquire an attitude for voluntary learning instead of one-way provision of knowledge and information.

(Measures to develop children's academic abilities and to enhance their interest in the science class)

In December 2004, the results of two international surveys on academic abilities were released. The surveys were the "Programme for International Student Assessment (PISA 2003)" conducted by the Organisation for Economic Co-operation and Development (OECD) targeting children aged 15 (first-graders of upper secondary school) and the "Trends in International Mathematics and Science Study (TIMSS 2003)" conducted by the International Association for the Evaluation of Educational Achievement (IEA) targeting fourth-graders of elementary school and second-graders of lower secondary school (Figure 1-2-23).

According to the results, the overall academic standard of Japanese children ranked high in the world, but in the PISA 2003, the reading ability has been declining to the same level as the OECD average, and is not at the world's top level. In the TIMSS 2003, the overall academic abilities ranked high in the world, but the scores for science achievement of elementary school students and mathematics achievement of upper secondary school students were lower than those in the previous survey. Looking at children's willingness and attitude to study, not many Japanese students said they enjoy learning or they usually do well in mathematics or science. The time spent on study outside of school was at the lowest level among the participating countries, while the time spent on watching television and videos was long. The results indicated that there is much room for improvement with respect to children's willingness to study and study habits.

Programme for International Student Assessment (PISA) 2003
(Conducted by the Organisation for Economic Co-operation and Development (OECD))

○ The overall academic abilities of Japanese students ranked high in the world. (Targeting first-graders of upper secondary school)
○ However, reading ability is declining, so Japan is not at the world's top level.
○ Japanese students have a good attitude about taking lessons, but there are problems regarding their willingness to study and study habits.

1. International comparison of average scores (40 countries/regions)

Performance in mathematics (ranking highest in the previous survey)	Top ranking group: Hong Kong, Finland, South Korea, Netherlands, Liechtenstein, Japan (sixth)
Performance in reading (ranking eighth in the previous survey)	Same level as the OECD average (14th)
Performance in science (ranking second in the previous survey)	Top ranking group: Finland, Japan (second), Hong Kong, South Korea
Performance in problem solving (introduced this time)	Top ranking group: South Korea, Hong Kong, Finland, Japan (fourth)

2. Results of the questionnaire survey

○Willingness to study

	Students interested in the things they learn in mathematics
Japan	32.5%
OECD average	53.1%

○Time spent on studying outside of school

Japan	6.5 hours/week
OECD average	8.9 hours/week

○Students' attitude in taking lessons

	The teacher has to wait a long time for students to quieten down.			
	Always	Mostly	Sometimes	Hardly ever
Japan	3.9%	9.6%	34.8%	50.4%
OECD average	12.0%	19.2%	41.5%	24.8%

Trends in International Mathematics and Science Study (TIMSS 2003)
(Conducted by the International Association for the Evaluation of Educational Achievement (IEA))

- The academic abilities of Japanese schoolchildren ranked high in the world.
  However, the scores for science achievement of elementary school students and mathematics achievement of upper secondary school students were lower than those in the previous survey. (Targeting fourth-graders of elementary school and second-graders of lower secondary school)
- There are problems in children's willingness to study and study habits.
- The time spent watching television and videos was long while the time spent doing jobs or chores at home was short.

(1) Japan's scores

(i) Mathematics achievement

	Elementary school	Lower secondary school
1964 (First survey)	Not implemented	Second place/12 countries
1981 (Second survey)	Not implemented	First place/20 countries
1995 (Third survey)	Third place/26 countries	Third place/41 countries
1999 (Third survey-repeat)	Not implemented	Fifth place/38 countries
2003 (Fourth survey)	Third place/25 countries	Fifth place/46 countries

(ii) Science achievement

	Elementary school	Lower secondary school
1970 (First survey)	First place/16 countries	First place/18 countries
1983 (Second survey)	First place/19 countries	Second place/26 countries
1995 (Third survey)	Second place/26 countries	Third place/41 countries
1999 (Third survey-repeat)	Not implemented	Fourth place/38 countries
2003 (Fourth survey)	Third place/25 countries	Sixth place/46 countries

(2) Awareness of mathematics/science

	I enjoy learning		I usually do well in	
	mathematics	science	mathematics	science
Lower secondary school	39%	59%	39%	49%
World average	65%	77%	54%	54%

(3) Things students do outside of school

	I do my homework	I watch television and videos	I do jobs or chores at home
Lower secondary school	1.0 hour/day	2.7 hours/day	0.6 hours/day
World average	1.7 hours/day	1.9 hours/day	1.3 hours/day

Figure 1-2-23 Outline of the Results of PISA and TIMSS

Source: MEXT

Meanwhile, according to the "Research on Curriculum for Primary and Lower Secondary Schools" conducted by the National Institute for Educational Policy Research in fiscal 2001 and fiscal 2002, the proportion of schoolchildren who agreed with the opinion, "I like studying the subject," for science and mathematics tended to be lower for students in higher grades.

Therefore, in the area of elementary and secondary education, necessary reform must be promoted for overall compulsory education, including the educational content, the teaching method, and the quality of teachers, in order to "cultivate solid academic capabilities" targeted by the current Courses of Study, to develop intellectual curiosity as well as an attitude to learn and think voluntarily, and to achieve the world's top-level academic abilities.

In particular, in order to enhance the understanding of and interest in science and technology of children who will lead Japan in the future, MEXT implements diverse projects concerning science education such as the "Science Literacy Enhancement Initiatives" including designation of Science Literacy Enhancement Schools (elementary and lower secondary schools) and Super Science High Schools (upper secondary schools), as well as creation and distribution of "White Paper on Science and Technology for Kids" (See Part 3).

Measures will also be required in higher education such as universities to develop the science literacy of students who do not specialize in science and technology, and to ensure that students majoring in science and technology acquire extensive knowledge, application abilities, and literacy that are not limited to their major field.

[Column No.16]

International Science Olympiads and Inter-High School Tournament of Science

In July 2004, the International Mathematics Olympiad (IMO) for high school students was held in Athens, Greece—the place where Japanese athletes won many medals, exciting viewers of the Olympics throughout Japan. The six winners of the domestic preliminary rounds participated in the IMO as Japan's representatives. Their excellent performances were rewarded with 2 gold and 4 silver medals. The International Chemistry Olympiad was also held in Germany in the same year, and a Japanese participant won a gold medal for the first time.

The International Science Olympiads (ISO) is an annual competition with six divisions (mathematics, chemistry, physics, informatics, biology and astronomy) for high-school students or below. All the competitions originated in Eastern European countries in the former Communist bloc, and have spread to Western bloc countries.

The aims of the ISO are as follows: (1) promotion of learning activities for students who are interested in science and technology: (2) cultivation of learners' creativity and inspiration; and (3) establishment of friendship between participants through international exchange. It is also effective in attracting public attention to science and technology.

Japan has participated in the Olympiads' Mathematics (since 1990) and Chemistry categories (since 2003). Japanese participants in these Olympiads are selected through tightly-contested domestic preliminary rounds, which are supported by the related academic societies, teachers and volunteers.

The number of Japanese participants in the ISO has been increasing, although there is concern that it will decrease in the future because of the trend of fewer children and the unpopularity of science. The increasing number of participants could be due to increased name-recognition of the ISO, and to the Japan Science and Technology Agency (JSTA) introducing the ISO support system in fiscal 2004. JSTA subsidizes the expenses of overseas trips by participants and their supervisors, as well as of domestic training camps. Japan will also participate in the Biology Olympiad from the Beijing competition in 2005 and in the Physics Olympiad from the Singapore competition in 2006. The people involved the Physics Olympiad have been preparing for Japan's first participation. In August 2005, for example, the "Physics Challenge 2005" will be held in Okayama Prefecture, partly as the domestic elimination rounds of the Physics Olympiad.

Inside Japan, the first Super Science High School event was held at Tokyo Big Sight in August 2004. Science lovers from high schools throughout Japan gathered in the meeting to present their research. In the "Inter-high-school Tournament of Science," the 72, which were designated as "Super Science High Schools" in fiscal 2002, participated, and 26 of them presented the results of their studies over the last three years. The Honorable Mention by the Minister of Education, Culture, Sports, Science and Technology was awarded to students of the science and mathematics seminar at Hiroshima Kokutaiji High School, Hiroshima Prefecture, for their study "Genetic Analysis of the Great Salamander." For the first time in the world, high school students succeeded in analyzing the DNA of the great salamander, the world's biggest amphibian, which is designated as a special national treasure in Japan. As their study was so outstanding, they had an opportunity to present it at the meeting of the Society of Evolutionary Studies, Japan, in the same month, and received high praise from the specialists.

Such efforts to cultivate young people's intellectual curiosity and inquisitive spirit are highly beneficial, not only for nurturing world-class scientists and engineers, but also for stimulating other students and school education. Despite the trend of unpopularity of science and technology, events such as the ISO and the Super Science High School are expected to become more popular.

(Building channels between researchers and society)

Scientists and engineers play a significant role in enhancing people's understanding of science and technology and encouraging children to take up a career in science or technology in the future.

However, there is a considerable gap in awareness between the general public and scientists. For example, according to the "Survey of the State of Japan's Research Activities" in fiscal 2003, which targeted researchers, those who answered that people's impression of researchers seemed to have "improved" or "slightly improved" accounted for 42.3% of all respondents, which is a considerable increase from the 9.2% in the same survey in fiscal 1999 (Figure 1-2-24). The reason mentioned by nearly 80% of these respondents was "Japanese people winning famous scientific prizes such as the Nobel Prize." On the other hand, in the "Public Opinion Poll on Science and Technology and Society," which was conducted on the general public at around the same time, about 15% answered "agree" or "slightly agree" with the statement, "scientists and engineers are a familiar and close presence," while more than 70% answered "disagree" or "slightly disagree" (Figure 1-2-25).

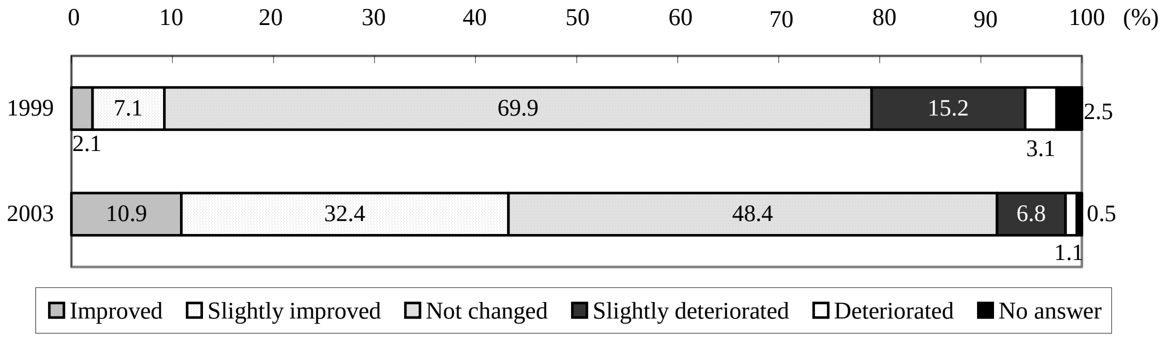


Figure 1-2-24 Changes in Society's and People's Impression of Researchers (Researchers' Awareness)

Source: MEXT, "Survey of the State of Japan's Research Activities"

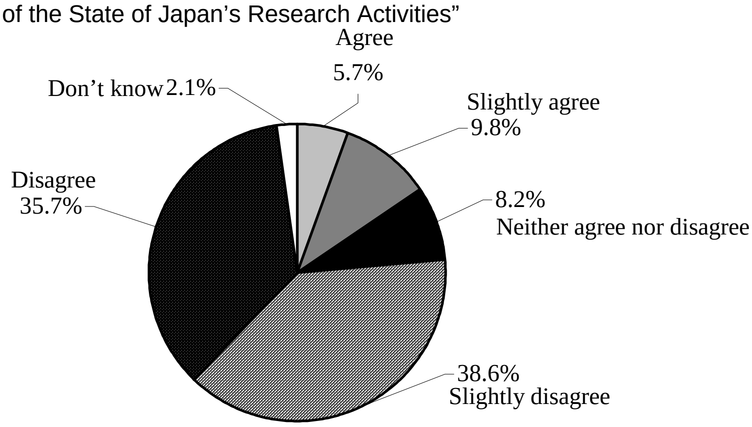


Figure 1-2-25 Sense of Closeness with Scientists and Engineers (People's Awareness)

Note: Figure indicates the respondents' opinions on the statement, "scientists and engineers are a familiar and close presence."
Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society (February 2004)."

Looking at the places that scientists and engineers want to use for presenting their research in the FY 2003 "Survey of the State of Japan's Research Activities," the greatest number of respondents mentioned contribution of an article to a magazine for the public and lectures/lessons for the public. However, looking at how people access information on science and technology in the "Public Opinion Poll on Science and Technology and Society," the main means were television and newspaper. Such difference in awareness and practices seem to be causing a distance between scientists and the people.

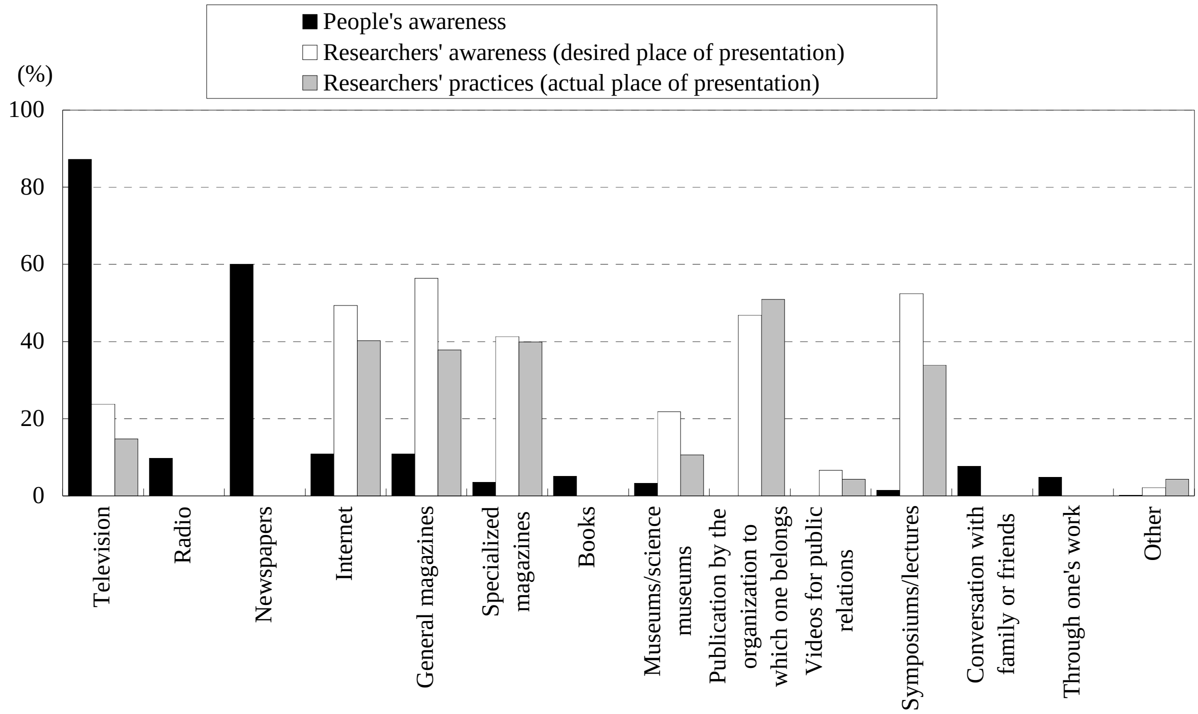


Figure 1-2-26 People’s Means of Access to Scientific and Technological Information and Places Where Scientists Disseminate Information

Note: Results of the survey of the state of Japan’s research activities were compared with the results of the public opinion poll by deeming the survey items to correspond to the following:
“mass media such as television and radio” as “television”;
“Web sites on the Internet” as “Internet”;
“contribution of an article to a magazine for the public” as “general magazines”;
“activities of an academic society or association such as public relations” as “specialized magazines”;
“demonstration of experiments and activities for experiencing science and technology at science museums” as “museums/science museums”; and
“lectures for the public and lessons at citizen’s colleges” as “symposiums/lectures.”
Sources: Cabinet Office, “Public Opinion Poll on Science and Technology and Society (February 2004)”;
MEXT, “Survey of the State of Japan’s Research Activities (FY 2003).”

Therefore, scientists and engineers and the organizations to which they belong should send out information and conduct outreach activities[1] more actively through the mass media and other diverse media.

Also, because science and technology is a specialized field, the vehicle for conveying the information to people in an understandable manner would be important, so science journalists should be developed and the public relations section of research institutes should be reinforced.

At the same time, museums and science museums are places where people of various ages, particularly children, can actually experience and observe science and technology, but while the number of these facilities is increasing every year, there is little growth in the number of visitors. Therefore, they are expected to contribute to enhancing children’s interest in science education through adopting unique display styles and in coordination with school education.

1 Researchers join in the local community on their own initiative, interact with the community members, and provide them with learning opportunities.

1.2.3 The Science and Technology Basic Law and the Science and Technology Basic Plan

Research achievements derived from researchers ideas go through various twists and turns until they are put to practical use and reach consumers, and various public support becomes necessary in that course. Japan, which enacted the Science and Technology Basic Law in 1995, took a step forward toward becoming an advanced science- and technology-oriented nation. Based on this law, the First and Second Science and Technology Basic Plans were formulated to support the diverse R&D of universities, public research institutes, companies, and individual researchers, and to establish the foundation for producing many research achievements. This section focuses on the background of formulation of the Science and Technology Basic Law and the Science and Technology Basic Plans as well as the status of their attainment.

1.2.3.1 Enactment of the Science and Technology Basic Law

(Expectations for science and technology)

The bill for the Science and Technology Basic Law was submitted to the Diet by a cross-party group of Diet members in order to make the promotion of science and technology as one of Japan's top priority issues, and to achieve an "advanced science-and technology-oriented nation." The bill was unanimously approved, and the law was promulgated and entered into force in November 1995. For a long time, people had held high expectations for enactment of the Science and Technology Basic Law, which indicates the roadmap for the country's science and technology policy, and the government submitted the bill to the Diet in 1968. However, the bill was repealed as a result of not being approved by the end of the session, due to considerable differences in the ideas of people concerned regarding coordination between industry, academia and government and the handling of universities.

Nevertheless, nearly 30 years later, enactment of the Science and Technology Basic Law gathered momentum again due to considerable changes in the domestic and international situations. Japan grew to become the world's second largest economic power. Japan was no longer in a catch-up era, but it was time for it to make challenges in unexplored fields of science and technology and open up a path for the future by demonstrating creativity as a front-runner. At the same time, because Asian countries were making efforts to catch up with Japan by making use of their inexpensive labor, there were growing concerns about a possible hollowing out of industry in Japan, such as the percentage of overseas production of the Japanese manufacturing industry increasing from 6.0% in 1991 to 8.9% in 1995. Thus, development of new technologies was also necessary for creating conditions that make companies remain in Japan. Furthermore, Japan had come to be expected to make scientific and technological contributions to the world in addressing energy and environmental issues as one of the front-runners.

(The situation of science and technology in Japan at the time)

The situation of science and technology in Japan at the time of enactment of the Science and Technology Basic Law was a matter of concern. First of all, public funds were considerably lacking. While the percentage of R&D funds to gross domestic product (GDP) in Japan was at the highest level in the world, exceeding that of major western countries, the percentage of government-financed R&D funds to GDP was low at 0.59 in Japan when the percentage was 0.88% in the United States (1994) (Figure 1-2-27). Because R&D funds were mostly financed by the public sector in this way, research was not so active in areas of medium to long-term technology seeds, such as in the basic research field, which are indispensable for development of science and technology.

Furthermore, the amount of R&D funds per researcher was low, and research facilities, which support researchers' creative research activities, were becoming old. Facilities that were 20 years old or older accounted for 50% of the facilities of all national universities, which was 35% of the facilities of all national research institutes.

There was also a serious shortage of human resources for conducting research. Although there were demands for unique and creative researchers and engineers, such human resources were quite small in number in Japan in reality. In 1991, the number of persons who earned a doctor of science degree in Japan was 600 as compared to 9,700 in the United States, and the number of persons who earned a doctor of engineering degree in Japan was 1,000 as compared to 6,400 in the United States. Therefore, it was necessary to increase the number of postdoctorals and develop an environment for allowing them to get jobs with advantage also for expanding the researcher population and fostering creative researchers. Moreover, there was a need to form a research environment where talented young researchers are promoted and the principle of competition takes effect, so as to have researchers demonstrate their free creativity. However, researchers at universities and national testing laboratories lacked mobility since they were basically subject to lifetime employment, and the competitiveness of the research environment was insufficient. What is more, it was quite difficult to provide young researchers with appropriate places for engaging in research.

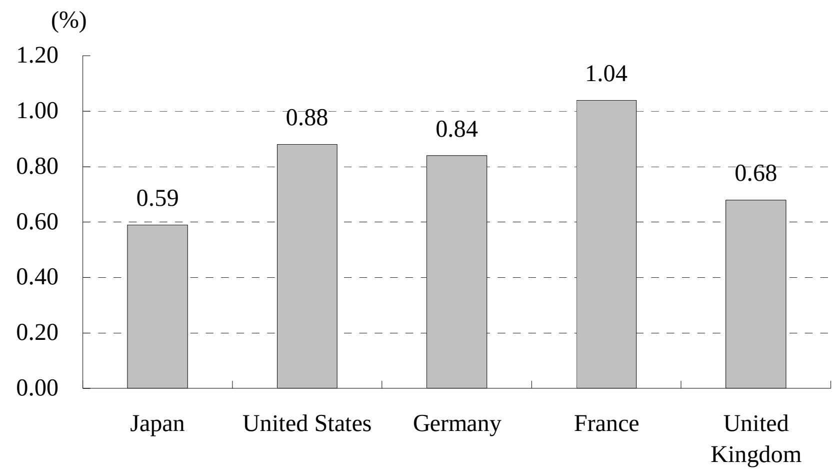


Figure 1-2-27 Percentage of R&D Funds to GDP (1994)

Source: Japan: Statistics Bureau, MIC, “Survey of Research and Development”;
United States: National Science Foundation, “National Patterns of R&D Resources”;
Germany: Federal Ministry of Education and Research, “Bundesbericht Forschung,” “Faktenbericht Forschung”;
France: “Project de Loi de Finance: Rapport Annexe sur l’Etat de la Recherche et du Development Technologique”;
United Kingdom: Office for National Statistics, “Gross Domestic Expenditure on Research and Development”

(Significance of the Science and Technology Basic Law)

The Science and Technology Basic Law indicates policies for the promotion of science and technology including harmonized development among basic research, applied research, and development research, and clearly states that the nation and local governments are responsible for actively promoting science and technology. In addition, it provides that the government should formulate a Science and Technology Basic Plan in order to comprehensively and systematically implement policies. Furthermore, it lists measures that should be implemented by the government, such as improving and securing researchers. In this manner, the Science and Technology Basic Law indicated a path for establishing the necessary research environment for the development of science and technology, and put forward the country’s basic attitude toward becoming an advanced science-and technology-oriented nation in Japan and overseas. The significance of establishing this law as a basic law instead of a mere promotion law was in declaring the direction for future promotion of science and technology and attempting to achieve a national consensus on the promotion of science and technology.

Outline of the Science and Technology Basic Law
- Guidelines for promotion of science and technology (Article 2)
- Responsibilities of the nation and local governments (Articles 3 and 4)
- Formulation of a Science and Technology Basic Plan (Article 9)
- Measures that should be taken by the nation (securing researchers, improvement of facilities, promotion of information intensive R&D, promotion of international exchanges, and promotion of learning on science and technology; Articles 10 to 19)

1.2.3.2 Formulation of the First and Second Science and Technology Basic Plans

(First Science and Technology Basic Plan)

In the year following the promulgation of the Science and Technology Basic Law, a Science and Technology Basic Plan was formulated in order to give shape to the principles of the law and systematically promote measures for promoting science and technology. The first key point of the First Science and Technology Basic Plan was institutional reform toward building a new R&D system, which was aimed at achieving a flexible, competitive, and open research environment. The specific measures included an increase of mobility of researchers through introduction of a tenure system for the researchers of national research institutes, the fostering and securing of researchers through accomplishment of the "Program to Support 10,000 Postdoctorals," promotion of coordination between industry, academia and government, encouraging acceptance of non-Japanese researchers, and impartial evaluation of researchers. The second point was an increase in government investment in R&D, which was the most important target of the Science and Technology Basic Plan. The plan required the doubling of government investment in R&D during the Basic Plan period with an aim of raising its percentage to GDP to match the level of major western countries by the beginning of the 21st century. The total expenditures related to science and technology that were to be required during the Basic Plan period to this end were 17 trillion yen. In addition, in order to establish desirable R&D infrastructure, the need for systematic improvement of facilities that are expected to become aged was pointed out.

Key Points of the First Science and Technology Basic Plan
- Promotion of institutional reform for building a new R&D system
  (Introduction of a tenure system, accomplishment of the "Program to Support 10,000 Postdoctorals," promotion of coordination between industry, academia and government, etc.)
- Increase in government investment in R&D
  (Overall amount of expenditures related to science and technology during the Basic Plan period: 17 trillion yen)

(Second Science and Technology Basic Plan)

The First Science and Technology Basic Plan achieved success in the areas of accomplishing the "Program to Support 10,000 Postdoctorals" and achieving a sum exceeding the 17 trillion yen, which had been indicated to be the necessary amount of expenditures related to science and technology, as government investment in R&D. The Second Science and Technology Basic Plan, which was formulated in 2001, indicated the following three goals for the future of Japan, while presenting a vision for the 21st century: "a nationcontributing to the world by creation and utilization of scientific knowledge," "a nation with international competitiveness and ability for sustainable development," and "a nation securing safety and quality of life." In order to attain these goals, the Basic Plan set up targets including efforts to increase government investment in

R&D to 24 trillion yen[2] so as to match the level of major western countries, achieve closer coordination between industry, academia and government, double the competitive funds in order to foster a competitive environment, and resolve the aging and overcrowding of university facilities and equipment. Furthermore, for making selective and intensive fund injections, "life sciences," "information and telecommunications," "environmental sciences," and "nanotechnology and materials" were chosen as the four priority fields that Japan should promote from the viewpoints of creating knowledge that will give rise to new development, achieving sustainable growth in the world market, improving industrial technical abilities, generating new industries and employment, improving people's health and the quality of life, ensuring national security, and preventing disasters.

Key points of the Second Science and Technology Basic Plan

- Indication of a clear vision of Japan
- Raising the total government investment in R&D to 24 trillion yen[3]
- Strategic priority setting in science and technology
  (Promotion of basic research, prioritization of R&D on national/social subjects, and focus on emerging fields)
- Reform of the science and technology system
  (Establishment of a competitive R&D environment, improving mobilization of researchers, improving self-reliance of young researchers, reform of evaluation systems, reform of coordination between industry, academia and government, development of environment for promoting science and technology in the region, human resources development and reform of universities, establishment of interactive channels between science and technology and society, and maintenance of infrastructure such as improving facilities of universities, etc.)

(Establishment of the Council for Science and Technology Policy and changes in the framework for promoting science and technology)

During the period of the First Science and Technology Basic Plan, there were great changes in the framework for promoting science and technology policy. In January 2001, the "Council for Science and Technology Policy" was established in the Cabinet Office as part of the central government reform. While the former Council for Science and Technology Policy only held a meeting once a year, the new Council for Science and Technology Policy holds a meeting once a month always with the participation of Prime Minister, and holds discussions among experts and bureaucrats. Specifically, the council plans and totally coordinates basic policies, and makes deliberation and evaluation of the direction for allocation of resources, such as budget. In addition, the national framework for administration of science and technology was restructured, such as the consolidation of the Ministry of Education, Science, Sports and Culture and the Science and Technology Agency into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for promoting science and technology policies and academic policies in an integrated manner. At the same time, in order to make national experimental and research institutes and national universities more diverse and unique by putting them in a more competitive environment, there was also a major change in the status of public research institutes and universities, such as a measure to turn national experimental and research institutes into independent administrative institutions (starting in fiscal 2001) and incorporating national universities (fiscal 2004).

2 The percentage of government investment in R&D to GDP during the Basic Plan period is premised to be 1%, and the nominal GDP growth during the same period to be 3.5%.
3 The percentage of government investment in R&D to GDP during the Basic Plan period is premised to be 1%, and the nominal GDP growth during the same period to be 3.5%.

1.2.3.3 Status of Accomplishment of the First and Second Science and Technology Basic Plans

(Transition and prioritization of government investment in R&D)

Although the financial circumstances had been severe and the budget for general expenditures had been cut or has remained at the same level throughout the periods for the First and Second Science and Technology Basic Plans, national expenditures related to science and technology steadily increased. The total science and technology related expenditures during the First Basic Plan period was 17.6 trillion yen, and during the Second Basic Plan, including local budgets, reached 21.1 trillion yen (until the initial budget for fiscal 2005) (Figure 1-2-28).

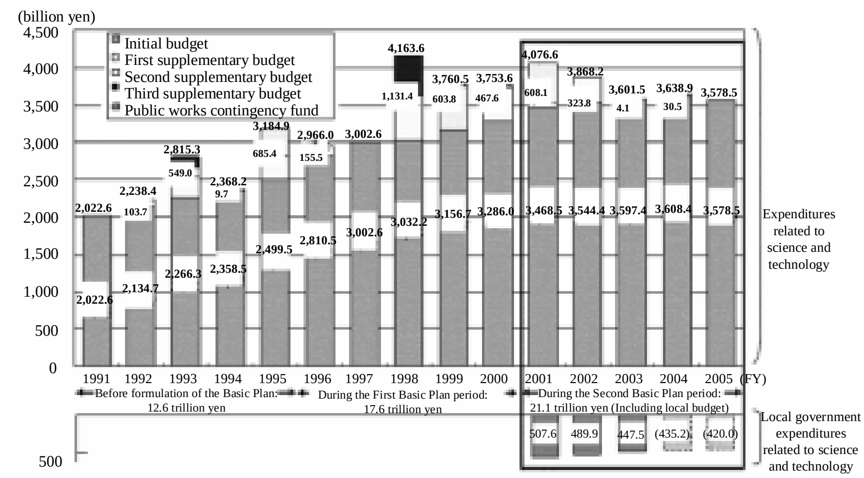


Figure 1-2-28 Expenditures Related to Science and Technology (on a Budget Basis)

Notes: 1. Initial budget for fiscal 2005 is a preliminary value.
2. Figure includes `local government expenditures related to science and technology (the values for fiscal 2004 and 2005 are estimated values).
3. Of the expenditures related to science and technology for 2004 onward, those related to national university corporations etc. are calculated based on the total sum of the operation subsidy and the subsidy for construction of facilities, which are national expenditures, and the corporation’s own income (hospital income, tuition fees, amount received for entrusted projects). (This sum corresponds to the expenditures related to science and technology in the Special Account for National Educational Institutions before the incorporation of national universities, etc.)

Source: Surveyed by MEXT

According to an analysis by NISTEP,[4] the proportion of basic research in the research related expenditures increased during these periods from the five-year average of 33.8% prior to the formulation of the First Science and Technology Plan (pre-first period), to 37.1% in the first period, and to 38.5% in the second period(until fiscal2004). In the same manner, the proportion of the fourpriority fields, namely, life sciences, information and telecommunications, environment, and nanotechnology/materials also increased from 29.1% in the pre-first period, 37.6% in the first period, and to 42.1% in the second period, indicating that emphasis was placed on these fields.

4 Calculated based on the sum of the “research expenditures” in the expenditures related to science and technology plus the amount of the basic education and research school funds that is registered as expenditures related to science and technology, which corresponds to the research expenditures of independent administrative corporations (estimated based on data before incorporation) and those of national universities (research related expenditures).

(Increase of competitive funds)

The amount of the competitive funds extended increased dramatically. In fiscal 2000, the final year of the First Basic Plan period, the amount was 296.8 billion yen, or 2.4 times the amount in fiscal 1995, and in fiscal 2005, which was the final year of the Second Basic Plan period, the amount was 467.2 billion yen, or 1.6 times the amount in fiscal 2000. These funds fostered a competitive environment at R&D sites (Figure 1-2-29).

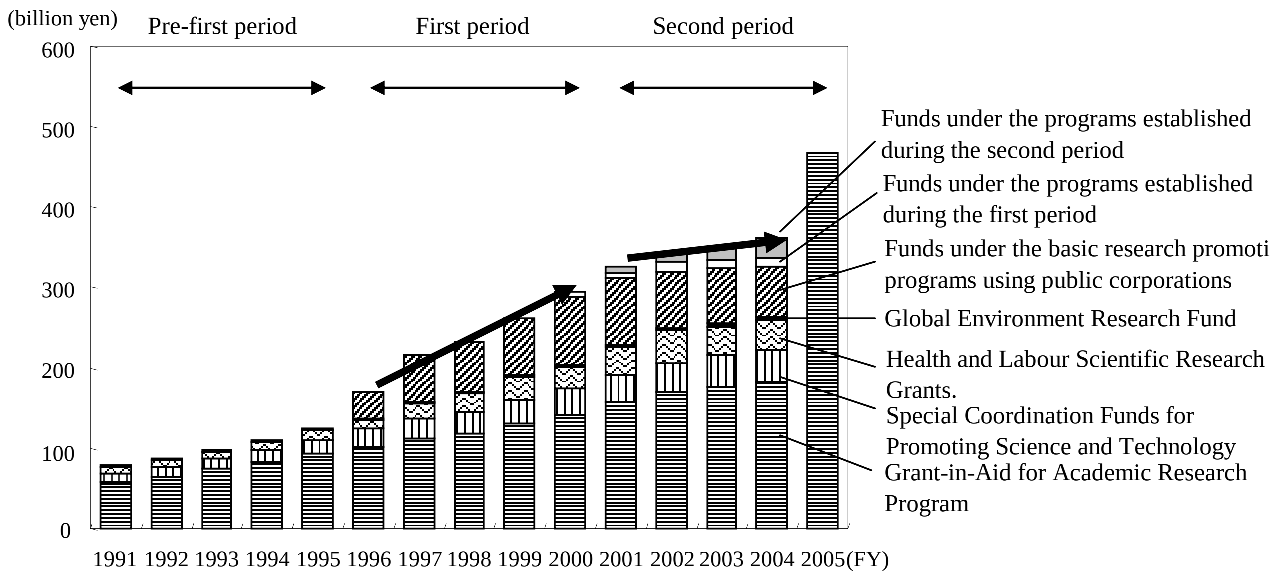


Figure 1-2-29 Budget for Competitive Funds

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Development and mobilization of human resources)

With regard to human resources, the "Program to Support 10,000 Postdoctorals" was set up in the First Basic Plan, and effort was made to improve the mobility of researchers and the self-reliance of young researchers throughout the First and Second Basic Plans. As a result, the number of persons subject to support under the budget, such as postdoctorals, reached 10,000 during the First Basic Plan period, and the number has stayed above 10,000 every year since 1999. However, there are also problems including the difficulty for these people to gain a desired post for lifetime employment immediately after the termination of the support period including such positions in private companies.

In the area of improving the mobility of human resources, the number of institutes adopting a tenure system for assistants to professors, who tend to be young, increased, mainly among national universities, and the proportion of assistants under a tenure system in all assistants working for universities grew to about 11% (Figure 1-2-30). On the other hand, movement of researchers between organizations is not active; in particular, movement of researchers from universities or public research institutes to private companies is rare. Thus, mobility of human resources is still insufficient (Figure 1-2-31).

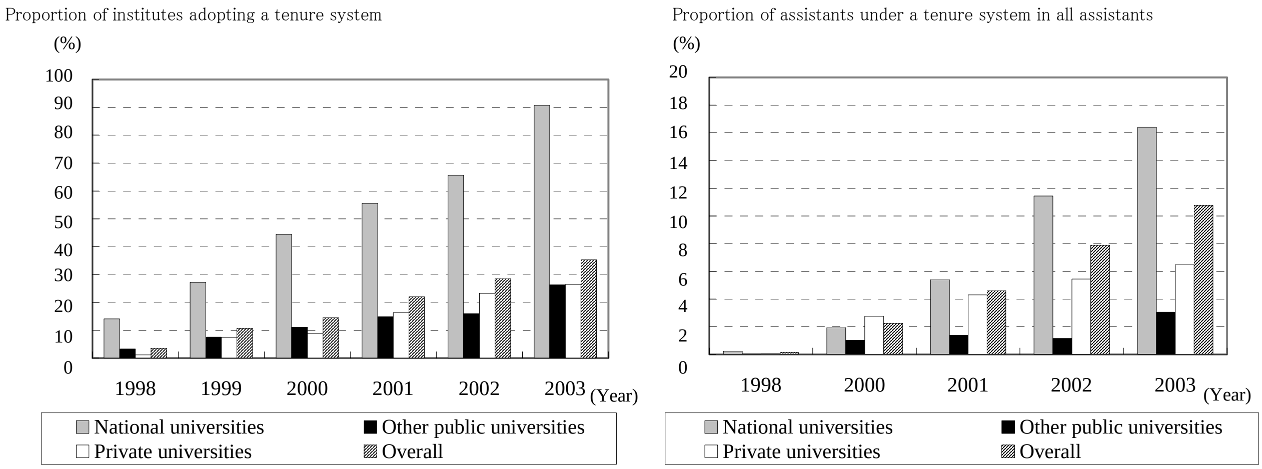


Figure 1-2-30 Introduction of a Tenure System at Universities

Notes: 1. Left graph shows the proportion of universities that adopt a tenure system in all universities in the respective years.
2. Right graph shows the proportion of assistants under a tenure system in all assistants in the respective years.
3. Graphs show the status of introduction of the system under the "Law on the Tenure System for University Instructors." Some private universities adopt a tenure system that is not based on this law.

Source: Surveyed by MEXT

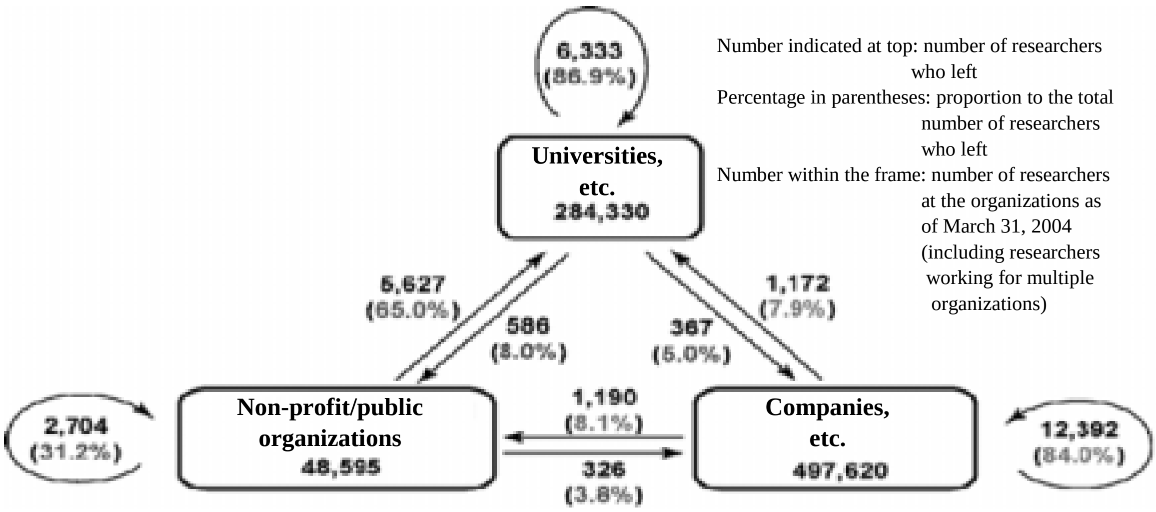


Figure 1-2-31 Mobility of Researchers Among Organizations

Note: 1. Number of researchers includes those in social sciences and humanities.
2. Chart only targets movements between organizations, and does not include movements within the same organization, such as transfer to another department of the same university.
3. Researchers include postdoctorals.
4. University researchers include students taking a doctor's course.
5. "Non-profit/public organizations" refers to national or other public research institutes, public corporations, and independent administrative institutions for the purpose of conducting experimental research or survey research.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Promotion of coordination between industry, academia and government)

In terms of coordination between industry, academia and government, joint research projects between national universities and private companies continued to increase as a result of various measures to improve the environment, such as development of related systems and facilities as well as deregulation. The number of such joint research projects reached a record high of 8,023 in fiscal 2003 (an 18.3% increase over the previous year), and 9,255 with those of public and private universities combined (Figure 1-2-32). Looking at the company size of the counterpart, joint research projects with small and medium-sized enterprises (SMEs), such as national universities, was 2,717, increasing by 387 projects (a 16.6% increase) over the previous year, and accounting for 33.9% of the total. This is considered to be an outcome of progress in development of the conditions for such projects and the gathering of momentum for promotion of coordination between industry and academia among both universities and companies.

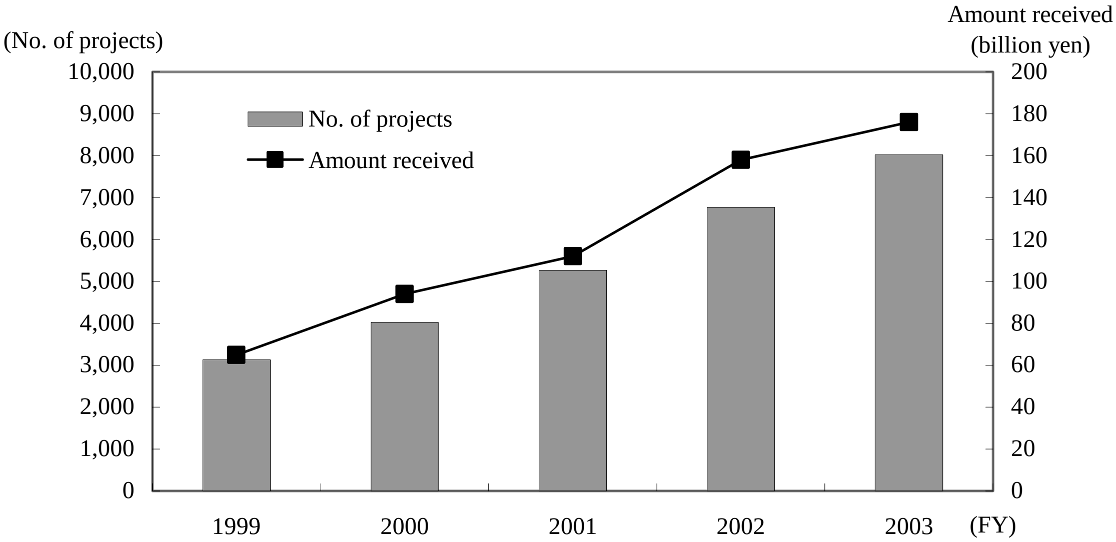


Figure 1-2-32 Joint Research Projects of National Universities, etc.

Source: MEXT, "Survey on Industry-Academia Collaboration Implemented in Universities, etc. (FY 2003)"

The number of university-launched ventures, which start up by using the "knowledge" of universities, etc. as the core of their business, is also increasing. According to a survey conducted by the University of Tsukuba from fiscal 2000 as part of the MEXT's "Model Program for Establishing a 21st Century Method for Coordination Between Industry and Academia," the number of university-launched ventures as of the end of August 2004 was 916. The number has been rapidly increasing from around 1998 when the Law Promoting Technology Transfer from Universities to Industry was enacted, and more than 100 such companies are established every year (Figure 1-2-33).

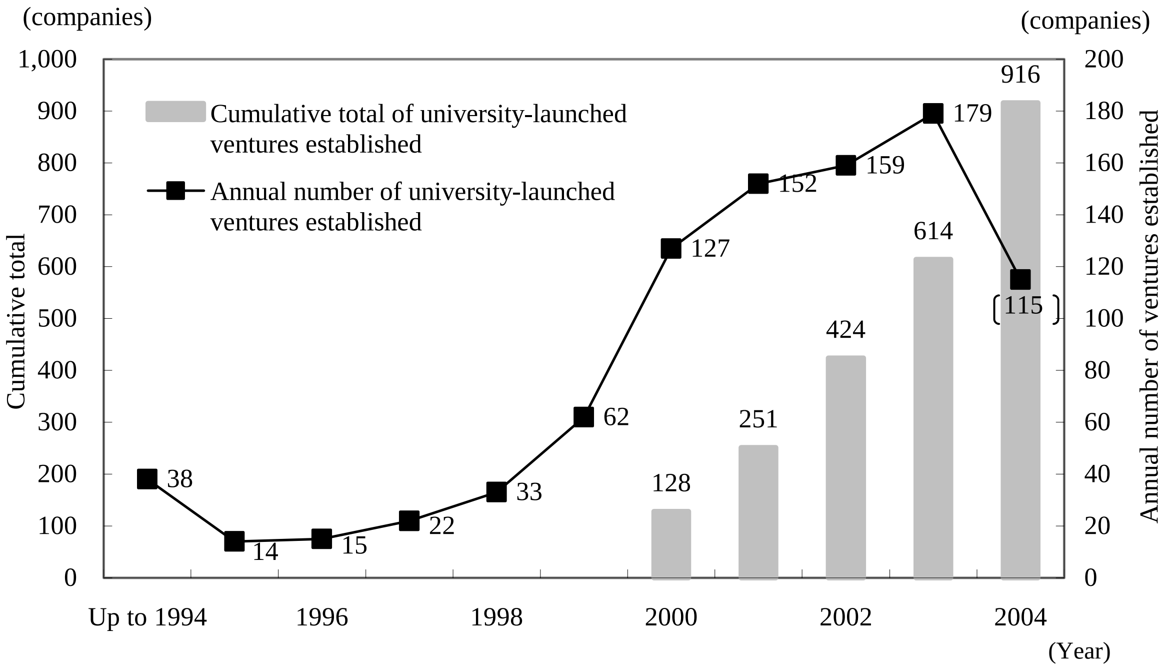


Figure 1-2-33 Number of University-Launched Ventures Established

Note: 1. "Cumulative total" indicates the number of ventures that were revealed by the survey conducted at the end of August every year, starting in 2000."Annual number of ventures established" indicates the number of ventures that were established during the period
from January to December of each year out of the 916 ventures that were revealed by the survey conducted at the end of August 2004.
2. Number of ventures established in 2004 is not the annual number, but the number as of the end of August.
Source: Surveyed by University of Tsukuba

(Promotion of science and technology in the region)

In order to promote science and technology in the region, MEXT has engaged in the "Intellectual Cluster Program" since fiscal 2002, and currently implements the program in 18 regions. In fiscal 2003, the number of patent applications filed from all regions reached about 160, while about 140 universities and about 230 companies participated in joint research projects. In addition, the Ministry of Economy, Trade and Industry (METI) has launched the "Industrial Cluster Program" since fiscal 2001, and currently implements 19 projects nationwide. Under this program, METI makes efforts to build close cooperative relationships with about 5,800 small and medium-sized local companies that are venturing into new businesses and researchers of more than 220 universities, enhance the quality and quantity of information distributed among industry, academia, and government, and support technology development that makes use of the characteristics of the region. Close coordination between these two kinds of clusters will become important in future regional development.

(Improvement of facilities)

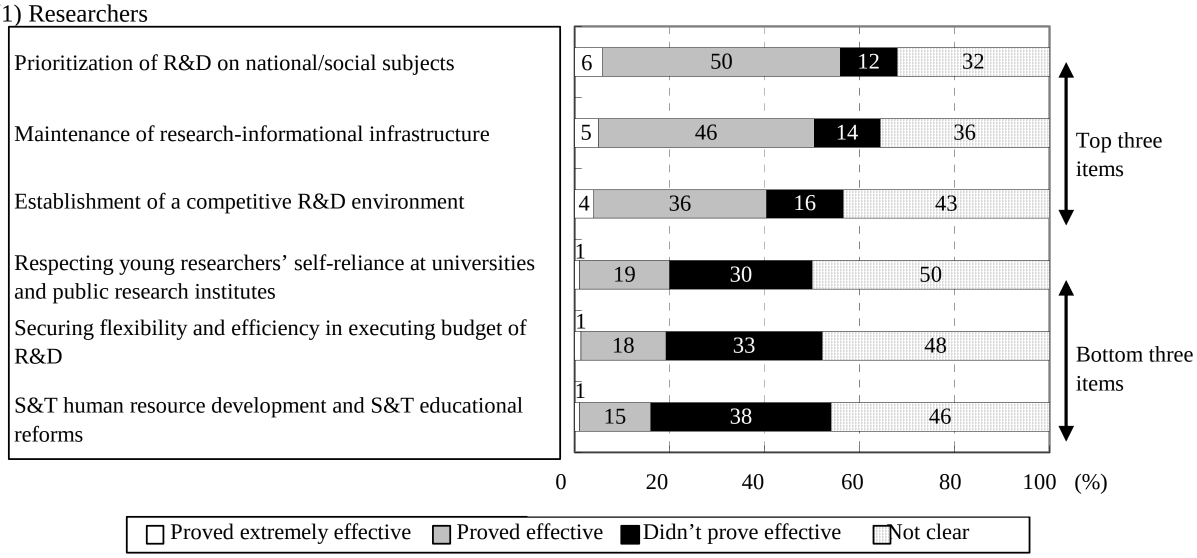
With regard to improvement of facilities, Japan had promoted a plan to improve facilities of approximately six million square meters during the Second Basic Plan period in the "Five-Year Plan for Urgent Development of the Facilities of National Universities, etc." Of this plan, improvement of facilities of graduate schools, centers of excellence (COE), and university hospitals, which was a priority target, is likely to be attained as planned with 3.73 million square meters being improved with the budget of up to fiscal 2004. However, the projects for upgrading aged facilities have only made about 50% progress at national universities. Meanwhile, the proportion of facilities that require repair or improvement at national research institutes, which once fell below the 20% recorded in fiscal 1995, increased again in fiscal 2003, so further improvement efforts are needed.

(Researchers' awareness of the Science and Technology Basic Plan)

When MEXT conducted a questionnaire survey on researchers about the abovementioned measures under the Second Basic Plan, the three items for which the most respondents answered "proved extremely effective" or "proved effective" were "prioritization of R&D on national/social subjects," "maintenance of research-informational infrastructure," and "establishment of a competitive R&D environment (an increase of competitive funds)." In contrast, the three items for which the least respondents gave such answers were "science and technology human resource development and science and technology educational reforms," "securing flexibility and efficiency in executing national budget," and "respecting young researchers' self-reliance at universities and public research institutes." The measures that should continue to be promoted were "maintenance of research-informational infrastructure," "prioritization of R&D on national/social subjects," and "an increase of government investment in R&D." These results suggest that researchers welcome the government's active investment in science and technology, and find problems in the government measures on human resources development. When the same questionnaire survey was conducted on private companies, "promoting R&D by private companies" and "reform of universities, etc. and promotion of R&D" ranked high along with "prioritization of R&D on national/social subjects," which suggests that private companies highly evaluate reform of universities. On the other hand, similar to the results for individual researchers, human resources development and flexibility in executing budget were mentioned among other items as measures that did not prove to be effective (Figure 1-2-34).

In a questionnaire survey conducted by NISTEP on the head authors of the top 10% scientific papers that were most cited by other papers (top researchers), the respondents answered that the research environment had been improved in many ways compared to before the First Basic Plan, but they had less "time for research." The most improved areas were "introduction of a tenure system for researchers at one's institute," "programs supporting coordination/ technology transfers between industry, academia and government," and the "amount of competitive R&D funds provided by the government." The only worsened aspect was the "time for research," and less improved areas included the "amount of ordinary R&D funds" (Figure 1-2-35).

(1) Researchers



Note:Respondents were asked to evaluate 28 items extracted from the measures under the Second Science and Technology Basic Plan.
Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

(2) Private companies

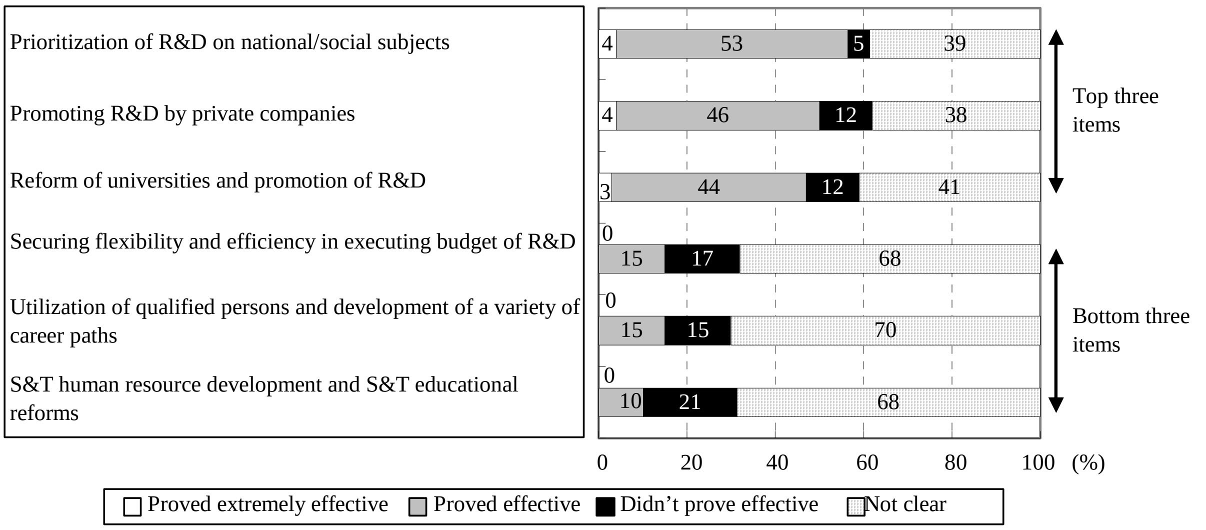


Figure 1-2-34 Measures under the Second Science and Technology Basic Plan That Proved Effective

Note:Respondents were asked to evaluate 28 items extracted from the measures under the Second Science and Technology Basic Plan.
Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

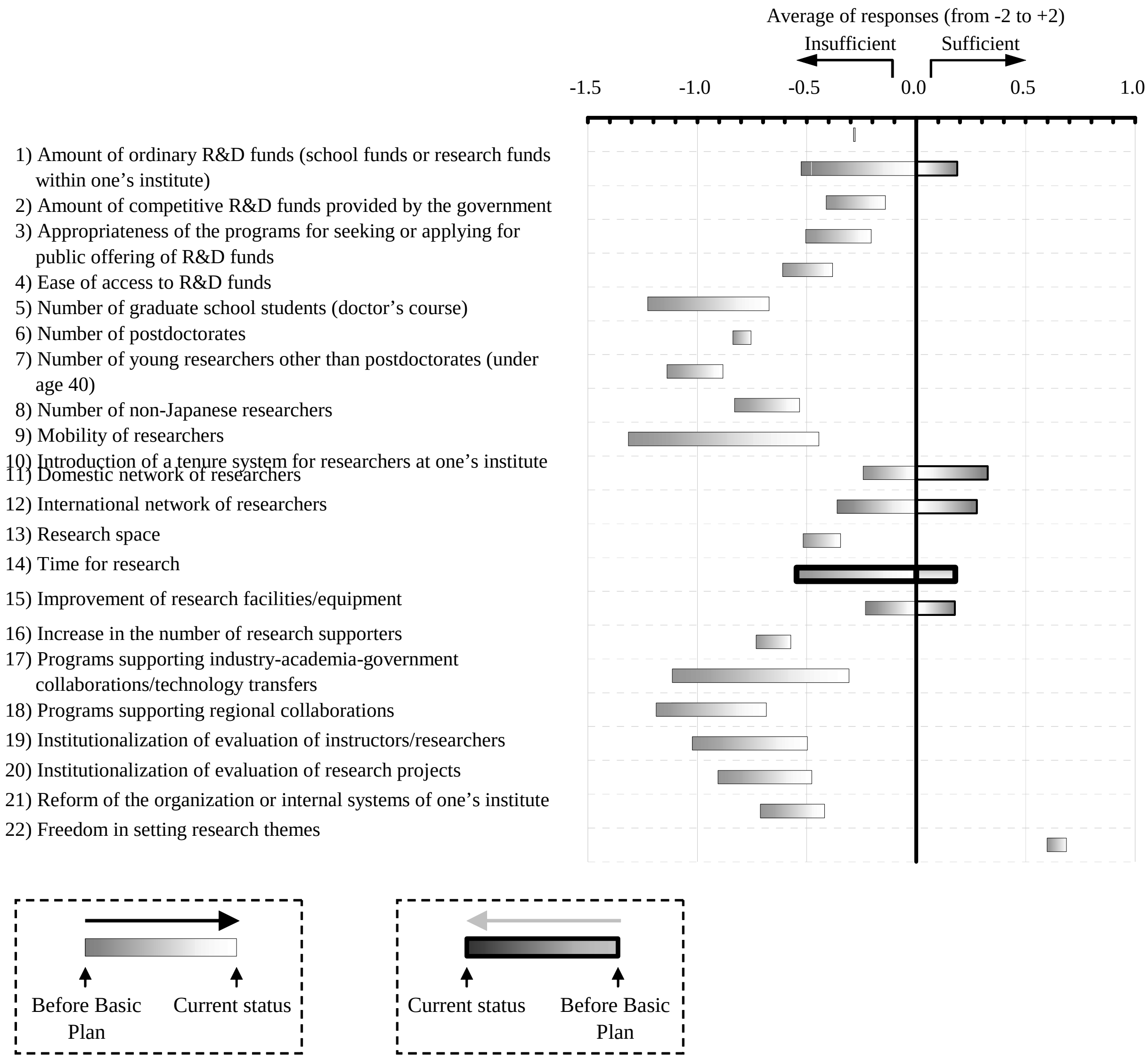


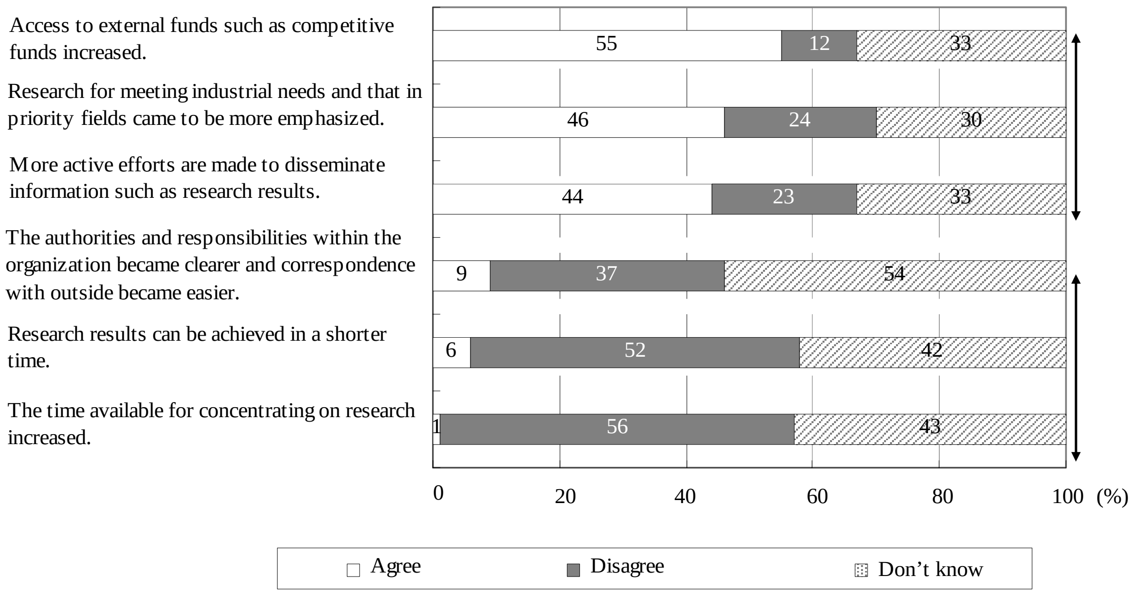
Figure 1-2-35 Changes in Research Environment Perceived by Top Researchers

Note: "Top researchers" refers to the 846 respondents of NISTEP's "Survey on the Effects of Science and Technology Policies and the R&D Level Perceived by Top Researchers (October - December 2004)," which targeted the authors of the top 10% scientific papers that were most cited by other papers based on the Science Index (2001).
Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Changes pertaining to incorporation)

When MEXT conducted a questionnaire survey on researchers about changes pertaining to the incorporation of national universities and public research institutes, both the researchers at national universities and those at public research institutes said "access to external funds such as competitive funds increased," "research for meeting industrial needs and that in priority fields came to be more emphasized," and "more active efforts are made to disseminate information such as research results" as the top three changes. On the other hand, the three items that were least mentioned as notable changes were "the time available for concentrating on research increased," "research results can be achieved in a shorter time," and "the authorities and responsibilities within the organization became clearer and correspondence with outside became easier" (Figure 1-2-36). When the same survey was conducted on private companies, the respondents made favorable evaluation of incorporation of universities and public research institutes, such as "universities and institutes came to participate in coordination between industry, academia and government as an organization," "research that meets the needs of the private sector is conducted more frequently," and "it became easier to conduct joint research and commissioned research."

(National universities)



(Public research institutes)

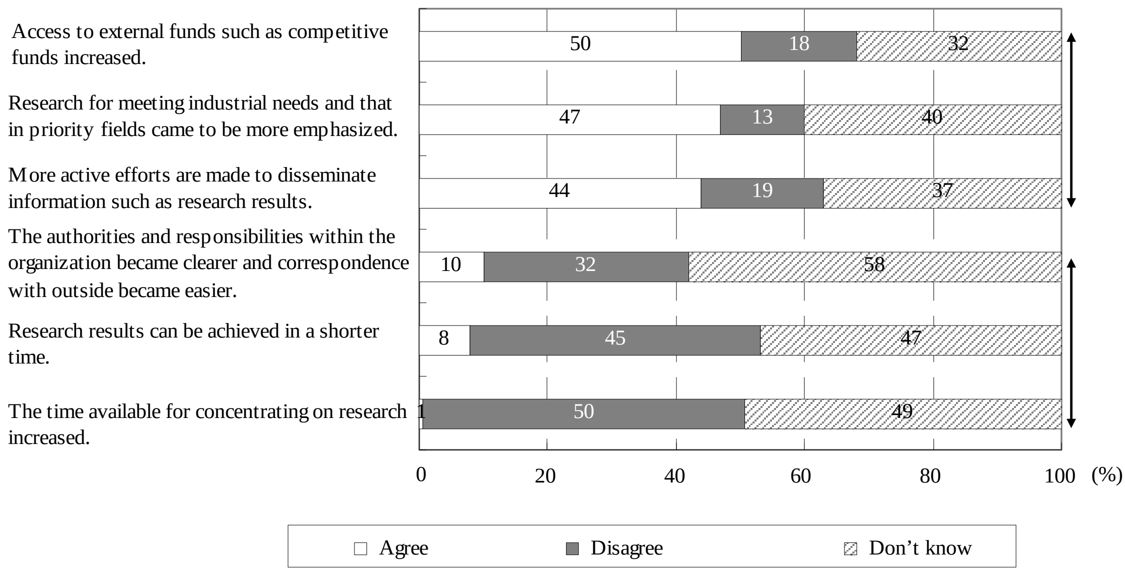


Figure 1-2-36　Changes Pertaining to Incorporation Perceived by Researchers

Source: MEXT, "Survey of the State of Japan's Research Activities"

(Achievements and challenges)

As mentioned above, various measures have been implemented based on the First and Second Science and Technology Basic Plans. In addition, there have been changes in the promoting frameworks such as the incorporation of national universities and public research institutes. As a result, considerable improvements have been made to the research environment, including more active implementation of coordination between industry, academia and government, progress in the fostering of a competitive population due to an increasein post-doctorals. As discussed in detail in the next section, the research standard is rising due to an increase in the number of influential scientific papers, and, as mentioned in 2.1, achievements and spillover effects of the measures are also appearing. At the same time, there are still challenges to be tackled. For example, Japan is still behind the United States and other countries in the area of full-fledged joint research and technology transfer among industry, academia, and government, there is still a need to improve the self-reliance of young researchers, and the efforts to secure diverse human resources including females and non-Japanese are not necessarily sufficient.

1.2.4 Level of Science and Technology in Japan

This section discusses Japan's international level of science and technology as well as its strong and weak points, while introducing the international situation surrounding science and technology and the trend of the relevant policies of other countries.

1.2.4.1 International Trend and Foreign Countries' Policies Concerning Science and Technology

(Worldwide trend toward a knowledge-based society)

In Japan, measures for promotion of science and technology have been further strengthened after the enactment of the Science and Technology Basic Law in 1995. However, due to the world's shift to being a knowledge-based society, other countries are also recognizing the importance of the role of science and technology and holding increasing expectations for contributions of science and technology.

Looking at the trend of research and development (R&D) expenditures in major countries,[5] the increase in the R&D expenditures temporarily slowed down in western countries and Japan in the first half of the 1990s, immediately after the end of the Cold War. However, in the second half of the 1990s, investment in R&D activities became active again with expenditures starting to increase rapidly first in Japan and the United States, and expenditures also turning to an increase a little later in Germany and the United King dom (Figure 1-2-37).

Furthermore, the growth in R&D expenditures and the number of researchers in China and South Korea has also been remarkable in recent years. In 2001, China became the world's third-ranking country following Japan in terms of R&D expenditures, surpassing Germany, while it also became the world's second-ranking country following the United States in terms of the number of researchers in 2000, overtaking Japan. R&D expenditures and the number of researchers in South Korea are still far from the levels in the United States and Japan, but are becoming closer to the level in the United Kingdom and France (Figure 1-2-37 and Figure 1-2-38).

In this manner, knowledge competition worldwide, including China, South Korea, and other Asian countries in addition to conventional western developed countries and Japan, is becoming more and more intense.

5 In this section, major countries refer to the United States, Germany, France, the United Kingdom, EU, China, South Korea, and Japan unless otherwise specified.

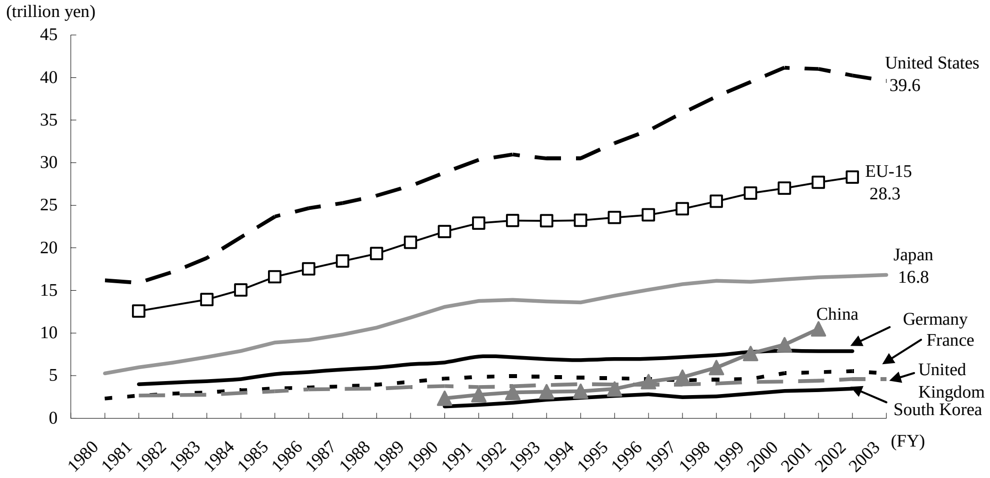


Figure 1-2-37 Total R&D Expenditures in Major Countries

Notes: 1. Values are converted in yen based on OECD's purchasing power parity rates.
2. Values for all countries include those of social sciences and humanities in order to make international comparison.
3. With regard to the values for Japan, the industries covered by the survey were expanded in fiscal 1996 and fiscal 2001.
4. Values for the United States from 2002 onward and values for France in fiscal 2003 are provisional ones.
5. Values for EU are OECD estimates.

Sources: Japan: Statistics Bureau, MIC, "Survey of Research and Development";
United States: National Science Foundation, "National Patterns of R&D Resources";
Germany: Federal Ministry of Education and Research, "Bundesbericht Forschung," "Faktenbericht Forschung";
France: "Project de Loi de Finance: Rapport Annexe sur l'Etat de la Recherche et du Development Technologique";
United Kingdom: Office for National Statistics, "Gross Domestic Expenditure on Research and Development"; however, values for 1983 and earlier are based on OECD, "Main Science and Technology Indicators"
EU-15, China, and South Korea: OECD, "Main Science and Technology Indicators"

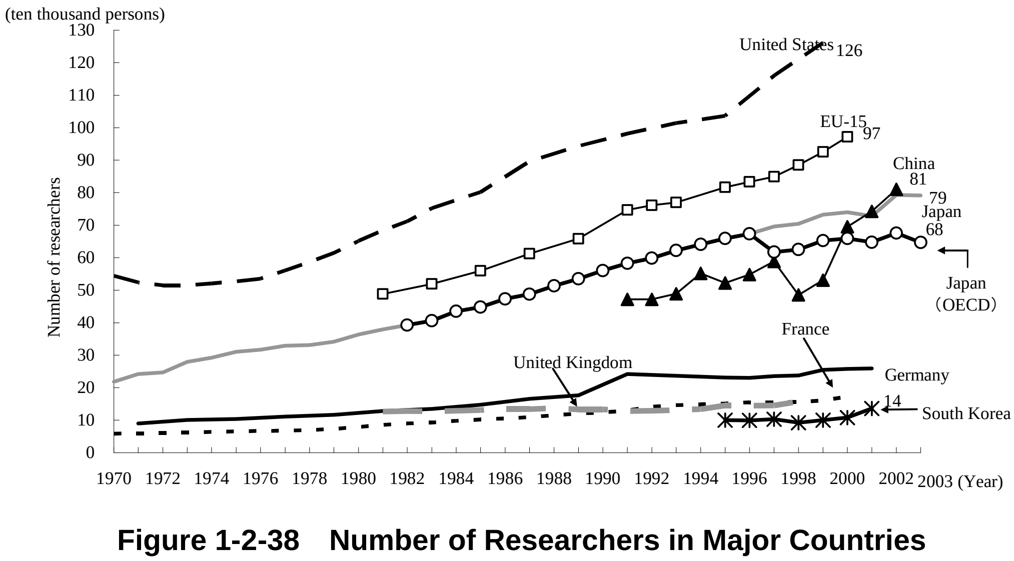


Figure 1-2-38 Number of Researchers in Major Countries

Note: Values for "Japan (OECD)" are those reported to the OECD. Full-time equivalent values (when a person working eight hours a day spends four hours in research activities, this person is counted as a 0.5 [four hours/eight hours] researcher) have been reported from 1997 onward.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report No. 88, March 2005)

(Positioning of science and technology policy)

Due to these circumstances, promotion of science and technology is being positioned as one of the government's important issues in all of the countries.

At the Meeting of the OECD Committee for Scientific and Technological Policy (CSTP) at Ministerial Level in January 2004, the ministers of the member countries highlighted the benefits that society can derive from advances in science and technology, and they reaffirmed that knowledge creation and diffusion are increasingly important drivers of innovation, sustainable economic growth, and social well-being.

The positioning of science and technology policy and efforts for individual key policy issues in the major countries are summarized in Table 1-2-39.

The table shows that scientific and technological progress is regarded as a driving force for economic growth and creation of employment in all countries. For example, in the Unite States, the awareness that investment in science and technology is the key to eternal development of the country's industry and economy and is important for national security has become widely established, as symbolized by the words "Science—The Endless Frontier" in the 1945 Bush Report, which has been the undertone of U.S. science and technology policies after World War II. In the EU, the Lisbon Strategy (2000), which is a comprehensive social and economic policy until 2010, has set targets including making the EU "the most dynamic and competitive knowledge-based economy" and measures to promote science and technology, such as creation of the European Research Area, are indicated as important measures for achieving these targets.

One of the factors underlying this situation is the worldwide awareness that the proportion of economic activities based on advanced scientific and technological knowledge is increasing in the economy of developed countries and that this tendency will become even stronger in the future; in other words, it will be the time for a knowledge-based economy in the not-so-distant future.

In reality, the amount of real value added in the high and medium-high-technology manufacturing industries is considerably increasing in developed countries including Japan, according to OECD statistics. This trend also applies to post and telecommunications industries and finance/insurance industries, which are referred to as knowledge-intensive "market" services (Figure 1-2-40).

The science and technology policies of the respective countries are not only intended for economic purposes, but are positioned as means for resolving wide-ranging social problems, such as improving the quality of people's lives, maintaining and promoting health, conserving the environment, as well as ensuring safety and security, which have particularly drawn attention in recent years.

For example, Germany implements the "FUTUR" program, which predicts the social changes and new social demands in the future and explores the science and technology required to deal with these predicted developments through dialogue among not only researchers, but also people from the industrial sector and various social and political segments. As its first step, visions including "lifelong health and vitality through prevention" and "living in a network world: individual and secure" were adopted in July 2002, and they have been put into practice as policies.

	Japan	United States	EU-25	United Kingdom
Positioning of science and technology; basic principles of science and technology policy	- Creation of wisdom - Vitality from wisdom - Sophisticated society by wisdom (Second Science and Technology Basic Plan)	- Promotion of people's health - Economic development - National security (Bush Report)	- Strengthening the scientific and technological base of industries - Strengthening - Promotion of necessary research activities for other various measures (Treaty of Nice) Creation of the European Research Area toward making the EU "the most dynamic and competitive knowledge-based economy" (Lisbon Strategy)	- Creation of wealth and improvement of productivity - Improvement of people's health, environment, and quality of living (Science Budget 2003-2004 to 2005-2006)
Basic law; basic plan	- Science and Technology Basic Law (1995) - Second Science and Technology Basic Plan (FY 2001-2005)	None	Sixth Framework Program (2002-2006)	Science and Innovation Investment Framework (2004-2014)
Quantitative targets concerning amount of R&D investment	Total government investment in R&D during the Basic Plan period: 24 trillion yen[*1]	- Doubling the budget for the National Institutes of Health (NIH) (FY 1998-FY 2003; already achieved) - Doubling the budget for the National Science Foundation (NSF) (FY 2002-FY 2007) - Doubling the budget for the National Nanotechnology Initiative (NNI) (FY 2005-FY 2009)	Increasing the R&D investment in entire EU to 3% of GDP (of which 2% will be private investment) by 2010	- Increasing the government research budget by an annual rate of 5.7% until FY 2007 (Office of Science and Technology and Department of Education and Employment) - Increasing the research budget for the whole country to 2.5% of the GDP by FY 2014 - Allocating about 650 million pounds to the priority fields from FY 2001 to FY 2005
Government-financed R&D expenditure proportion to GDP[*2]	3.4 trillion yen (0.68%) (FY2003)	10.2 trillion yen (0.81%) (FY2003)	6.7 trillion yen (0.67%) (FY2001)	1.2 trillion yen (0.59%) (FY2003)
Priority fields	Prioritization of R&D on national/social subjects (1) Life sciences (2) Information and telecommunications (3) Environmental sciences (4) Nanotechnology and materials science/technology (5) Energy (6) Manufacturing technology (7) Infrastructure (8) Frontier	(1) National security (2) Networks and information technology (3) Nanotechnology (4) Environment and energy (5) Life sciences	(1) Life sciences (2) Information society technology (3) Nanotechnlogy and nanoscience (4) Aviation and space (5) Food quality and safety (6) Sustainable development (7) Citizens and governance	(1) e-science (2) Life sciences such as genome (3) Basic technologies (nanotechnology, etc.) (4) Stem cell (5) Sustainable energy economy (6) Agricultural economy and land use (revitalization of rural areas; measures against animal diseases; food safety, etc.)
Distinctive policy or trend		Country with largest number of science and technology human resources in the world; dependence on inflow of human resources and a sense of crisis about the future	Prevention of brain drain and calling back human resources; improvement of mobility within the region (Marie Curie Action Program)	Reform of the dual funding system

	Germany	France	China	South Korea
Positioning of science and technology; basic principles of science and technology policy	Making Germany strong - economically, socially and ecologically (Aims and Tasks of the Federal Ministry of Education and Research)	- Competitive power; driving force for growth and employment - Resolution of social problems - One of the components of culture in a broad sense (Annexes to Evaluation des Voies et Moyens FY 2005)	Science and technology is the chief force of productivity (Deng Xiaoping's slogan)	Achievement of economic growth and a welfare society (Science and Technology Basic Plan)
Basic law; basic plan	None	Formulation of research basic plan and law currently under consideration	- Tenth Five-Year Plan - National Long- and Medium-Term Plan for Science and Technology Development (under formulation)	- Science and Technology Basic Law (2001) - The Long-term Vision for Science and Technology Development toward 2025 (1999) - Science and Technology Basic Plan (2002-2006)
Quantitative targets concerning amount of R&D investment	- Increasing R&D investment to 3% of GDP (of which 2% will be private investment) by 2010 - Increasing the budget for research institutes at an annual rate of 3% for a while	Increasing R&D investment to 3% of GDP (of which 2% will be private investment) by 2010	- Increasing R&D investment in the whole country to 1.5% of GDP by 2005	- Increasing R&D investment in the whole country to 80 billion dollars by 2025 - Increasing R&D investment in the whole country to 2.4 trillion won by 2025 - Making the growth in government R&D budget during the Science and Technology Basic Plan period exceed the growth rate of the overall budget
Government-financed R&D expenditure proportion to GDP*2	2.0 trillion yen (0.80%) (FY2002)	1.9 trillion yen (0.92%) (FY2003)	0.4 trillion yen (0.33%) (FY2000)	0.4 trillion yen (0.63%) (FY2003)
Priority fields	(1) Information and telecommunications (2) Biotechnology (3) Medical care and health (4) Environmentally-friendly technologies for sustainable development (5) Materials (6) Nanotechnology (7) Energy (8) Transportation and mobility (9) Aviation and space	- Life sciences - Communication and information science and technology - Human/social sciences - Energy - Transport and living environment - Space field - Global environmental science	- 863 Plan (high-tech) Biotechnology, space, information, laser, automation, energy, advanced materials, marine - 973 Plan (basic research) Genome, information science, nanoscience, environment, earth science	6T - IT (information technology) - BT (biotechnology) - NT (nanotechnology) - ST (spatial technology) - ET (environmental technology) - CT (cultural technology)
Distinctive policy or trend	- Cluster development policy through BioRegio, which developed the largest number of biotech ventures in Europe - FUTUR program, which provides society-oriented science and technology forecasts	Invitation of prominent researchers working overseas (Attractiveness of French science: "Excellent Teaching " program)	- Powerful policy to call back overseas human resources (Haigui [sea turtle] policy) - Establishment of national high-tech parks including Zhongguancun (Taimatsu plan)	Special education for gifted children at science schools for gifted children, etc.

Figure 1-2-39 Policy Trend in Major Countries

Notes: 1. Table assumes the proportion of government R&D investment to GDP during the Basic Plan period to be 1% and GDP nominal growth rate during the same period to be 3.5%.
2. Government-financed R&D expenditures and their proportion to GDP include those of local governments. Government-financed R&D expenditures were calculated in Japanese yen based on IMF rates.

Source: Produced by MEXT based on the National Institute of Science and Technology Policy, "Comparative Analysis on Science and Technology Policies and Their Achievements between Major Countries" (NISTEP REPORT, No. 91, March 2005), OECD, "Science, Technology and Industry Outlook 2004," and other materials.

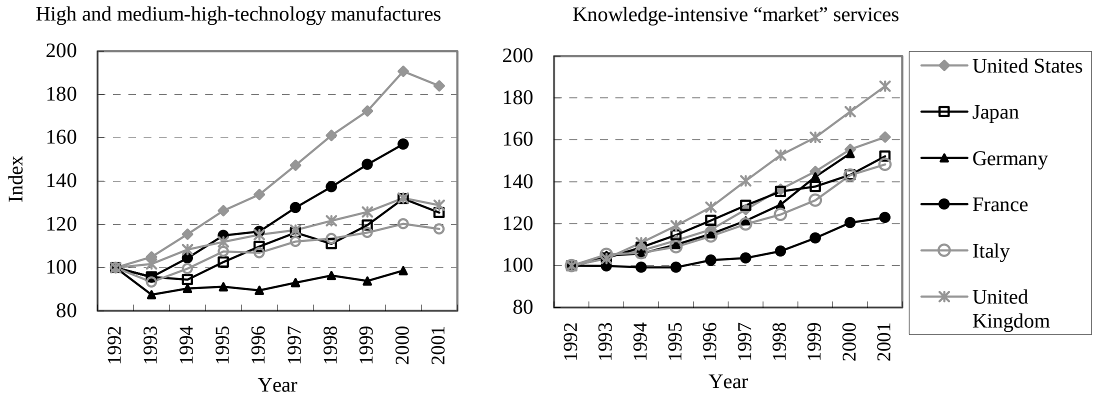


Figure 1-2-40 Real Value Added in High and Medium-High-Technology Manufactures and in Knowledge-Intensive “Market” Services (value in 1992 is indexed at 100)

Notes: 1. High-technology manufactures refer to the following five manufacturing industries in which the proportion of R&D cost in the manufacturing cost is high: aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, TV, and communications equipment; and medical, precision, and optical instruments.
2. Medium-high-technology manufactures refer to the following five manufacturing industries in which the proportion of R&D cost in the manufacturing cost is high next to such proportion in the high-technology industry: electrical machinery and apparatus; motor vehicles, trailers, and semi-trailers; chemicals excluding pharmaceuticals; railroad equipment and transport equipment; and machinery and equipment.
3. Knowledge-intensive “market” services refers to the following three service industries: post and telecommunications; finance and insurance; and business services (excluding real estate).

Source: OECD, “Science, Technology and Industry Scoreboard 2003”

(Expansion and intensification of R&D investment)

In light of the importance of science and technology, many developed countries including Japan make efforts to expand the R&D investment made by the whole nation (public and private combined) or made by the government, by setting quantitative targets.

The positioning and the compulsory nature of the targets are not necessarily the same in the respective countries. However, the EU has set a numerical target to raise the percentage of public and private investment in R&D within the region to GDP from the 1.9% in 2002 to 3% (of which about one-third is government investment) by 2010 as part of the Lisbon Strategy. In line with this, Germany, France, and the United Kingdom, which are EU members, have all set a quantitative investment target for the entire country or for the government, with an effort to expand the investment. Among major countries, the United States has no investment target for overall R&D, but has set a target for the federal government’s R&D budget for specific fields and organizations, such as nanotechnology and the National Science Foundation.

At the same time, the countries make intensive investment in scientific and technological fields for which large effects can be expected for future economic growth, employment, and social benefits. Although the extent of intensification varies among countries, the priority fields of the respective countries have much in common, and not only Japan, but all the major countries categorize life sciences, information and telecommunications, and environment as priority fields. In addition, nanotechnology, energy, and space development are also specified as priority fields in most of the countries.

Some countries also make efforts to take strategic and long-term measures to build cutting-edge research facilities that engage in development of specific science and technology fields that are important for the country, apart from setting such priority fields. For example, in 2003, the U.S. Department of Energy selected large science and technology-related facilities that should be established or improved with priority over the next 20 years. In the United Kingdom also, the Office of Science and Technology formulated a strategic roadmap for development of large research facilities that cannot be established by a single organization in 2001 (revised in 2003).

(Developing and securing scientific and technological human resources)

It is predicted that the demand for scientific and technological human resources that engage in creation, diffusion, and use of knowledge will increase in line with the further shift to being a knowledge-based society. Meanwhile, a large number of scientific and technological human resources in the baby-boomer generation are expected to retire in Japan and major western countries. In consideration of these factors, the developing and securing of scientific and technological human resources has become a key, common, urgent issue for countries.

Therefore, with respect to development of domestic human resources, all countries are promoting activities for enhancing people's understanding of science and technology, reviewing science education curriculums, and improving the training programs for instructors in response to the declining interests of children and young people in science and technology. In addition, the countries are providing financial aid to young researchers including doctoral students and postdoctorals and encouraging the activities of female researchers. Also, from the viewpoint of using overseas human resources, countries make efforts to actively support the researchers of their own country who are working overseas and good overseas researchers by accepting them in their country.

(Promoting coordination between industry, academia and government)

Since promotion of economic use of scientific and technological achievements is being increasingly emphasized, it has become an important task to establish a system of intellectual cycle that links private companies, universities, and public research institutes. All the countries take measures to promote coordination between industry, academia and government. Although the details vary depending on the situation of the respective countries, they implement measures to have research achievements, which are mainly made by universities, commercialized by venture companies, etc., as well as to establish incubators and form networks or clusters to promote such commercialization.

Notable examples include the "BioRegio" in Germany, which succeeded in forming the sole bio-clusters in Europe by adopting a "contest for development of clusters" where regions compete for government funds, and China's "Torch Plan" for building high-tech parks in 53 locations nationwide including Zhongguancun in Beijing, which is referred to as the Silicon Valley of China.

[Column 17]

Intensifying International Competition for Procurement of Human Resources

In the race to gather the best human resources from around the world, the United States has recently been the clear winner. Eminent scientists from all over the world have been gathered in the United States. As of 2001, for example, at least 33% of doctorates in natural science, as well as at least 56% of doctorates in engineering presented in the United States are held by non-American citizens. Additionally, at least 28% of science/engineering doctors hired by a college or university in the United States are born outside the country. A total of 38% of doctors in science or engineering engaged in their fields except college/university instructors in the United States are born outside the country, too.

To compete with the United States, other countries have also taken various policies to promote acceptance of human resources from foreign countries.

The European Union, for attaining the goal of achieving R&D investment equivalent to 3% of GDP, is in its present state lacking 700,000 researchers, according to a trial calculation. To address this lack, the EU has been working on calling back its researchers from other countries such as the United States, while improving the mobility of human resources inside the EU. As part of the Marie Curie Action under the Sixth Framework Programme, for example, the subsidy system is enforced for eminent academics outside the EU to invite or call them back to EU member nations. The grant is given to researchers in and/or from a foreign country such as the United States, when they work on in a facility inside the EU. Furthermore, there is a grant system for researchers who are from an EU nation and working in another EU nation.

China has the next-most researchers in the world after the United States (the number of researchers in China was approximately 810,000 in 2002). The Chinese government set a target of increasing the number of scientists and engineers to 900,000 by 2005. To solve the difficult problem whereby many Chinese students studying abroad do not return to China, the government is carrying out callback policies for talented Chinese scientists working overseas. Based on the “100 People Incentive Project,” for example, the Chinese government gives priority to talented young Chinese scientists working outside the country when it comes to giving grants. The researchers who return to China, who are called “turtle scientists,” have been playing a major role in R&D in China.

Corresponding to the intensifying competition for procurement of human resources all over the world, the U.S. government has a sense of crisis about gathering talented people in the future. Current U.S. human resources issues include immoderate dependence on talented people from other countries, as well as the forecast that citizens born in the United States and who graduate from science and technology departments will decrease. In the National Science Board, discussions have been made to examine the measures that the federal government should take for the training and procurement of talented people in the field of science and technology.

1.2.4.2 Level of Science and Technology in Japan

(Research expenditures and number of researchers)

Japan’s research expenditures have been on an increasing trend throughout the First and Second Basic Plan periods, ranking second in the world after the United States, and the percentage of research expenditures to gross domestic product (GDP) is the highest among the major countries. The government-financed R&D expenditures in major western countries had been declining for a long time since the 1980s, but began to rise again from around 2000. Meanwhile, those of Japan had been increasing since 1990, but have stayed on the same level for the past several years (Figure 1-2-41).

The growth in the number of researchers slowed down slightly in the Second Basic Plan period, but Japan ranks third among the major countries following the United States and China, and ranks highest among the major countries in terms of the number of researchers per 10,000 citizens.

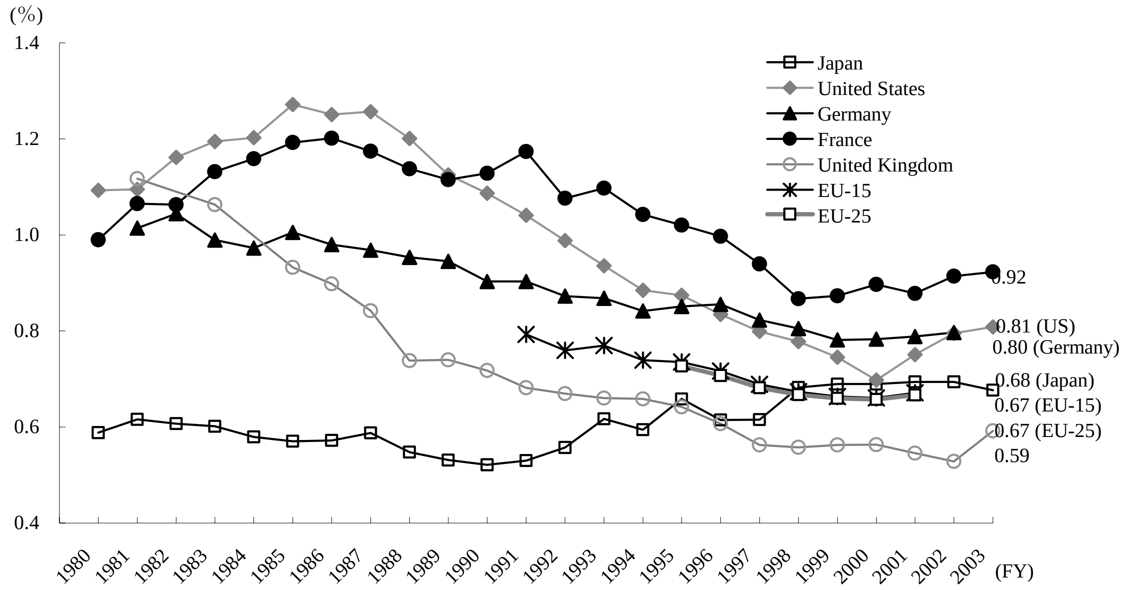


Figure 1-2-41 Trends in the Proportion of Government-Financed R&D Expenditures to GDP in Major Countries

Notes: 1. Values for all countries include those of social sciences and humanities in order to make international comparison.
2. With regard to the values for Japan, the industries covered by the survey were expanded in fiscal 1996 and fiscal 2001.
3. Values for the United States Fiscal 2003 data for Finance is provisional from 2002 onward are provisional ones.
4. Fiscal 2003 values for France are provisional ones.

Sources: Japan: Statistics Bureau, Ministry of Internal Affairs and Communication, "Survey of Research and Development"
United States: National Science Foundation, "National Patterns of R&D Resources"
Germany: Federal Ministry of Education and Research, "Bundesbericht Forschung," "Faktenbericht Forschung"
France:"Project de Loi de Finance: Rapport annexe sur I'Etat de la Recherche et du Developpment Technologique"
United Kingdom: Office for National Statistics, "Gross Domestic Expenditure on Research and Development"; however, values for 1983 and earlier are based on OECD, "Main Science and Technology Indicators"
EU: Eurostat Website databases; OECD, "Main Science and Technology Indicators"

(Scientific papers)

During the First and Second Basic Plan periods, the number of Japanese scientific papers and the frequency of their citation have steadily increased their shares (Figure 1-2-42). Although there are still large gaps with the United States and EU-15, the gap with the United States has narrowed. After the beginning of the First Basic Plan period, larger growth was observed for the share in the frequency of citation than for the share in the number of scientific papers. In particular, Japan greatly increased its share in the "top 1%" of the most frequently cited scientific papers (Figure 1-2-43), indicating an improvement in the quality of scientific papers.

Looking at the number of scientific papers by sector, the university sector accounts for the largest proportion in all countries, but the situation in Japan is characteristic in that the proportion of the industrial sector is relatively high. From 1991 to 2001, the number of scientific papers by the university sector and government research institutes increased significantly in Japan, while that by the industrial sector remained at the same level (Figure 1-2-44)

In China and South Korea, the number of scientific papers has been rapidly increasing. Although there are still gaps with Japan in terms of the absolute number of scientific papers, China ranks sixth and South Korea ranks highest in the world in terms of the increase rate.

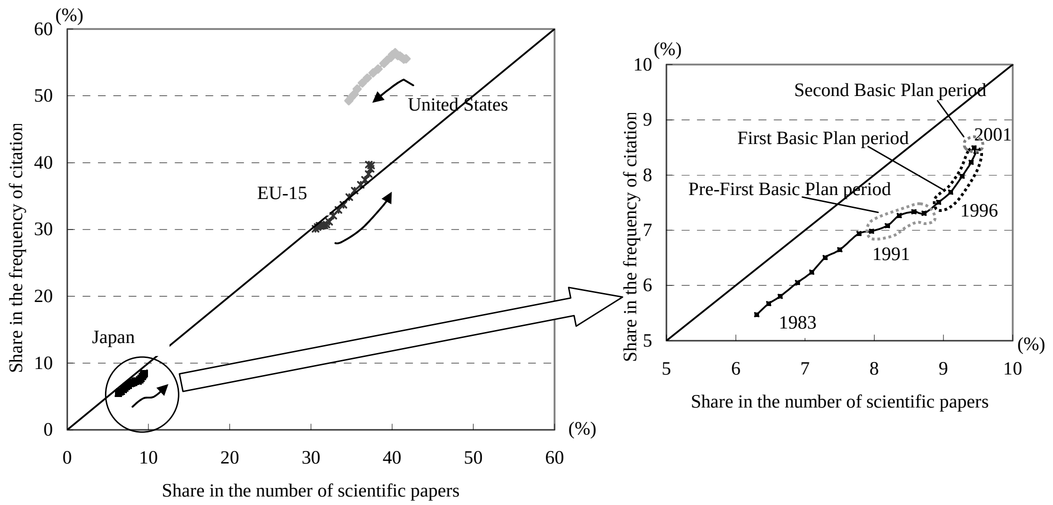


Figure 1-2-42 Shares of Japan, the United States, and EU-15 in the Number of Scientific Papers and the Frequency of Citation

Note: Value for each year is calculated based on five-year duplicated data (number of scientific papers: aggregate sum of the number of scientific papers published during five years; frequency of citation: aggregate sum of the number of times the scientific papers published during five years have been cited in another scientific paper during the same five years). The figure indicates the middle year of such five years; e.g., "1983" for a value based on five-year duplicated data for 1981-1985.

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the Science and Technology Basic Plans in Japan" (NISTEP REPORT, No. 83, March 2005)

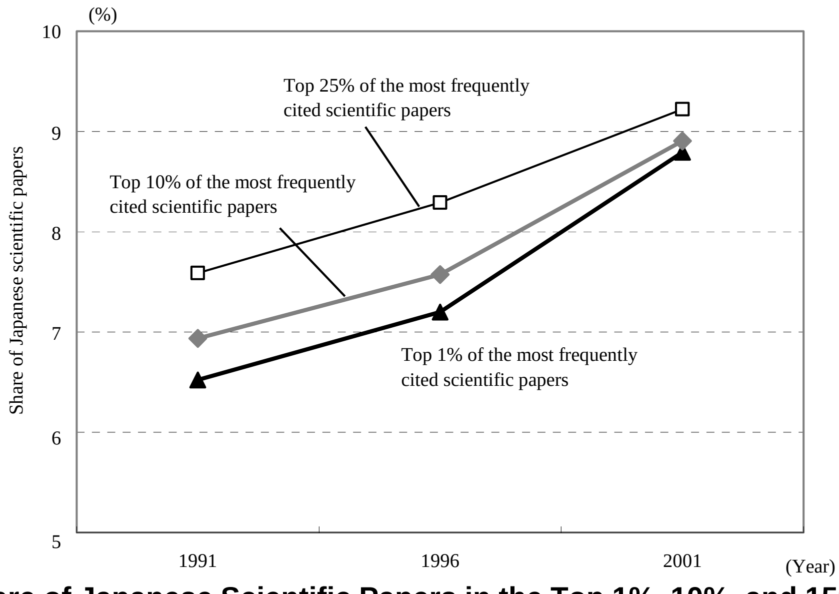


Figure 1-2-43 Share of Japanese Scientific Papers in the Top 1%, 10%, and 15% of the Most Frequently Cited Scientific Papers

Notes: 1. Frequency of citation is a value that has standardized the number of times a scientific paper was cited according to the field and the year of publication.

2. Share of Japanese scientific papers is the proportion of scientific papers in which at least one Japanese organization has participated.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

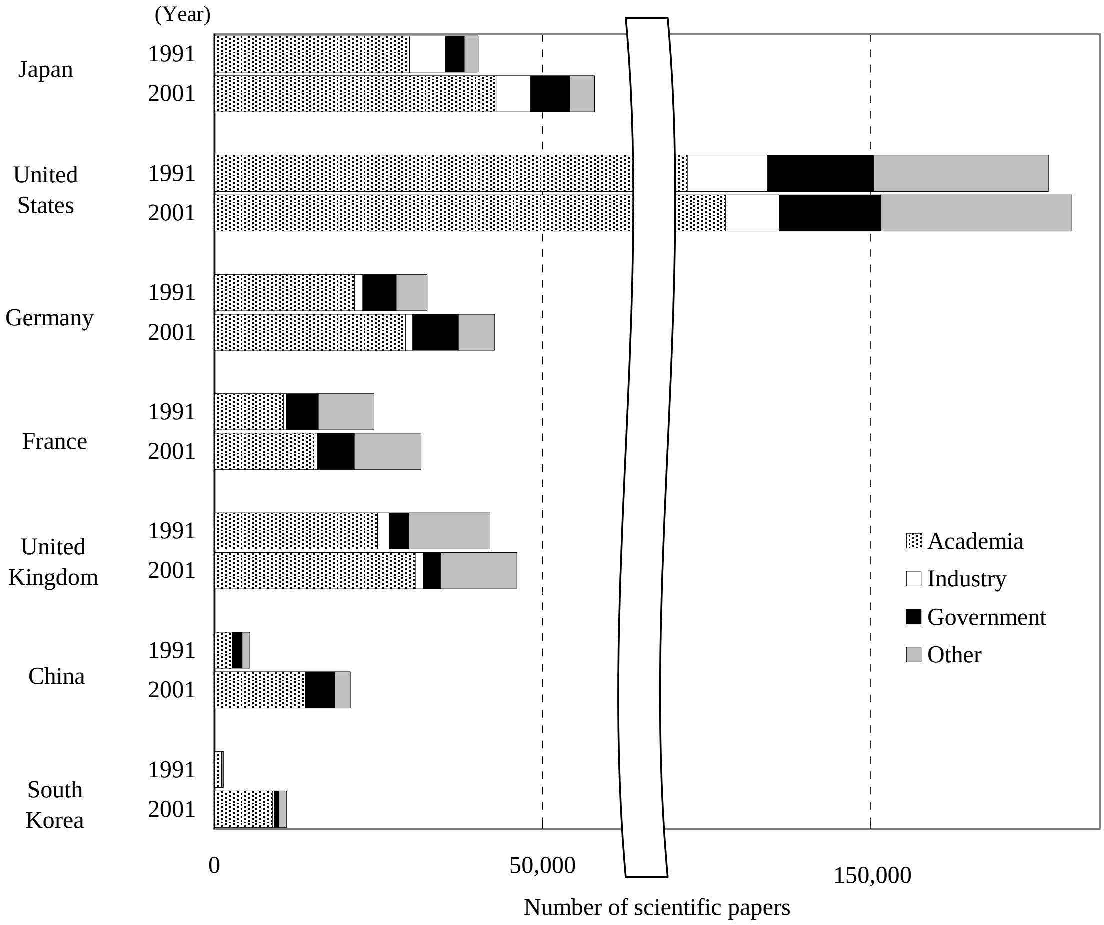


Figure 1-2-44 Number of Scientific Papers in Major Countries by Sector

Note: A co-authored paper (co-authored between different countries or co-authored between sectors) was counted by a fractional number.
Source: Produced by MEXT based on NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

(Productivity of scientific papers)

In this manner, the number of scientific papers has been steadily increasing in Japan in line with the increase in the resource input for research, such as R&D expenditures and the number of researchers. One way to examine research efficiency would be to verify the ratio of resource input to one type of output—the number of scientific papers—or in other words, the productivity of scientific papers. Considering that the productivity of scientific papers differs considerably by sector and that the systems and the statistical methods differ by country, the NISTEP compared the productivity of scientific papers at universities, which can be defined in a relatively similar manner in Japan and the United States, as follows.

Firstly, in calculating the productivity of scientific papers per R&D expenditures, there was a difference between Japanese and U.S. universities regarding the definition of research expenditures, such as treatment of the personnel cost for instructors. Thus, the productivity was estimated after adjusting the R&D expenditures in Japan in two ways to make them approach the values under the U.S. definition (Japan [U.S.-based estimation (1)] and Japan [U.S.-based estimation (2)] in Figure 1-2-45). While Japan's productivity directly obtained from the statistical values (Japan [statistical values] in Figure 1-2-45) was considerably lower than that of the United States, the values based on these estimates stayed at a certain level when the U.S. values were declining in recent years, and they were close to the U.S. values.

As for the productivity of scientific papers per researcher, the definition of researchers at universities differed between Japan and the United States, so a trial calculation was made by using the number of faculty members at universities of natural science as data that can be compared under the same conditions as much as possible. As a result, the productivity of scientific papers per faculty member at universities of natural science in Japan has continued to increase in recent years, and the gap with the United States has been narrowing to an extent that such productivity is slightly lower in Japan than in the United States (Figure 1-2-46).

In this way, there are analysis results indicating that the productivity in terms of the number of scientific papers in Japan may reach the same level as that of the United States, at least in estimate.

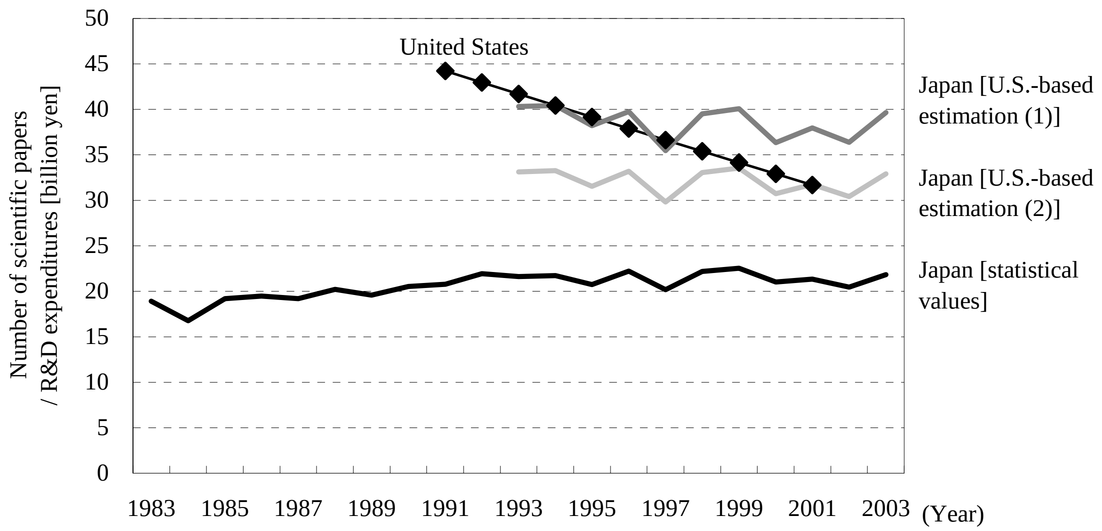


Figure 1-2-45 Japan-U.S. Comparison of the Number of Scientific Papers per R&D Expenditures of Universities (Natural Science)

Notes: 1. R&D expenditures of Japanese universities are turned into real values by using the R&D expenditure deflator (for natural science; universities) and those for U.S. universities by using the GDP deflator.
2. Period from the spending of R&D expenditures until publication of a scientific paper is deemed to be two years for both Japan and the United States (e.g., the value for "2001" on the graph was calculated based on the R&D expenditures in 1999 and the number of scientific papers in 2001).
3. In Japan [U.S.-based estimation (1)], the personnel expenditures for researchers at universities who only engage in research were first estimated, and the R&D expenditures were calculated by excluding the personnel expenditures for the other personnel (fixed personnel expenditures), in order to make the values closer to the definition of R&D expenditures in the United States. In Japan [U.S.-based estimation (2)], considering the possibility that the expenses for U.S. R&D projects may include personnel expenditures for instructors for a span of about three months, a quarter of the fixed personnel expenditures was added to the R&D expenditures of Japan [U.S.-based estimation (1)].

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

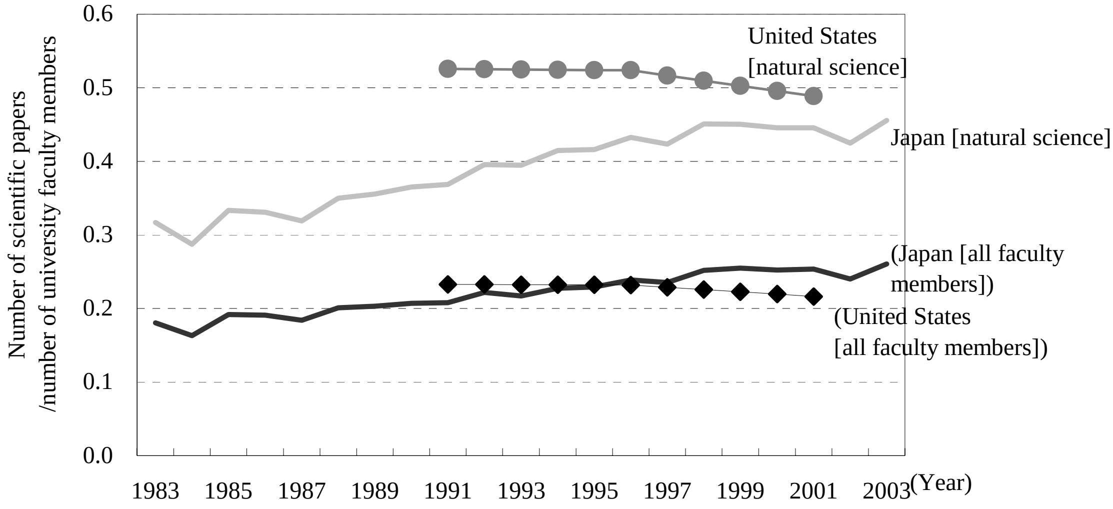


Figure 1-2-46 Japan-U.S. Comparison of the Number of Scientific Papers per University Faculty Member

Notes: 1. Number of university faculty members is based on head-count both in Japan and the United States.
2. Period from the spending of R&D expenditures until publication of a scientific paper is deemed to be two years for both Japan and the United States (e.g., the value for "2001" on the graph was calculated based on the R&D expenditures in 1999 and the number of scientific papers in 2001).
3. Since data on the proportion of university faculty members in natural science to all university faculty members for each year could not be obtained, the values for "United States [natural science]" were obtained by applying the proportion in 1992 to the other years as well.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

(Patents)

Figure 1-2-47 shows the shares of countries in terms of the number of patent applications filed in the world. Since a patent application filed with multiple countries is counted in an overlapped manner, the graph is likely to indicate how much the patenting of technologies is being promoted in addition to the number of inventions. Although the number of patent applications has increased for Japan, its share has declined from slightly less than 30% in 1991 to a little over 10% in 2001. On the other hand, the United States and countries other than the major western countries such as China and South Korea are greatly increasing their shares (Figure 1-2-48).

Meanwhile, Figure 1-2-49 shows the relative citation impact of U.S. patents owned by patentees of the respective countries. According to this, the relative citation impact of U.S. patents owned by Japanese patentees has increased in recent years, so the quality gap with U.S. patents is narrowing.

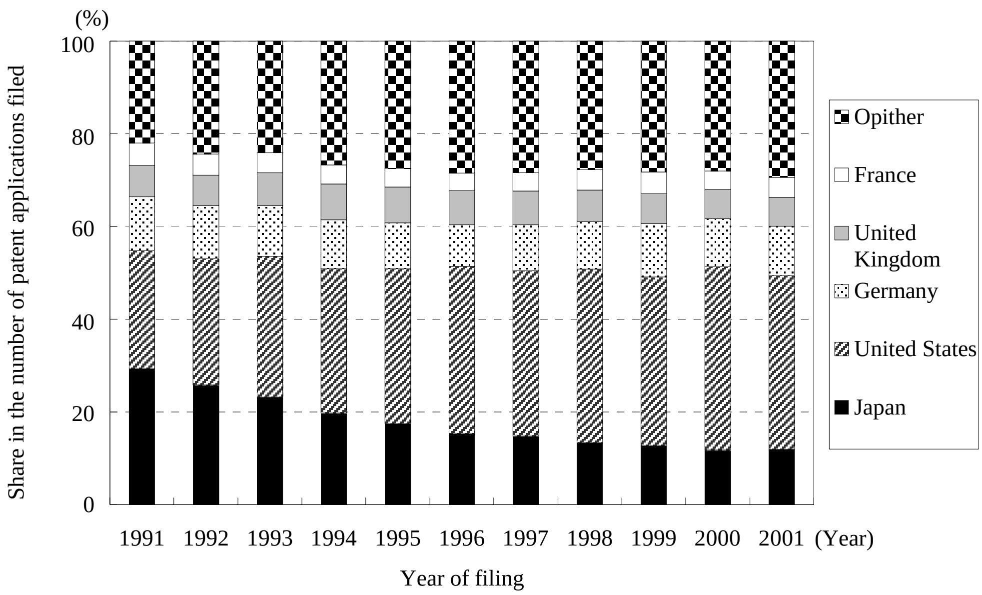


Figure 1-2-47 Shares of Major Countries in the Number of Patent Applications Filed in the World

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

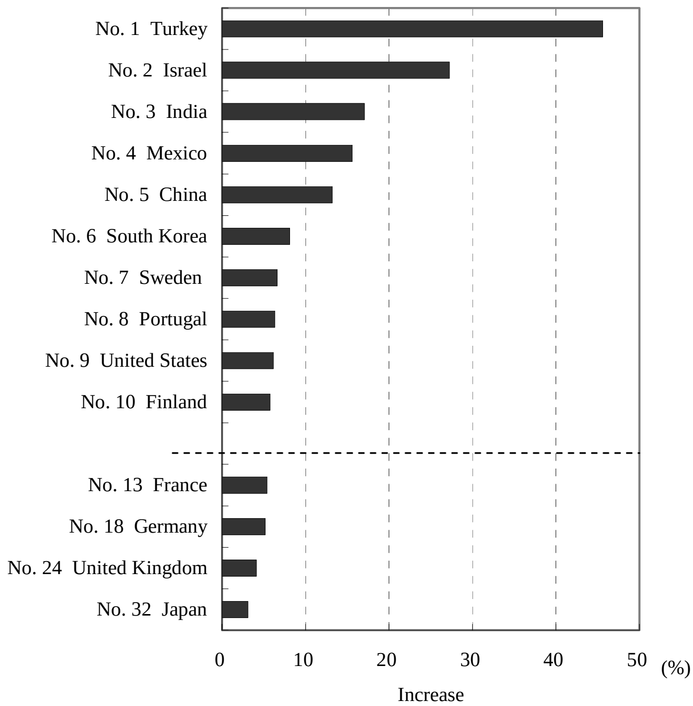


Figure 1-2-48 Increase in the Number of Patent Applications Filed in the World by Applicants of the Respective Countries (ranking of the rate of increase from 1994 to 2001)

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

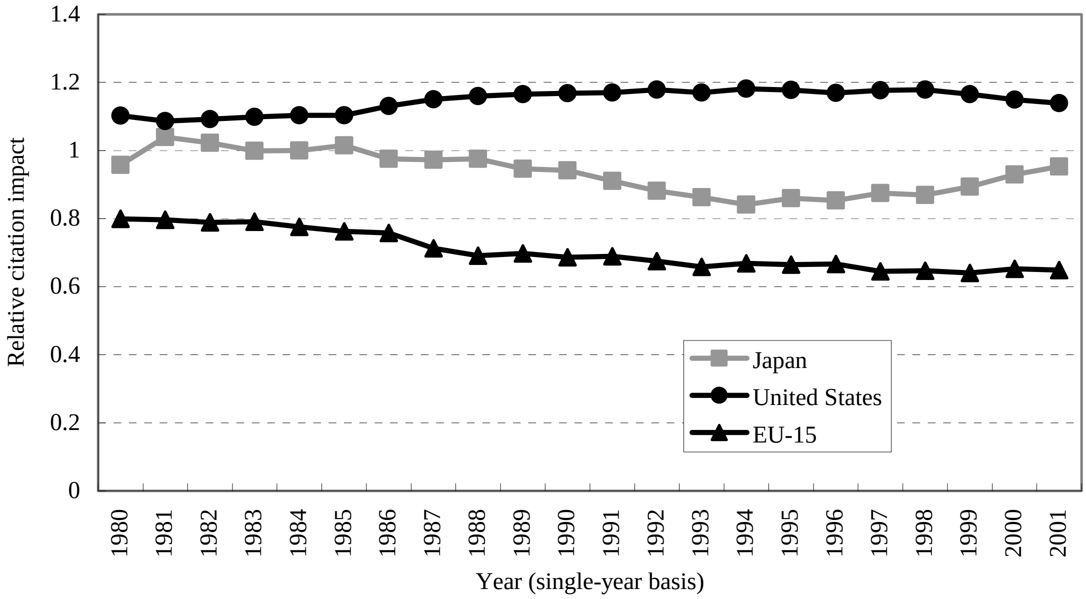


Figure 1-2-49 Relative Citation Impact of U.S. Patents Owned by Japanese, U.S.,and EU-15 Patentees

Source: NISTEP, “Study for Evaluating the Achievements of the S&T Basic Plans in Japan” (NISTEP REPORT No. 88, March 2005)

(Technology transfer from universities)

Technology transfer from Japanese universities to industry has made progress to a certain extent in terms of patenting and licensing, but it has yet to produce revenues such as royalties. Compared with the United States and the United Kingdom where institutional infrastructures were established 20 years earlier, real achievements have yet to be made based on organizational partnerships in Japan, where use of intellectual property had mainly relied on individual initiatives (Figure 1-2-50).

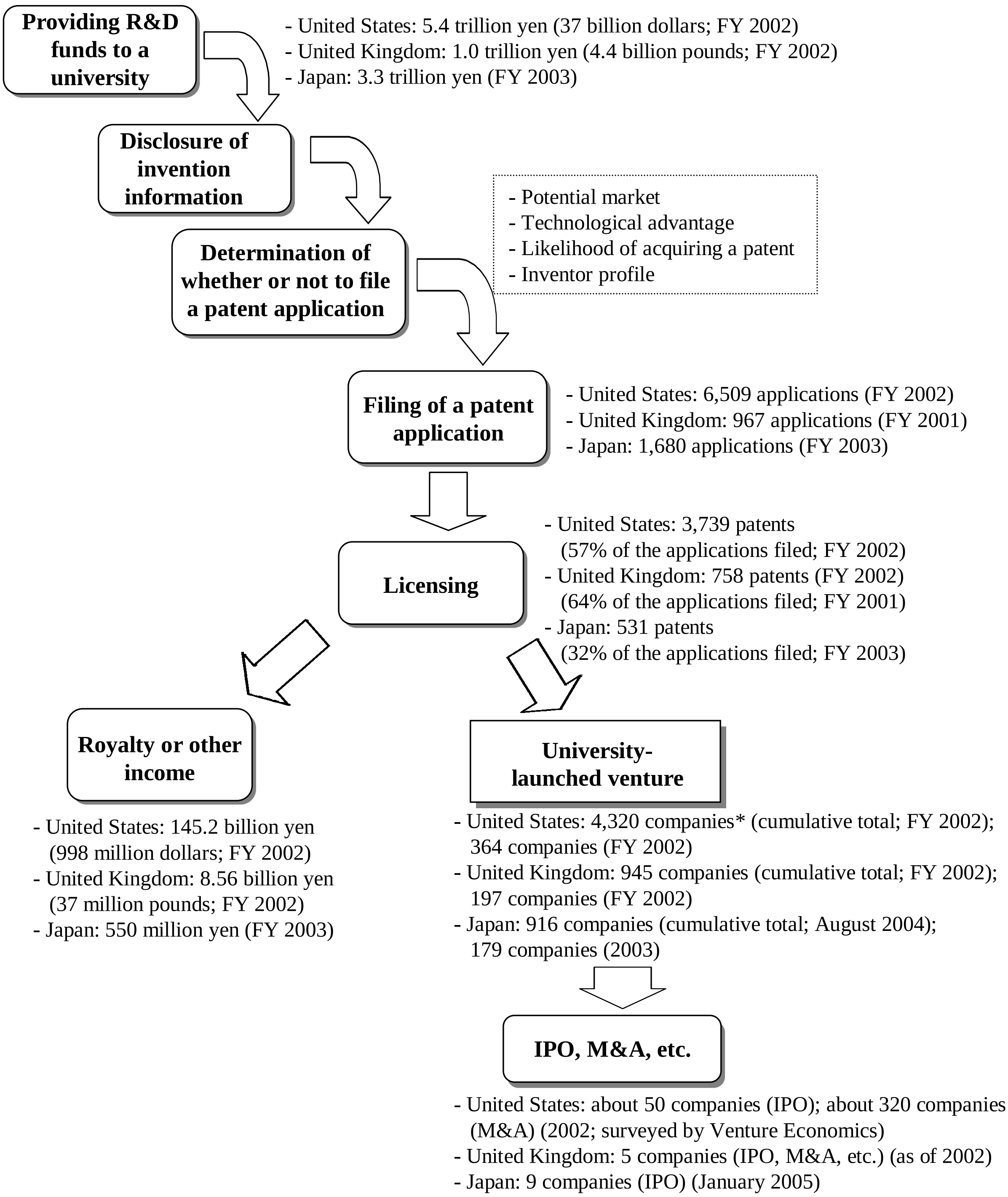


Figure 1-2-50 International Comparison of Coordination Between Industry and Academia

Note: "IPO, M&A, etc." indicates the number of university-launched ventures that were made subject to public offering of stock, merger, acquisition, business alliance, or the like.

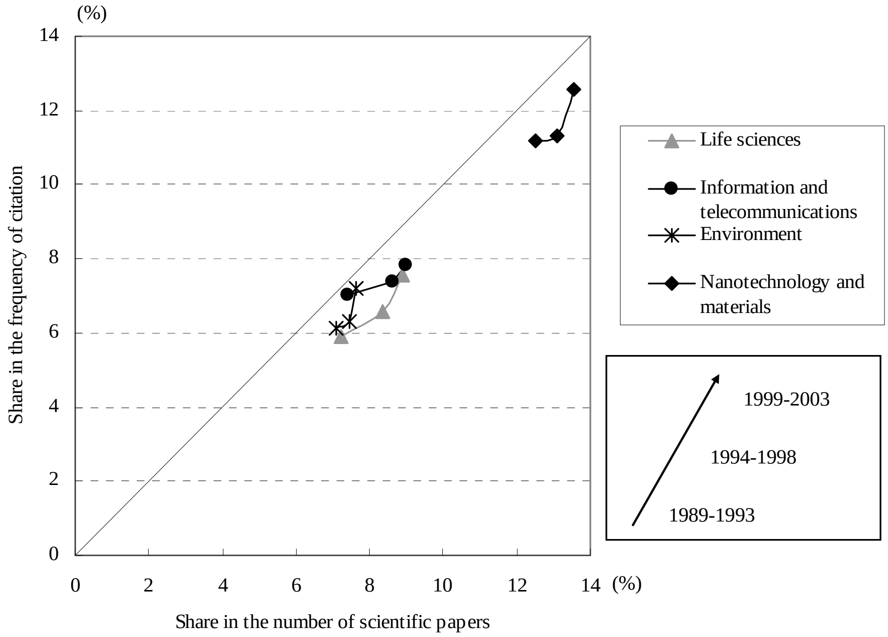
Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

(Priority fields)

Figure 1-2-51 shows Japan's shares in the num ber of scientific papers and the frequency of their citation in the four priority fields under the Second Basic Plan (life sciences, information and telecommunications, environment, nanotechnology/materials) and four other fields (energy, manufacturing technology, social infrastructure, and frontier).

The graphs indicate that both the shares in the number of scientific papers and the frequency of their citation are steadily increasing in all fields. Japan is relatively strong in the fields of nanotechnology/materials, manufacturing technology, and energy, while it is relatively weak in the fields of frontier and social infrastructure compared to the other fields. The fields in which the share in the frequency of citation increased more than the share in the number of scientific papers, or in other words, the fields in which quality increased remarkably from the 1994-1998 period to the 1999-2003 period were nanotechnology/materials, manufacturing technology, energy, environment, and social infrastructure.

According to patent-related indices aggregated by NISTEP, the share of Japanese applicants in the number of U.S. patents registered in recent years has been relatively high for nanotechnology/materials and manufacturing technology, and low in social infrastructure and life sciences, though the trend of increase varies by field. Meanwhile, the relative citation impact was high for environment, social infrastructure, frontier, and energy compared to the other fields, and low for information and telecommunications, and life sciences.



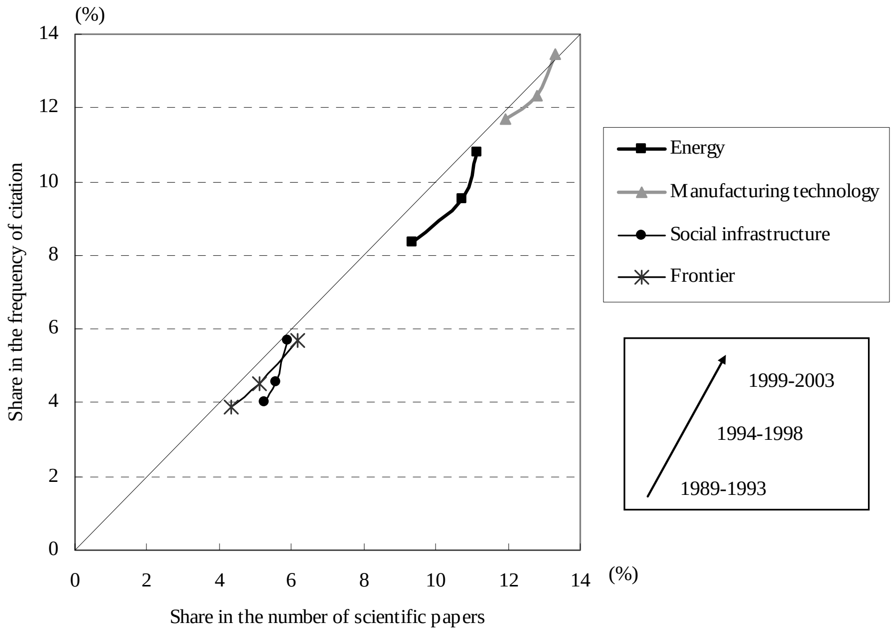


Figure 1-2-51 Japan's Shares in the Number of Scientific Papers and Frequencyof Their Citation by Field (1989-2003)

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

(Opinion survey)

According to the opinion survey conducted by MEXT targeting researchers in industry, academia, and government, researchers considered the research level in Japan to be generally behind compared to that in the United States and Europe, but was ahead of that in China, South Korea, and other Asian countries. They thought that the gap with the front-runner, the United States, had been narrowing, but the gap with Europe had widened, and Asia was closing in from behind. This trend coincides with other trends, such as the changes in the share in the number of scientific papers.

Furthermore, researchers considered that Japan had a relatively higher advantage in applied/development research rather than basic research (Figure 1-2-52).

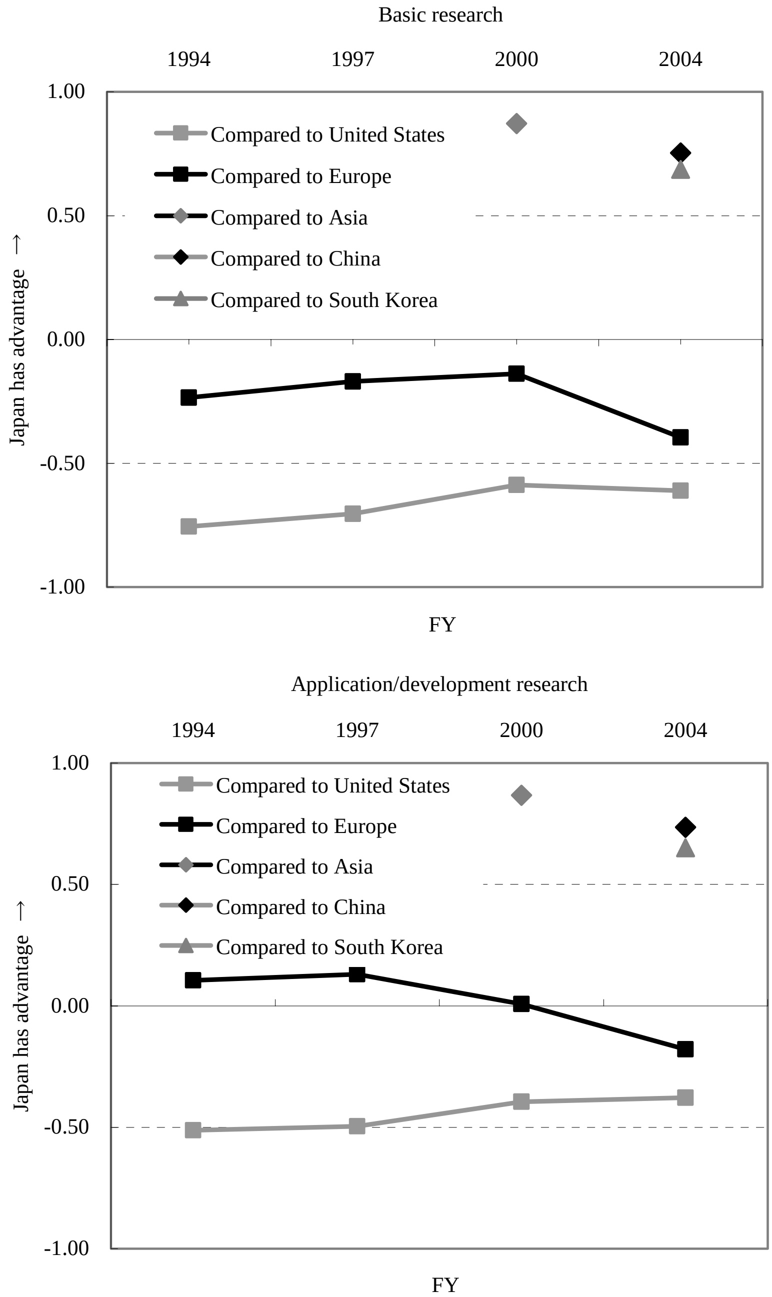


Figure 1-2-52 Research Level of Japan Compared to Other Countries

Note: Values were derived by counting the respondent's answer as +1 if he/she thought that Japan has advantage over the country/region, 0 if he/she thought that Japan is at the same level as the country/region, and –1 if he/she thought that the country/region has advantage over Japan, then totaling these scores and dividing it by the number of respondents.

Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

1.2.4.3 Japan's Characteristics, Strengths, and Weaknesses

(Japan's strengths and weaknesses viewed from its history of accepting modern science and technology)

The history of modern science and technology in Japan started in full-scale in around the Meiji Restoration by accepting science and technology from the West. The efficient introduction of science and technology led by the Meiji government was one of the major reasons that Japan could achieve modernization ahead of other non-western countries. This success is said to have owed to the availability of social infrastructure for introducing science and technology. For example, people's average educational level was high, such as a high literacy rate, and the manufacturing technology in traditional crafts was highly advanced already in the Edo period. Science and technology was also actively imported from the United States and other countries in the process of making economic recovery after being defeated in World War II. Then, the imported science and technology, in combination with Japan's excellent quality control system and diligent workforce, contributed to developing such industries as iron and steel, home electrical appliances, and automobiles, and lead Japan to high economic growth.

In this manner, Japan's attitude toward science and technology had basically placed emphasis for a long time on practical use—efficiently importing science and technology from other countries and applying them in the economy—in order to catch up with western developed countries. In this process, a characteristic of Japanese culture—relativizing the subject—had been suitable for such import of science and technology, as indicated by Japan's history of absorbing and assimilating the ideas and cultures of other countries by processing and improving them to make them more adaptable to Japanese people. This characteristic can still be seen today in that there is a relatively small number of bachelors of science and a relatively large number of bachelors of engineering in Japan and that a large number of patent applications are filed in Japan. Furthermore, the national character and social characteristics that are expressed as Japan's strong points with such keywords as people's strong sense of belonging to an organization, good teamwork, a high level of discipline, field-oriented ideas, and meticulousness, seemed to have had advantageous effects mainly at the manufacturing sites of private companies.

Then again, emphasis on practical use is not always suitable for creating science, which aims at exploring the absolute truth. It has been pointed out that Japan tends to overlook the basics of science and technology and is strongly oriented toward making efficient use of the achievements. This tendency makes people attach more importance to uniformity and being safe and sure than to creativity, prefer loyalty to the organization over active human resource mobility, increasingly feel a sense of sectionalism, and more inclined to look inward and disregard the international dissemination ability. Because of this, Japan's characteristics, which had been regarded as strengths, have come to be indicated as weaknesses through the dramatic changes in the times.

(Challenges for being a front-runner)

The mobility of researchers in Japan, which has been indicated as being low since the First Basic Plan period, is still at a low level in the world. In an interview survey conducted by NISTEP on overseas top-class scientists and researchers, the respondents mentioned that long-term acceptance of scientists from other countries and overseas dispatch of young researchers should be further promoted for making research by Japanese people more globalized. In the same survey, there was an opinion on Japan's ability to disseminate information to the world that the presence of publications in Japanese language is good in providing a dynamic research environment in Japan, but it delays the presentation overseas, making it difficult for Japanese research to be evaluated as being innovative. According to the survey conducted by MEXT in fiscal 2004 targeting Japan's researchers in industry, academia, and government, about 60% of researchers mentioned they submit their scientific papers at first to journals in Japanese language. This percentage has hardly changed from that in the survey in fiscal 1998 (Figure 1-2-53). Moreover, due to excess focus on safeness and assuredness, the amount of venture capital investment for supporting practical application and commercialization of products using new ideas or technologies is low in Japan compared to other developed countries.

In order for Japan to advance science and technology in the intensified worldwide competition today as a front-runner, it needs to promote creative basic research and establish a system for efficiently using the achievements in society and the economy. To this end, it will be important to further use such potential as the characteristics of Japan’s manufacturing known as *suriawase* (tight coordination) and *konare no waza* (mature techniques), which had been Japan’s strengths, and Japanese children’s academic abilities, which rank high in the world, while tackling various challenges in Japan’s scientific and technological system, which are regarded as Japan’s weaknesses.

As discussed above, the research level of Japan has certainly risen in general. In addition, Japan is rapidly expanding its share in terms of the number of scientific papers in some fields including physics, material science, and immunology. Also, according to the interview survey conducted by the NISTEP on overseas top-class scientists and researchers, Japan is highly acclaimed for its outstanding projects, such as the Earth Simulator and the Super-Kamiokande, and its contributions in international joint research projects including those on decoding the human genome. Thus, Japan is significantly increasing its presence in some fields. It may be regarded as the sprouting of the results of measures that have been taken since the enactment of the Science and Technology Basic Law, so such efforts should be further promoted in the future.

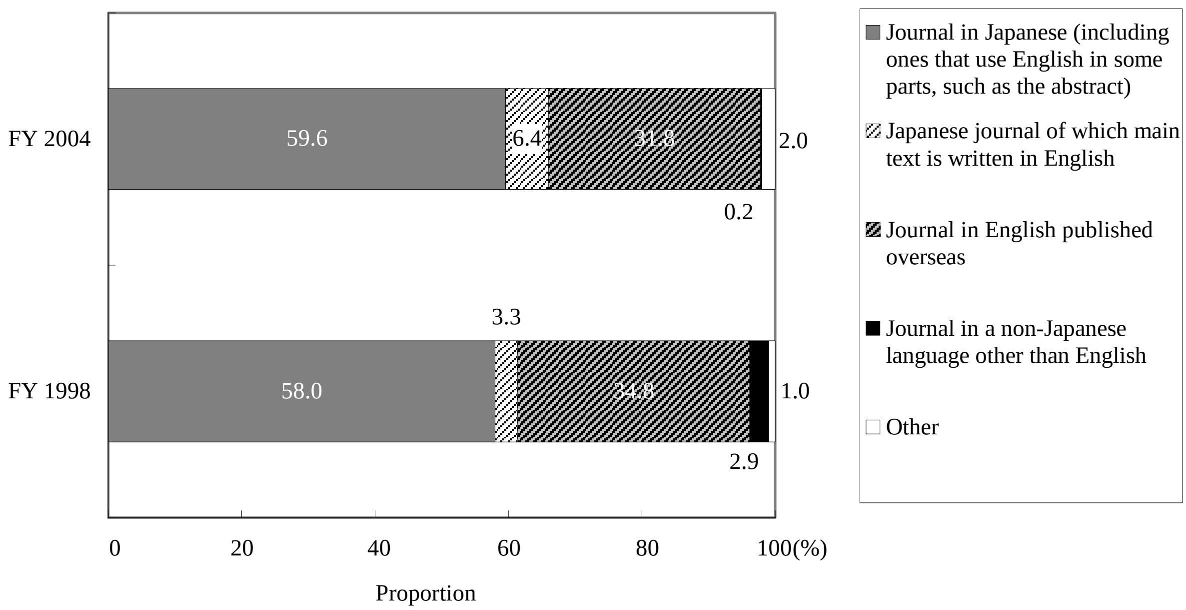


Figure 1-2-53 Journal to which Japanese Researchers Submit Their Scientific Papers at First

Source: MEXT, “Survey of the State of Japan’s Research Activities” (FY 2004, FY 1998)

[Column 18]

Japanese Traditional Arts Utilized for High Technologies

Prior to Japan's modernization since the Meiji era, traditional crafts and technologies have been developed in Japan, founded on its distinctive culture and climate. Such traditional arts and technologies have been continuously passed down through the generations until now, and some of them considerably influence current high technologies, as shown in the following examples:

<Traditional Japanese Paper and High Performance Paper>

"High performance paper" is made of synthetics, minerals, or metal fiber instead of vegetable fiber. Depending on the material of the fiber, the types of high performance vary, and include incombustibility, friction resistance, electric conductance and non-conductance. High performance paper is used for various products, including a friction material for vehicles, electronics parts and batteries.

The fibers of high performance paper should be evenly woven based on manufacturing techniques similar to those for traditional Japanese paper. That is why, in many of the manufacturing districts of high performance paper, traditional Japanese paper is also produced.

<Traditional Japanese Ceramics and Electronics Parts>

Japan has many ceramics production areas such as Kiyomizu and Arita. Traditional ceramic techniques are now utilized for technologies to produce condensers, which are indispensable to electronics devices. It is not surprising that Japan boasts such a high global market share in electronics and ceramics manufacturing.

<Gold Foil and Electric Circuits>

Gold foil is an essential material for traditional Japanese crafts. Japan has manufacturing and processing techniques of which it can be proud in the world for gold foil as thin as several ten-thousandths of a millimeter. The techniques are applied to manufacturing and processing of ultra-thin copper foil used for electric circuit substrates. The traditional technologies fundamentally support high technology industries, in which the lightness and thinness of the products are valued.

<*Tatara* Iron Making and Special Steel>

Tatara (foot bellows) iron making is a traditional art in Japan, using *masa* iron sand and charcoal unlike the less purer ingredients such as iron ore and coke that are used in modern iron making. Steel made based on the *tatara* method has been used for Japanese swords since old times. Utilizing the traditional method, the refinery techniques for mass-production of purer steel were established. The manufactured steel is combined with nickel and chrome to produce special steel with resistance to burning and abrasion. The special steel is used for products with rigorous mechanical, physical, or chemical requirements, such as tools and knives with high strength and abrasion resistance, electronics parts, ultra-heat-resistant alloys for aviation parts such as jet engines, and parts of nuclear facilities.

In addition to the examples above, many other traditional arts and technologies inherited in Japan have been applied to advanced technologies. For example, the braiding techniques for kimono sash cords and sword tassels have been applied to the development of compound materials with high strength, elasticity, and heat-resistance, by substituting carbon or glass fiber with vegetable fiber. Furthermore, the pattern printing in the *Yuzen* process of dyeing is considerably relevant to the technology of symbol printing on the buttons of mobile phones.

References: Kyodo News Editorial Office Ed., "*Washi* Paper and Mobile Phones";
NHK, "Japan Impact" Project, Ed., "Japan Impact: Traditional Techniques for Our Bright Future";
Institute for Future Technology (INTECH), "The Encounter between Japanese Culture and Science: Tradition for New Creation"

1.3 Future of Japan and Science and Technology

In the 21st century, the environment surrounding Japan and the world is expected to change considerably, and expectations are likely to rise for science and technology to resolve various problems that emerge as that happens. This chapter discusses the problems that Japan will face in the future, the expected roles of science and technology, and the direction in which science and technology should be promoted.

1.3.1 Challenges for Future Japan

In Japan, there is a concern that the working population will decrease in the future due to the declining birthrate and aging of the population. In addition, Japan is expected to face various difficult problems including measures against intensification of competition, such as the rise of Asian countries like China, and achievement of coexistence between environmental protection and economic development. This section focuses on the changing social conditions and the problems that Japan will face in the future.

1.3.1.1 Coexistence Between Environmental Protection and Economic Development

With development of science and technology, people have expanded their scopes of activities, and their social lives have become extremely affluent. On the other hand, the industrial society that uses a lot of underground resources, built by mankind in the 20th century, created the society of mass production, mass consumption, and mass disposal. However, resources on the Earth and the amount of waste that natural environment can dispose of are limited, so environmental pollution gradually came to have a strong impact on people's lives and surfaced as an environmental problem. Specific examples are global environmental issues, such as global warming, acid rain, depletion of the ozone layer, destruction of the rainforests, and desertification, and pollution issues, such as air and water pollution. Although the details of environmental problems are wide-ranging, they have all been caused by the spread or intensification of human activity pertaining to the development of science and technology.

(Environmental protection and sustainable development)

"Sustainable development," which was adopted by the World Commission on Environment and Development (Chair: Gro Harlem Brundtland, then Prime Minister of Norway) as the central concept of its report "Our Common Future" released in 1987, is the concept of viewing the environment and development not as contrary, but as able to coexist. It places importance on controlled development that "satisfies the needs of the present generation without compromising the chance for future generations to satisfy theirs" and gives consideration to environmental protection. It serves as the basic idea underlying current measures for global environmental problems.

(International efforts for sustainable development)

The International Panel on Climate Change proposes in its report that, in order to resolve climate change issues, a drastic reduction in use of greenhouse gases is necessary, and the amount of greenhouse gases used must be reduced to less than half of the current level in the future. Since the amount of greenhouse gas emissions is predicted to increase dramatically in line with the economic development of the world, particularly China and other parts of Asia, it will not be easy to achieve a coexistence between global warming prevention and economic development, and this issue is expected to become an increasingly important political and economic issue at global level as well as at private and regional levels. Under such circumstances, the Kyoto Protocol (Table 1-3-1), which has a legal binding force on the reduction of CO_2 emissions and greenhouse gases, entered into force in February 2005 to address a world-level environmental problem—global warming. This was important as the first step of the measures against global warming, but there still remain problems with respect to its effectiveness; for example, the United States has withdrawn from the protocol, and developing countries including China are outside the framework for specific emissions reduction.

Under the Kyoto Protocol, Japan is required to reduce its greenhouse gas emissions by 6% from the 1990 level by the 2008-2012 period. However, Japan's total greenhouse gas emissions in fiscal 2002 was 7.6% higher than the 1990 level, indicating that achieving the targets of the Kyoto Protocol is not easy. Therefore, further reinforcement of global warming countermeasures will be required.

Table 1-3-1 Outline of the Kyoto Protocol

(Key points) Adopted in 1997 and entered into force in February 2005
○ Legally binding numerical targets on the amount of greenhouse gas emissions are set for the respective developed countries.
○ Schemes are introduced in order to achieve the targets through international cooperation (emissions trading, clean development mechanism, and joint implementation)
○ No new obligations such as numerical targets are imposed on developing countries.
○ Numerical targets
Gases covered: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6)
Offset of emissions: greenhouse gas emissions can be offset by sink activities such as afforestation
Base year: 1990 (base year may be 1995 for HFCs, PFCs, and SF_6)
Target period: 2008 to 2012
Target: separate target for each country → e.g., Japan: -6%; United States: -7%; EU: -8%
Achieving at least 5% reduction in overall developed countries

Source: Ministry of the Environment, "Outline of the Kyoto Protocol"

1.3.1.2 Intensification of International Competition

(Progress of globalization)

The end of the Cold War structure, the development of larger and faster international transporttation means, development of information and communications technology, and establishment of communications networks caused activity of human, cultural, and economic exchanges beyond the border on all levels of society, such as individuals, regions, and states. Because of this, mutual understanding has been promoted and the closer relationships between countries and regions, mainly in the economic aspect, have intensified competition on a global scale. On the other hand, international coordination and cooperation has become indispensable for adderssing problems that can no longer be tackled by a single country, such as dealing with international criminal organizations and emerging/reemerging infectious diseases.

(Rise of Asian Countries including China and South Korea, and Multi-polarizing World)

In the medium to long-term, Japan's population is expected to decrease, but the world population is predicted to surge from the current figure of approximately 6.3 billion (2003) to about 8.9 billion by 2050.

Under such circumstances, the United States is likely to continue to have the most influence in all areas, namely, politics, military, and economics, and the EU is likely to increase its political uniformity and come to represent Europe in conducting diplomacy and security policy. Moreover, in addition to South Korea, which has maintained competitiveness mainly in the IT industry, China, India, and Brazil have also achieved high economic development in recent years (Figure 1-3-2). If China continues to significantly increase its international influence in line with economic development, Russia grows as an energy exporting country, and India and Brazil make further economic growth, the BRICs[6] and Asian countries will increase their influence in the international community, and while they maintain high growth rates, the world is expected to become multipolarized.

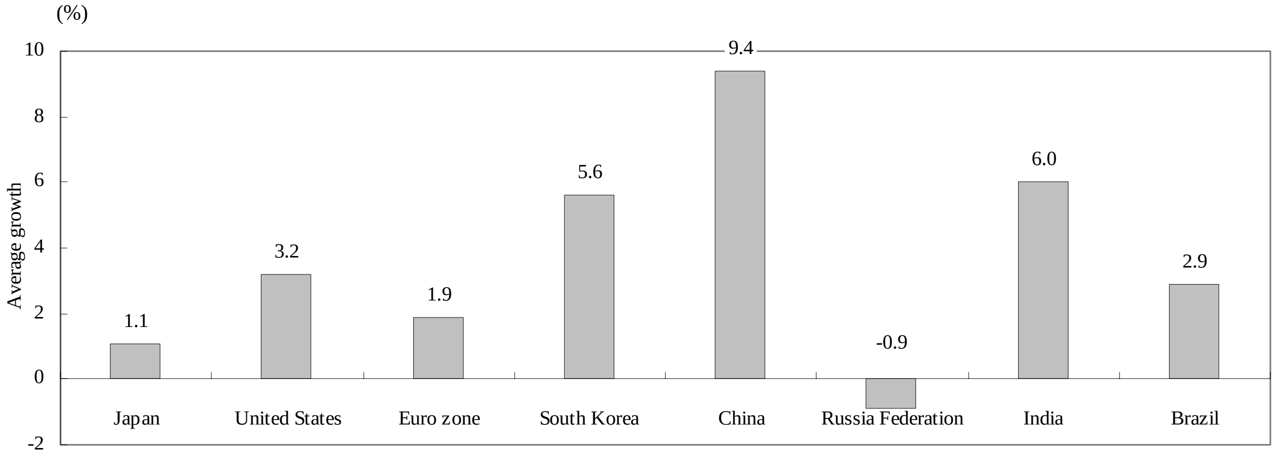


Figure 1-3-2 Average GDP Growth from 1993 to 2002

Note: "Euro zone" refers to the following 12 countries: Germany, France, Italy, Netherlands, Belgium, Luxemburg, Spain, Portugal, Greece, Ireland, Austria, and Finland.
Source: Cabinet Office, "World Economic Trend, Autumn 2004" (November 2004)

1.3.1.3 Decrease in Population Due to Aging Society with Fewer Children

Declining birthrates and aging populations are a worldwide trend, which faces developed countries and which will also face the neighboring countries in Asia in not-so-distant future. Japan's population is predicted to peak in 2006, start decreasing in 2007, and fall to about 100.59 million persons by 2050. This means going back to the 1967 level when the total population exceeded 100 million for the first time. During this process, the decline in birthrate and aging of the population will advance rapidly, and the proportion of young population aged 14 or under to the total population will decrease from the 14.6% in 2000 to 10.8% in 2050, while the population aged 65 or over will constitute about 30% of the whole population and three out of ten people will be elderly persons by the 2020s (Figure 1-3-3).

In line with this, the working population, which was about 67 million in fiscal 2003, is predicted to start declining after peaking in 2005, and become about 63 million by 2025, while the labor force of 60 or over will increase. In this manner, the aging of the working population is predicted to advance (Figure 1-3-4).

There is a concern that such changes in the social structure will invite contraction in GDP caused by a decrease in the working population and an increase in social security expenditures, and will reduce the vitality of society.

6 BRICs: The term is made up of the first letters of Brazil, Russia, India, and China. They draw attention as countries in which economic growth can be expected in the future.

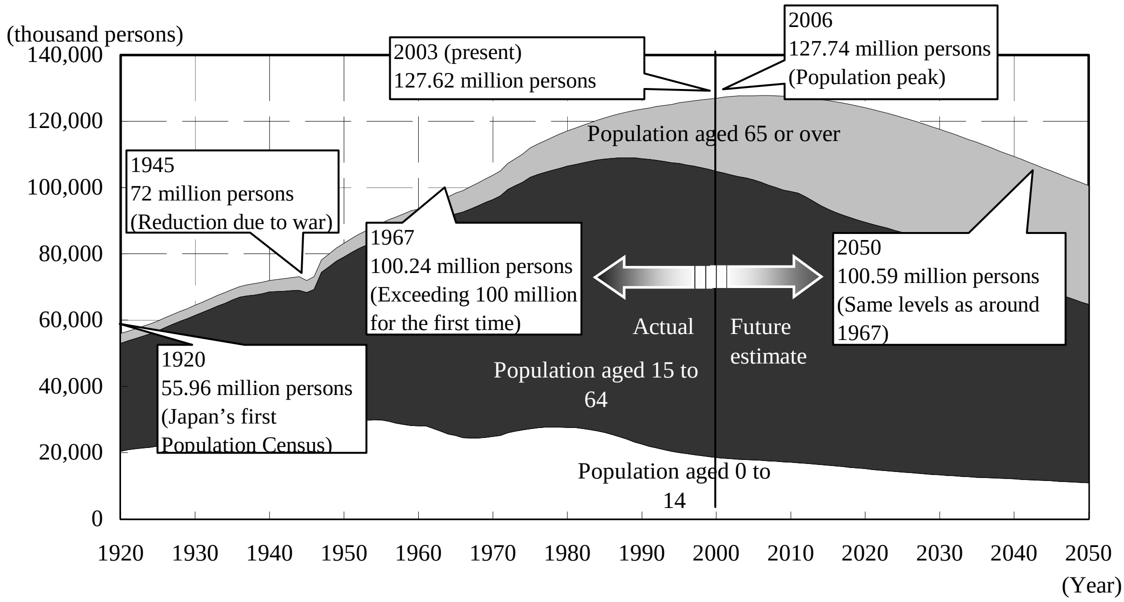


Figure 1-3-3 Japan's Population Structure

Sources: Values for 2003 and before: Statistics Bureau, MIC, "Population Census"
Values for 2004 and after: National Institute of Population and Social Security Research, "Population Projections for Japan, January 2002"
Note: Values from 1941 to 1943 were interpolated from the values for the three major age groups in 1940 and 1944.
Values from 1946 to 1971 do not include those of Okinawa Prefecture.
In "Population Census," the values for persons of uncertain age are proportionally distributed.
Source: Cabinet Office, "White Paper on Society with Declining Birthrate 2004" (December 2004)

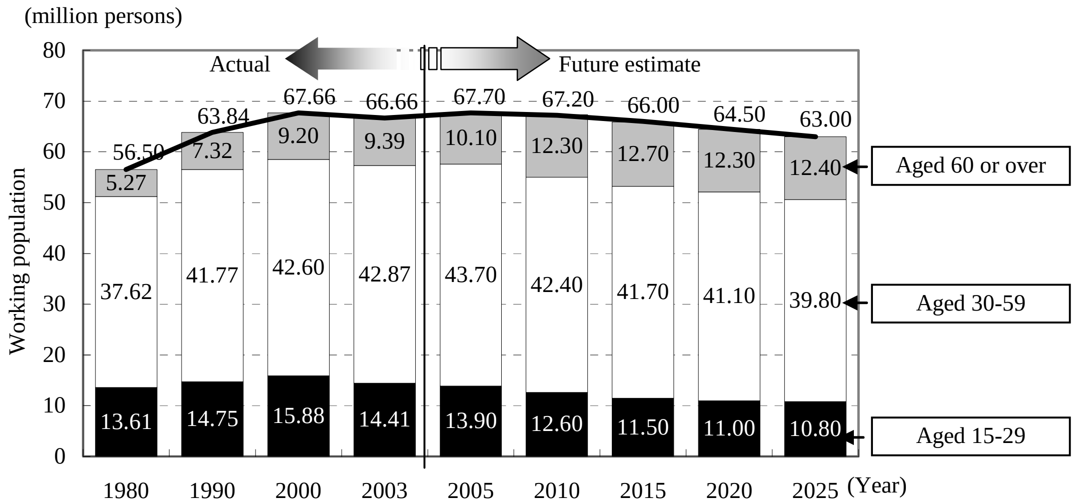


Figure 1-3-4 Transition and Prospects of Working Population

Sources: Values for 2003 and before: Statistics Bureau, MIC, "Population Census"
Values for 2005 and after: Estimated by Employment Security Bureau, Ministry of Health, Labour, and Welfare (July 2002)
Note: Values are rounded off, so they may not add up to the total.
Source: Cabinet Office, "White Paper on Society with Declining Birthrate 2004" (December 2004)

1.3.1.4 Sophistication and Diversification of People's Needs

As society matures, individuals and individual characters are expected to become even more respected, and people's lifestyles and values will become even more diversified. In addition, due to the advancement in globalization, depletion of food and energy, and increased intricacy of social systems, the science and technology is likely to become increasingly sophisticated and diversified, including areas such as establishment of a safe and secure society.

(Spiritual wealth)

Science and technology has deeply penetrated people's lives and material wealth has come to be attained recently, so people have begun to place more weight on seeking spiritual wealth (Figure 1-3-5). Since people's leisure time is expected to increase with the maturity of society and the coming of an aging society, the desire for spiritual wealth and comfortable lifestyles is likely to increase even more in the future along with diversification of lifestyles and values.

(Health)

Because the average life expectancy will prolong and individuals' lifestyles will become diversified with advancement in the aging of the population, mental and physical "health" will become an ever important concern for many people in planning their lives. While aging of the working population, swelling of social security expenditures, and an increase in adult disease patients are expected in the future, the challenge for addressing these problems would be to extend healthy longevity (the period during which a person is physically and mentally healthy and self-reliant while giving consideration to the quality of life and health) so that the elderly may live healthy lives. In addition, it is hoped that medical science for prevention and treatment will develop so as to allow young people and middle-aged people to stay healthy both physically and mentally.

(Safety and security)

In recent years, Japan has come to face various new threats, such as the spread of terrorism worldwide after the terrorist attacks in the United States on September 11, 2001, large-scale natural disasters, occurrence of infectious diseases on a global scale, worsening of international organized/heinous crimes, and a rapid increase in computer crimes that attack the weak points of the advanced information and communications network society. Thus, there is a need to reinforce the crisis management frameworks for combating these diverse threats and to build a safe and secure society.

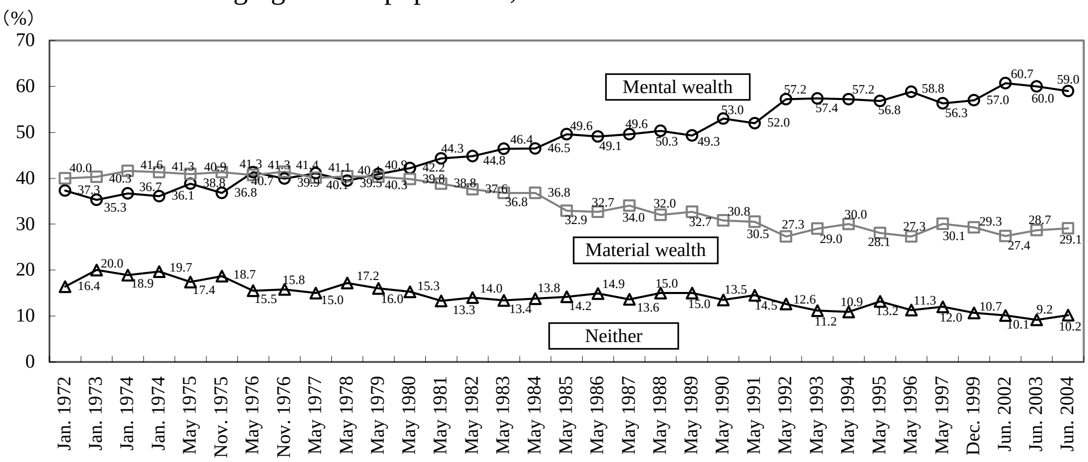


Figure 1-3-5 Changes in Type of Wealth Sought by People

Note: Mental wealth: "I have gained material wealth to a certain extent, so I want to focus on mental wealth and comfortable life from now on."
Material wealth: "I want to focus on further increasing material wealth in my life."
Source: Cabinet Office, "Public Opinion Survey on National Lifestyle" (June 2004)

1.3.2 Roles Expected from Science and Technology

As discussed above, science and technology has contributed greatly to creating intellectual/cultural values, economic values, and social/public values over a long period of history. Science and technology is expected to play a significant role in addressing problems for the whole society, such as the declining birthrate and aging of the population, a decline in productivity, and global environmental problems, as well as addressing individuals' desire for "wealth," which is becoming more diverse and sophisticated. In order for Japan to precisely deal with these changes and achieve sustainable development in the 21st century, when the society will become more complex and diverse, science and technology must fully play this expected role.

1.3.2.1 Creation of New Values (Creation of Intellectual/Cultural Values)

Science and technology creates intellectual/cultural values and has had a great deal of impact on the formation of our values, including our views on the universe, matter, and life. Intellectual curiosity is a desire common to mankind, and will continue to bring new knowledge to us.

The knowledge acquired through science and technology will be used for creating new goods and services as well as for solving various problems, and become intellectual assets (stock) for creating yet other important new knowledge. These intellectual assets must be used as common assets for mankind, and at the same time, they will become the source for sustainable creation of knowledge.

Basic research, which aims at discovering new principles, establishing creative theories, and predicting/discovering unknown phenomena, such as elucidation of the origin of matter, various phenolmena in space, and life phenomena, serves as the basis for creating knowledge, so it should continue to be actively promoted in the future.

1.3.2.2 Economic Development and International Competitiveness (Creation of Economic Values)

As discussed in 1.3.1, the situation surrounding Japan is expected to become extremely severe in the future due to such constraining factors as the global environmental issues and depletion of resources as well as a decrease in the working population due to the declining birthrate and aging of population.

Looking at the world, Japan's neighboring countries—China and South Korea—are rising as Japan's competitors amidst major changes including the advancement of globalization and growth of the BRICs. In these countries, new industries based on achievements of cutting-edge science and technology, such as the information and communications industry and the biotechnology industry, are emphasized as the key to economic growth and creation of employment. They are already implementing active measures to promote science and technology by regarding science and technology as the driving force for economic development, in this way.

It would require extraordinary efforts for Japan to maintain and reinforce its international competitiveness under such circumstances. Apparently, for resources-poor Japan, innovation will serve as the driving force for securing international competitiveness. Therefore, innovation using science and technology, such as adding high value to products and further strengthening Japan's superior technical fields, will be indispensable.

There is a concept called "Soft Power." It is used as an antonym to "Hard Power," which refers to military power and the like. It is the ability to attain the desired result not by force or for reward, but based on the appeal of knowledge or culture. Since information technology has greatly advanced, it is extremely important for Japan to disseminate its appeal to overseas at present and in the future. Japan has abundant "Soft Power" to be proud of, such as popular culture including animations and video games, as well as Japanese culture including traditional art and crafts. Japan, which has a high level of science and technology, would be able to acquire strong "Soft Power" by creating knowledge—the world's common property—through using science and technology and achieving economic development by making continuous innovation.

[Column 19]

Japan's Future Prospects and Technologies Indicated in the "Japan's 21st Century Vision"

On April 19, 2005, the special board of inquiry for examining "Japan's 21st Century Vision" (Council of Economic and Fiscal Policy) published a report on their examination.

In "Japan's 21st Century Vision," the year 2030 is assessed as the beginning of "a new era of dynamism." The report illustrates the future direction Japan should strive to take in the quarter of a century from now. It also shows the specific courses that Japan should take to work with the trends of the times, including the declining population, progressing aging of the population, globalization, and the advanced information-oriented world.

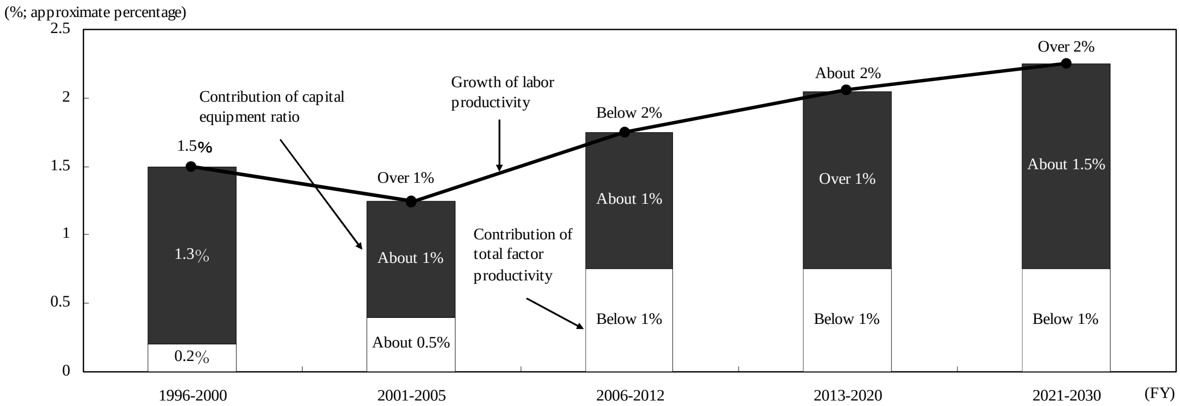
If Japan neglects to carry out reforms and fails to swim with the major currents of the times, according to "Japan's 21st Century Vision," the economy will stagnate, an increasing number of people will lose hope, and society will become unstable. In that case, Japan will follow a gradual but steady pathway to decline. If Japan can successfully work with the trends of the time, on the other hand, it will be able to see a new era of dynamism. To ensure a bright future, Japan should take the following actions: (1) creating a virtuous cycle of rising labor productivity and growing income; (2) taking maximum advantage of globalization; and (3) creating systems to provide public values as selected by the public.

Considering the economic situation in Japan in 2030 as results of the reforms, the rise of labor productivity is essential to the continuous development of Japan's economy, in spite of the decrease in population and the progressing aging of the population. It is highly expected that technological innovation can promote labor productivity.

"Japan's 21st Century Vision" indicates that there is a possibility of a more than 2% increase in labor productivity by the expansion of capital stock (the rise of capital equipment ratio) with the progress of mechanization, as well as the improvement of total efficiency (the rise of total factor productivity) with technological innovation. Based on this estimation, rising labor productivity will sustain the real GDP growth rate at somewhere about 1.5%, which is enough to maintain a high standard of living.

Prospects for Labor Productivity

The growth of total factor productivity will recover with progress in expansion of capital stock, and growth of labor productivity will increase to over 2%.



Note: 1. Labor productivity rises through the expansion of capital stock (with the progress of mechanization) plus the improvement of total efficiency (the rise of total factor productivity) with technological innovation. That is:

(Growth of labor productivity)

$$= \text{(Growth of total factor productivity)} + \underbrace{\text{(Capital relative share)} \times \text{(Growth of capital equipment ratio)}}_{\text{Contribution of capital equipment ratio}}$$

2. Note that the estimation is based on various assumptions with many uncertain factors, as it is a long-term projection.

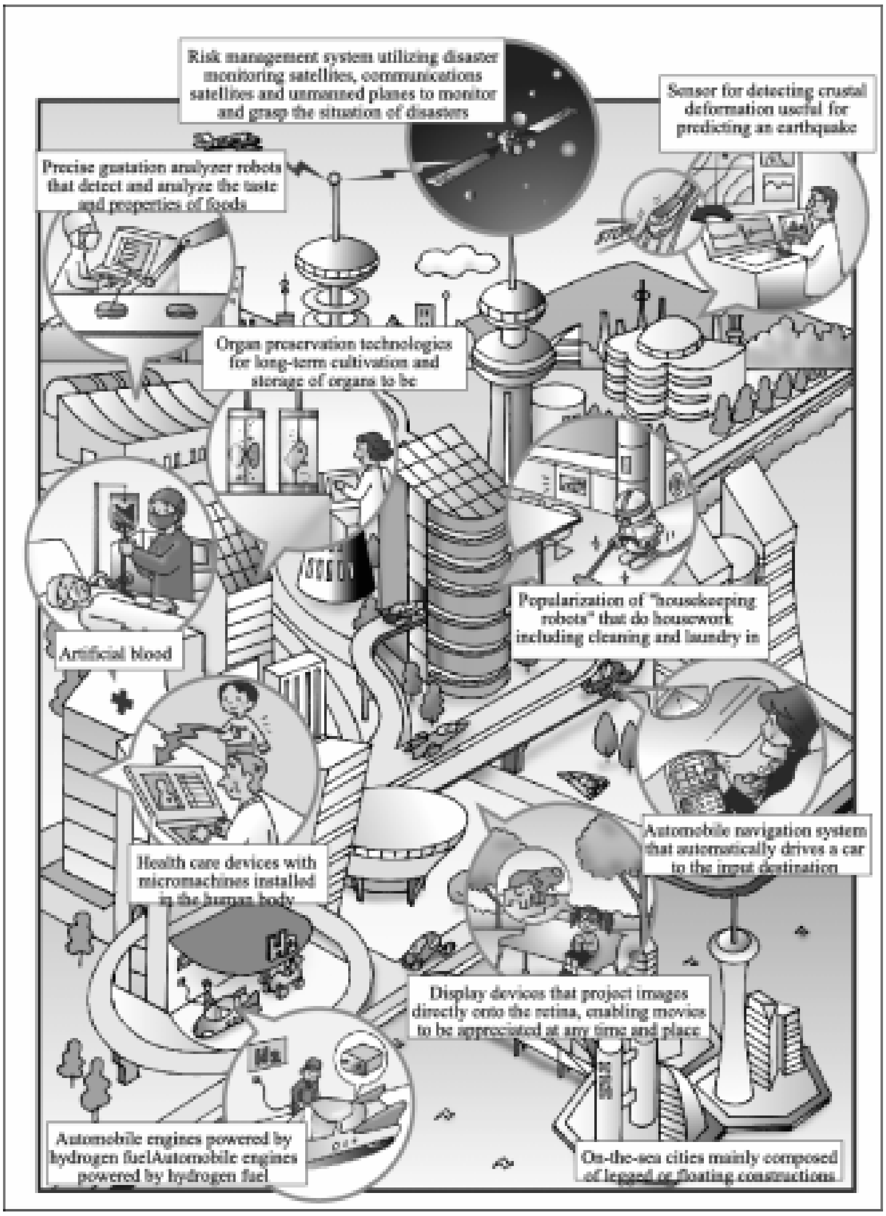
Source: Publication by the special board of inquiry for examining "Japan's 21st Century Vision"

[Column 20]

Our Society and Lives in 2025

In May 2005, the National Institute of Science and Technology Policy (NISTEP) made a report on the Science and Technology Foresight Survey Delphi, sending out questionnaires to over 2,000 specialists in various fields.

The NISTEP report concludes that the following technologies will be utilized in our society in 20 years, in about 2025. It is expected that our lives will change drastically with the introduction of those technologies 20 years from now.



Source: Illustration created by the Ministry of Education, Culture, Sports, Science and Technology, based on the "Eighth Science and Technology Foresight Survey Delphi" (NISTEP Report No.97)

1.3.2.3 Sustainable Development of Human Society (Realizing Social and Public Values)

(Dealing with diversified/more sophisticated social needs)

As society matures, individuals and individualities are expected to become respected even more, and people's lifestyles and values will become even more diversified. At the same time, people's needs for material affluence as well as spiritual affluence are expected to become more diverse and sophisticated. Science and technology is able to make contributions to culture, art, and entertainment, so it should be used to meet such diverse demands of the people.

One of the challenges that Japan will definitely face and must tackle in the near future is to address the "aged society." In order to form a vigorous society, not a mere extension of life, but prolongation of healthy longevity that considers the quality of life would become an important task. Therefore, Japan needs to steadily promote R&D on extending healthy longevity including prevention and treatment of lifestyle-related diseases.

Meanwhile, as society becomes more and more intricate, there has been strong demand for building a safe and secure society due to the increased factors that destabilize society such as terrorism, natural disasters, and a decline in public safety. As represented by the spread of infectious diseases due to advancement of globalization and computer crimes pertaining to progress in information technology, new threats have been emerging due to the increased complexity of society. Therefore, there are high expectations for science and technology to make further contributions in this field.

(Coexistence between environmental protection and economic development)

In the 21st century, it is no longer possible to think about the environment and economic development separately. In order for mankind to achieve sustainable development, coexistence between the environment and economy is indispensable, such as developing the economy while protecting/conserveing the environment or making economic advances that lead to improvement of the environment.

Because environmental problems such as global warming and air pollution are extremely wide-ranging, and due to the fact that each individual has an influence on the environment, multi-tiered measures throughout the social and economic systems will be required based on proactive participation of individuals and all sectors in order to achieve coexistence between the environment and the economy. These measures should encompass those on the "mind-set" level of individuals as well as fostering of markets that actively evaluate environmental values and building a recycling-oriented society. Of these measures, energy-saving and new-energy measures that actively adopt science and technology, as well as various environmental conservation technologies will be essential.

Japan has the world's most advanced technologies as follows in these fields.

Home electrical appliances that achieve the world's highest-level resource and energy saving performance

Low-emission vehicles including hybrid cars that adopt the world's most advanced technologies

Photovoltaic power generation systems that are introduced in the largest number in the world

R&D of innovative technologies that are essential for a recycling-oriented society, such as recycling technologies and use of hydrogen energy

Japan should fully use its scientific and technological potential and contribute to the world to help achieve coexistence between environmental protecttion and economic development, which is the common challenge for mankind.

(Strategic promotion of international activities based on science and technology)

While globalization of society and economy advances, Japan has been competing with other countries of the world over human resources, technologies, and knowledge, but at the same time, it faces problems that need to be resolved under international cooperation, such as global environmental problems. Today when international competition and cooperation are concurrently required, the role that should be played by science and technology is increasing.

In recent years, notably the rising China, South Korea, and ASEAN countries, which are seeking to develop as newly industrialized countries, are rapidly gaining strengths not only in the economic field, but also in the science and technology field. Japan needs to lead in the establishment of a science and technology community in the Asian region through addressing the problems common to the region, such as dealing with environmental problems and emerging/reemerging infectious diseases, and exchanging/accumulating knowledge through building a network of Asian researchers and increasing mobility of researchers within the region with these countries, which are also geographically close. If Japan plays an active role in these fields, it will contribute to raising the status of the Asian region in the world, while it will also allow Japan to take the leadership in the Asian region and attract talented Asian R&D human resources, which are flowing out to western countries, to Japan.

At the Science and Technology in Society Forum held in Kyoto in November 2004, active debates were conducted on ideal science and technology in society with the participation of overseas ministers of science and technology and famous experts from industry, academia, and government. Meanwhile, at the United Nations World Conference on Disaster Reduction held in Kobe City, Hyogo Prefecture in January 2005, the "Hyogo Framework for Action," which will serve as the guidelines on disaster prevention for the next 10 years, was adopted, and the importance of research, observation, and prediction of disasters for reinforcing the disaster prevention capacity was indicated. Furthermore, Japan called on establishing regional tsunami early warning systems in the Indian Ocean in light of the Indian Ocean Earthquake in December 2004.

Japan's effort to actively conduct scientific and technological activities in the international community and contribute to creating knowledge, which is the common asset for mankind, will receive trust and respect from other countries, and Japan will be able to gain important ground in the international community.

[Column 21]

Science and Technology in Society Forum (STS Forum)

From November 14 to 16, 2004, the first Science and Technology in Society Forum (STS Forum) was held at the Kyoto International Conference Hall. The forum is considered to be the Davos Conference (World Economic Forum Annual Meeting) of the scientific field. Approximately 500 participants from 50 countries throughout the world, including government ministers (e.g. the Minister of State for Science and Technology), eminent scientists and business executives, attended the three-day forum to discuss the theme of “Science and Its Social Aspects: Lights and Shadows.” The most distinctive feature of the STS Forum is that every participant attends the event as an individual, not representing a specific country or organization.

Japanese Prime Minister Junichiro Koizumi delivered the keynote address at the STS Forum. Since the hall was the site where the Kyoto Protocol had been agreed, he introduced the efforts of the Japanese government for prevention of global warming, including replacing existing official vehicles with low emission vehicles (LEV). Prime Minister Koizumi mentioned that science and technology could make environmental protection and economic development mutually achievable. On the other hand, he also indicated the disadvantages of the development of science and technology, giving the example that the invention of steam engine was so beneficial to us, but it increased the consumption of fossil fuels that cause global warming. He claimed that we should combine the best wisdom in the world to solve the problems that have occurred in line with the development of science and technology.

Subcommittees were set up at the STS Forum to discuss various subjects including bioethics, information technologies, technical experts, infectious diseases, safety and peace, nanotechnology, and the role of science and technology in governmental strategies. Based on the discussion, the following opinions were agreed: (1) science and technology should be used for solving the problem of global warming, which is a major problem for the human race; (2) it is necessary that developed countries support developing countries in improving their technological competence; and (3) science and technology should be used for the safety and peace of the human race.

The STS Forum is to be held annually in September. The second session is scheduled for September 11-13, 2005.

[Column 22]

World Conference on Disaster Reduction (WCDR) and Early Tsunami Warning System

From January 18 to 22, 2005, the United Nations World Conference on Disaster Reduction (WCDR) was held in Kobe, Hyogo Prefecture, Japan. In commemoration of the tenth year from the Great Hanshin earthquake, the disaster-stricken Kobe was chosen as the site of WCDR, which was established based on the "World Conference on Natural Disaster Reduction" in 1994.

At the intergovernmental and thematic meetings of the WCDR, more than 4,000 delegates were present, from 168 member states of the United Nations, 78 international organizations including U.N. agencies, and 161 nongovernmental organizations. Attendance at the symposiums and exhibitions totaled over 40,000, including the general public.

Recently, the approximate number of disaster victims throughout the world has reached 200 million per year, with 60,000 of them fatalities, and the total amount of damage approximately 37 billion dollars per year. At the WCDR, it was pointed out that disasters were a major obstacle to the accomplishment of sustainable development and eradication of world poverty, as they destroyed the results of development investment in just a short period. It was indicated that one of the biggest tasks for the international society was taking countermeasures against disasters, to reduce such damage.

On the last day of the WCDR, the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities" was formulated. It is a guideline for disaster prevention in the next ten years, aiming for the substantial decrease of the human, social, economic, and environmental damage caused by disasters. The measures in relation to science and technology include the promotion of technologies for research, observation, and prediction of disasters, and the establishment of a system for disaster reduction. Along with the framework for action, the "Hyogo Declaration" was also adopted at the WCDR. It is the promise by the participating nations to make efforts for disaster reduction.

Additionally, at the WCDR, the "Common Statement of the Special Session on the Indian Ocean Disaster" was adopted. The statement corresponds to the disaster in December 2004 when an earthquake and accompanying tsunami in December 2004 left over 200,000 people dead or missing. It appealed to participants to establish an early warning system for tsunami in the area, under the coordination by the United Nations. The Japanese government participated in the project, joining with the countries and organizations concerned. The early warning system for tsunami in the Indian Ocean will be established based on the know-how of the current tsunami warning system in the Pacific Ocean. Utilizing its advanced knowledge and experience in disaster prevention, Japan is required to make a wide range of efforts to reduce the damages caused by tsunami in the Indian Ocean, in a global cooperative setting.

1.3.3 Toward Promotion of Science and Technology in Japan

Section 1.3.2 discussed the roles that are expected of and should be played by science and technology in the severe conditions surrounding Japan.

In order for Japan to overcome various constraining factors and maintain sustainable development in the 21st century, it must exert an increasing effort to promote science and technology, which is hoped to make greater contributions in these fields.

(Promotion of basic research and important science and technology)

Basic research is the source of scientific development and innovation. Scientific development leads to creation of intellectual/cultural values and innovation leads to creation of economic/social values. In the international community, which will become more diverse and complex in the future, Japan needs to compete with other countries with its intellectual assets. Therefore, in order to secure diverse and solid intellectual assets that will continue to produce new knowledge, it is necessary to place even more weight on basic research and promote it extensively, steadily, and in a sustained manner. In addition, it is necessary to steadily promote facility improvements, and the development of infrastructure, such as information infrastructure and intellectual infrastructure.

Basic research, which is based on intellectual curiosity, forms the foundation for science and technology from the viewpoint of intellectual assets. Therefore, Japan, as a nation, should take responsibility for carefully selecting and promoting important fields of science and technology, which are necessary as infrastructure for the sustainable development of the nation and which the related ministries and agencies should work on in collaboration as a nation by clarifying the goals under a long-term national strategy. Specifically, Japan must examine and promote the fields of science and technology for which Japan has a comparative advantage and which will serve as the basis for strengthening its international competitiveness, the fields of science and technology in which Japan can maintain leadership in the international community, and based on which it can strongly advertise itself as being an advanced science-and technology-oriented nation in Japan and overseas, and the fields of science and technology which have spillover effects on extensive fields, which are promoted by the nation as a whole, and which contribute to the development of society. If Japan, which suffers many natural disasters like earthquakes and will become a super-aging society ahead of the world, contribute to "resolving the common problems for mankind" by effectively using its scientific and technological capabilities and actively engaging in science and technology, it will symbolize Japan's national power and serve as a source of soft power. Accordingly, such efforts would be essential for establishing Japan's presence in the world.

(Returning achievements to society)

It is extremely important to return scientific and technological achievements to society in a usable form. R&D achievements lead to industrial development and improve people's lives in the form of goods and services. At the same time, dissemination of the achievements to society in the form of scientific papers leads to accumulation of knowledge, which become seeds and develop into yet new science and technology. In order to develop an environment in which such creation and return of achievements take place continuously, Japan needs to further strengthen its current measures to reinforce coordination between industry, academia and government and protect/use intellectual property.

(Communication with society)

Science and technology has permeated throughout our lives and has a considerable impact on the whole society. It is indispensable to always look at the relationship between science and technology and society from the viewpoint of "science and technology in society for the sake of society." Scientists as well as the universities and scientific communities where they mainly conduct their activities are demanded to realize their social role and responsibilities, as well as fulfill their accountability and actively offer information, that is, actively conduct "outreach activities." At the same time, society must make efforts to maintain interest in and understand science and technology. The role of "science communicators," who explain details that are hard to understand for the general public and the significance of cutting-edge science and technology in an easy-to-understand manner, and the role of the mass media are also important. Two-way communication between science and technology and society will be indispensable for establishing and maintaining a good relationship.

(Developing and securing diverse human resources)

Meanwhile, due to the decline in the absolute number of human resources, which is attributable to the decline in the birthrate and aging of the population, it has become an extremely important challenge to develop and secure excellent human resources who will support science and technology. In addition, the results of two international surveys on academic abilities, which were released in December 2004, revealed that academic achievements of elementary school students and lower secondary school students in mathematics and science partially declined, and there were problems in their willingness to study and their studying habits.

Lack of human resources that will lead science and technology will have a considerable effect on future Japan. It is important how we can convey the "importance and the interesting aspects of science and technology" to the generation that will play a lead role in the future of science and technology. So, in addition to improving school education, multidimensional measures will be required, such as improving science museums. In addition, from the viewpoint of securing many excellent scientific and technological human resources, an environment should be established in which female researchers and non-Japanese researchers, and competent elderly researchers can fully demonstrate their abilities.

Conclusion

As discussed above, we are so closely involved with science and technology that it is not too much to say that we live in science and technology.

This year is the tenth year from the enactment of the Science and Technology Basic Law. In this time, the environment surrounding Japan's science and technology has been considerably improved, such as through an increase in the government investment in R&D, reform in the technological and scientific system, and promotion of coordination between industry, academia and government. Also, looking at the aspect of "scientific and technological capabilities," Japan has definitely accumulated its capabilities while scientific and technological activities have become more profound.

However, as we have entered an era of worldwide knowledge megacompetition, all countries have become fully aware that science and technology is the foundation of national strength. They all position promotion of science and technology as well as human resources development as an important policy and strengthen government investment. Also, China and South Korea are catching up quickly. When we look to the future of the 21st century, which is called the era of the "knowledge society," and consider the severe situation in which we are likely to be put, because of issues such as a decrease in population, a super-aging society, and energy restrictions, we realize that we have come to a time when people in all industries and all segments must seriously think about what kind of country we should aim at and how we should treat science and technology.

Nevertheless, Japan has an accumulation of culture, tradition, and technical capabilities of which it can be proud in the world, and a high academic standard on average among developed countries. The greatest resource for Japan, which is a resources-poor country, may be human resources. Japan needs to make efforts to overcome its "weaknesses" in the future throughout the whole society, weaknesses such as lack of human mobility, the follow-the-leader mentality, and the weak external dissemination capabilities. At the same time, Japan should not merely imitate or introduce western scientific and technological systems as they are, but it should integrate and develop them with Japan's original "strengths" and establish the most suitable and effective systems for Japan.

At present, discussions toward formulating the Third Science and Technology Basic Plan are in progress lead by the Council for Science and Technology Policy. This is an effort to decide the basic direction of Japan's scientific and technological policy for the next five years by taking an overall view of about 10 years. Investment in science and technology takes a long accumulation time of 20 to 30 years and requires participation and contribution of various entities in order to achieve results. In addition, in order to develop researchers and engineers who will promote scientific and technological activities, comprehensive and continuous measures should be taken from elementary and secondary educational levels. In light of these circumstances, it will be necessary to take a long-term perspective also for science and technology policies.

Furthermore, in order for science and technology to be accepted by society and the people and to gain their trust and support, administration, research institutes, and researchers must make efforts to promote interactive communications with society and the people.

Japan, which aims to become an "advanced science-and technology-oriented nation" through the promotion of science and technology, should use scientific and technological capabilities—power in intangible areas—to the full and build an affluent and vigorous society, as well as contribute to creating new knowledge and resolving common challenges for mankind, and aim at becoming a reliable country with large presence.

To this end, Japan must further promote science and technology and achieve an "education-and human-resources-oriented nation" as its basis, as cross-generation "investment for the future," and it needs to form a national consensus on this matter.

The leading advanced nations are reacting to economic globalization, to the attendant intensify-cation of competition in the global economy, and to the increased importance of energy, food, global environmental problems, and other global and pan-human issues by aggressively promoting science and technology policies toward the assurance of competitive strengths and employment, and toward the resolution of global and pan-human issues.

In Japan, despite the fact that the FY2003 Gross Domestic Product (GDP) showed an increase for the first time in three years, R&D expenditure witnessed an increase for the fourth consecutive year due to big increases among private-sector enterprises, bringing the total proportion of R&D expenditure to the GDP to 3.35%, the same as the previous year. In addition, the number of researchers in FY 2004 increased for the third year in a row, with R&D personnel on the whole, including research support staff and technicians, witnessing increases for the first time in five years.

As can be seen, R&D expenditures in Japan, al-though small, are on the increase despite Japan's prolonged economic stagnation. This upward trend is a step in the right direction for a Japan that aims to become "an advanced science- and technology-oriented nation." However, nations around the world are placing an emphasis on science and technology policy and are moving to expand R&D expenditures. If Japan is to continue in the future to enhance its international competitive power, to improve the quality of its people's lives, and also to respond to global and pan-human issues, Japan must further strengthen and expand research and development activities, while giving due consideration to the severe fiscal situation.

Part 2 will compare Japan and major countries [1] in the areas pertaining to science and technology, such as research expenditures and number of researchers, so as to highlight the special characteristics of Japan's science and technology activities. This information will then be used for a more in-depth analysis of the trends in Japan's research activities. [2]

(International Comparisons of Science and Technology Indicators)

A prerequisite for making international comparisons of statistical data is to examine the subject statistical data from each country based on unified standards. The Organisation for Economic Co-operation and Development (OECD) has prepared the Frascati Manual [3] as a guideline for the collection and analysis of data related to scientific and technological activities, and has asked member countries to base their science and technology indicators on that manual.

In the Frascati Manual, the method for calculating the number of researchers is derived from two types of data—a simple head count of the number of researchers, and a full-time equivalent (FTE) value [4] which takes into consideration the proportion of time actually devoted to research activities. The latter is touted in the Manual as being a proper quantitative method for measuring research personnel resources, and all OECD member countries are called upon to support the FTE value. In Japan, a conversion of various elements has been used to arrive at a number representing the number of full-time researchers, using the "full-time equivalent ratio" estimated from the results of a survey targeting instructors at universities and colleges taken in 1992 by the Ministry of Education Culture, Sports, Science and Technology, and, the number of researchers and amount of research expenses at universities and colleges from a2003 survey of research and development(Table 2-1-1).

1 In Part 2, the major countries refers to the United States, Germany, France, United Kingdom and Japan, unless otherwise noted.

2 Part 2 describes research activities including the humanities and social sciences. Descriptions of the natural sciences alone are annotated. Furthermore, the classification of the humanities and social sciences as distinct from the natural sciences is based on the research content, not on the individual research institute or university and college department concerned.

3 Frascati Manual: A manual for proper international comparisons of R&D statistics. The original proposal for the first edition of this manual was made at a meeting in Frascati, Italy, in 1963, and the manual was completed after discussions and revisions by experts of OECD member countries. Operations to revise the manual are currently underway. The sixth edition was published in December 2002.

4 FTE value: FTE is an abbreviation for Full Time Equivalent, and is a converted value showing the actual time engaged in research. If a re-searcher has an average of 30% of his/her working hours allocated to research and development operations, and is engaged in other activities (teaching, univer-sity administration, student counseling, etc.), he/she is said to have a 0.3 FTE. In the same way, a full-time researcher employed for only six months in research and development work is said to have a 0.5 FTE.

The FTE differs from the simple head count, especially in the case of researchers at universities and colleges, who are engaged in teaching activities, and thus, this also changes the corresponding amount of research expenses used at universities and colleges.

In Part 2, we shall use both the simple head count and the FTE value when we make international comparisons of researcher numbers and R&D expenditures for recent years.

(Research and Development in the European Union)

The Treaty on the European Union (commonly known as the Maastricht Treaty) was signed in 1992, and the European Union (hereinafter referred to as the EU) was established. The next step in this development was the introduction of a common currency in January 1999, which was followed three years later, in January 2002, with the circulation of Euro-denominated coins and bills in member states. In May 2004, ten central and eastern European countries were granted membership, increasing the number of EU member nations from 15 (EU-15) [5] to 25 (EU-25) [6] The EU has demonstrated its important presence in recent years in many arenas on the international stage, rapidly establishing its position as a global player. In terms of science and technology indicators, the EU is second only to the United States. In the future, Japan should not fail to ensure a good relationship with the EU so that Japan can enhance its international competitive strength (Table 2-1-2).

The basic objectives of the EU science and technology policy are "strengthening the scientific and technological basis of Community industry and encouraging it to become more competitive at an international level, while promoting all the research activities deemed necessary by virtue of other Chapters of this Treaty" (Treaty Establishing the European Community). Based on these objectives, the Framework Programme (Sixth Framework Programme (FP6), from 2002 to 2006, now in progress) showing the basic framework for research and development activities in the EU was adopted.

While the EU is not included in the international comparisons in this part of this publication, because it is not a nation but rather a community of nation states, indicators for the EU have been included in these comparisons in Part 2 wherever possible, as totals of science and technology indicators [7] for EU countries.

Table 2-1-1 Comparison of FTE value and simple head count (FY2003)

(Persons, Million yen)

Item	Simple head count (A)	FTE value (B)	Change (B/A)%
Number of university researchers	284,330	172,396	60.6
Total number of researchers	787,264	675,330	85.8
University R&D expenditure	3,263,109	2,142,357	65.7
Total R&D expenditure	16,804,155	15,683,403	93.3

Note: The number of researchers is as of March 31, 2004.

Source: Ministry of Internal Affairs and Communications, Statistics Bureau (Statistics Bureau).
"Report on the Survey of Research and Development"
FTE value: Statistics Bureau data

5 The EU-15 consists of Belgium, Germany, France, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, and Sweden.

6 The EU-25 consists of the EU-15 and the following 10 countries: Cyprus, Czech, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia.

7 EU science and technology indicators: The EU science and technology indicators used in Part 2 utilize research expenses drawn from data reported by Eurostat (European Commission Statistics Bureau), numbers of researchers from data reported by the OECD, and numbers of patent applications and registrations from WIPO (World Intellectual Property Organization) data.

Table 2-1-2 Comparison of the tripolar world

Category	Japan	United States	EU-25	EU-15
Population	130,000,000	290,000,000	460,000,000	380,000,000
GDP	505 trillion yen	1,269 trillion yen	1,276 trillion yen	1,219 trillion yen
R&D expenditure	16.8 trillion yen	36.6 trillion yen	22.0 trillion yen	21.5 trillion yen
Number of researchers	790,000	1,260,000	1,160,000	970,000
Number of patent applications	1,420,000	4,470,000	—	3,976,000
Number of patents	191,000	196,000	—	238,000

Notes: 1. Japan population and GDP is for 2004, R&D expenditure is for FY2003, researchers figure is for 2004.
2. U.S. population and GDP is for 2004, R&D expenditure is for 2002, researchers figure is for 1999.
3. EU-25 population and GDP is for 2003, R&D expenditure is for 2002, researchers figure is for 2002.
4. EU-15 population and GDP is for 2003, R&D expenditure is for 2002, researchers figure is for 2001.
5. The number of patent applications and patents refers to those for 2001.
6. The IMF exchange rate is used to convert U.S., EU-25 and EU-15 currency to Japanese yen.

2.1 R&D Expenditures

2.1.1 Total R&D Expenditures

2.1.1.1 Trends in R&D Expenditures in Selected Countries

When a country examines its R&D expenditures[8], its statistical contents and approach may differ from other nations. As a result, a simple comparison of R&D expenditures among countries may not present comparable data, although it gives a general idea as to a country's attitude towards science and technology. In terms of R&D expenditures, the United States registered the highest total, at 32.9 trillion yen at the IMF currency conversion rate (39.6 trillion yen at the OECD purchasing power parity conversion rate), followed by the EU-25 at 22.0 trillion yen at an IMF exchange rate conversion (29.4 trillion yen in OECD purchasing power parity), and Japan at 16.8 trillion yen (or 15.7 trillion yen at the FTE value) (Figure 2-1-3).

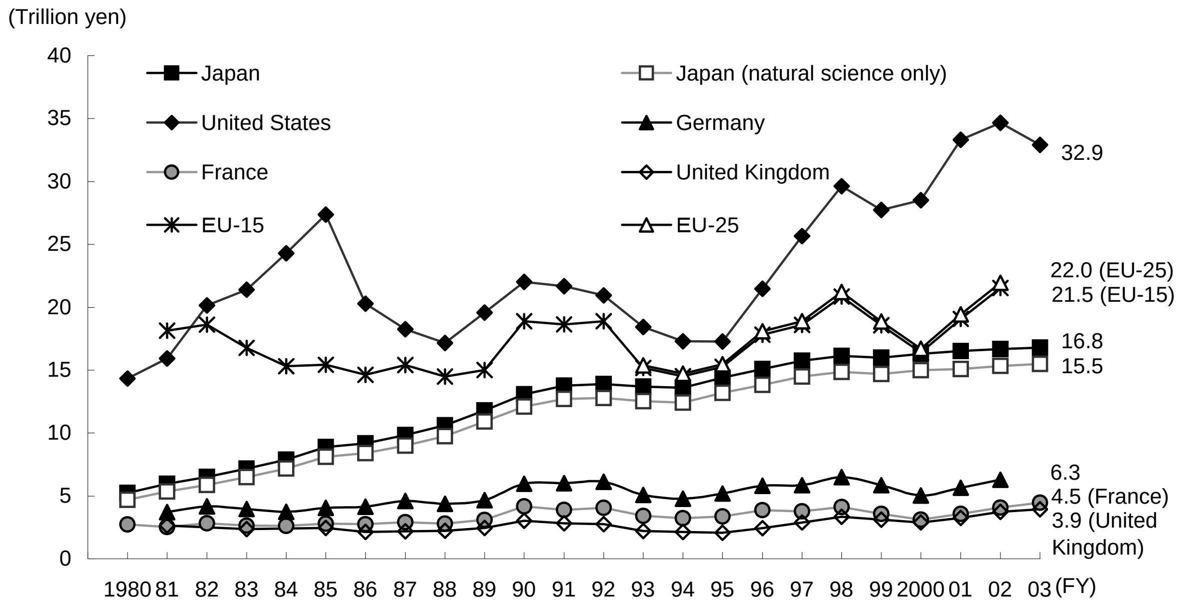


Figure 2-1-3 (1) Trends in R&D expenditures of selected countries－IMF exchange rate conversion

8 Definition of R&D expenditures: In the "Report on the Survey of Research and Development" by the Statistics Bureau of the Ministry of Internal Affairs and Communications, "research" is defined as "creative efforts and investigations conducted to obtain new knowledge about things, functions, and phenomena, or to open paths toward new applications of existing knowledge." All outlays incurred for these activities (labor costs, materials, expenditures on tangible fixed assets, etc.) are treated as research expenditures.

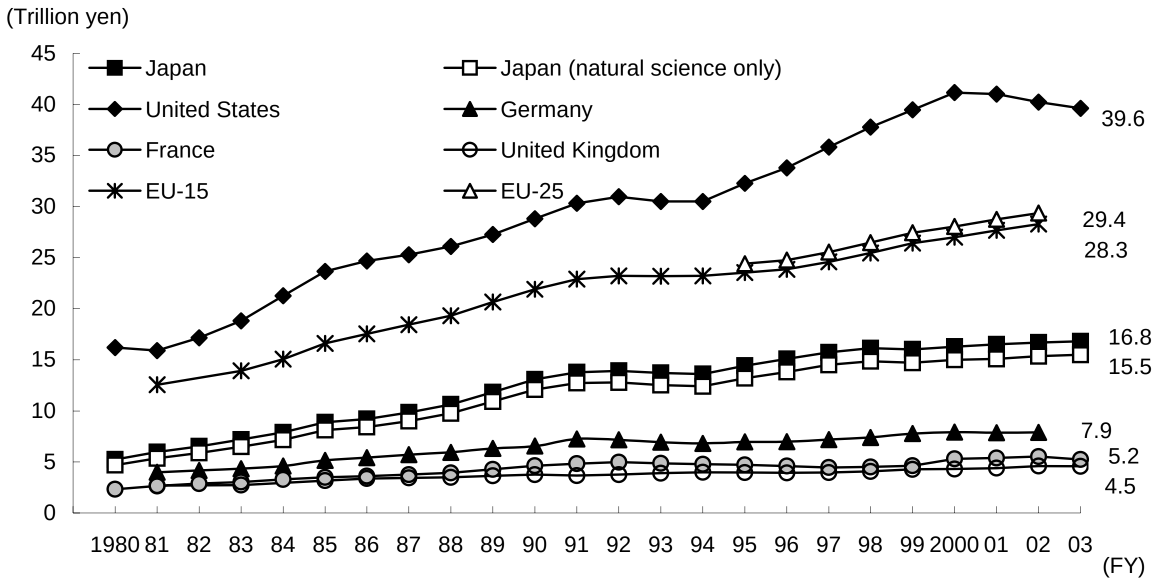


Figure 2-1-3 (2) Trends in R&D expenditures of selected countries－OECD purchasing power parity

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities. The figure for Japan shows also the amount for natural sciences only.
2. Japan added industries as new survey targets in FY1996 and FY2001.
3. U.S. figures for 2002 and later are provisional.
4. French figure for FY2003 is provisional.
5. The EU figures converted at the IMF currency conversion rate are estimates by Eurostat, while the figures based on the purchasing power parity conversion are OECD estimates.
6. EU-15 consists of 15 countries: Belgium, Germany, France, Italy, Luxembourg, Netherlands, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, and Sweden.
7. The EU-25 consists of the EU-15 and the following 10 countries: Cyprus, Czech, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia.

Source: Japan - Statistics Bureau. "Report on the Survey of Research and Development"
United States - National Science Foundation. "National Patterns of R&D Resources"
Germany - Federal Ministry of Education and Research. "Bundesbericht Forschung"
France - "Project de Loi de Finance: Rapport annexe sur l' Etat de la Recherche et du Developpement Technologique"
United Kingdom - Office for National Statistics. "Gross Domestic Expenditure on Research and Development"
Data before 1983 - OECD. "Main Science and Technology Indicators"
EU - Database on website of Eurostat (Statistical Office of the European Communities, hereinafter abbreviated)OECD. "Main Science and Technology Indicators"

2.1.1.2 Increase of R&D Expendit-u res in Real Terms

R&D expenditures in real terms for selected countries are calculated in order to compare nati-onal growth rates. The trend in the last decade sho-ws the United States, Germany[9] and Japan register-ring high growth. The high growth in the United St-ates is seemingly due to increased research and de-velopment investment by private corporations with the economic boom while that for Japan reflects expansion in private-sector companies' research and de-velopment investment, which registered nine straight years of growth beginning in FY1995, de-s-pite Japan's long-running economic slump (Figure 2-1-4).

9 Germany: The data for Germany in Chapter 2.1 and 2.2 cover Western Germany only until 1990, and Unified Germany from 1991. In Chapter 2.3, Germany before FY1990 refers to a combination of the figures of West and East Germany.

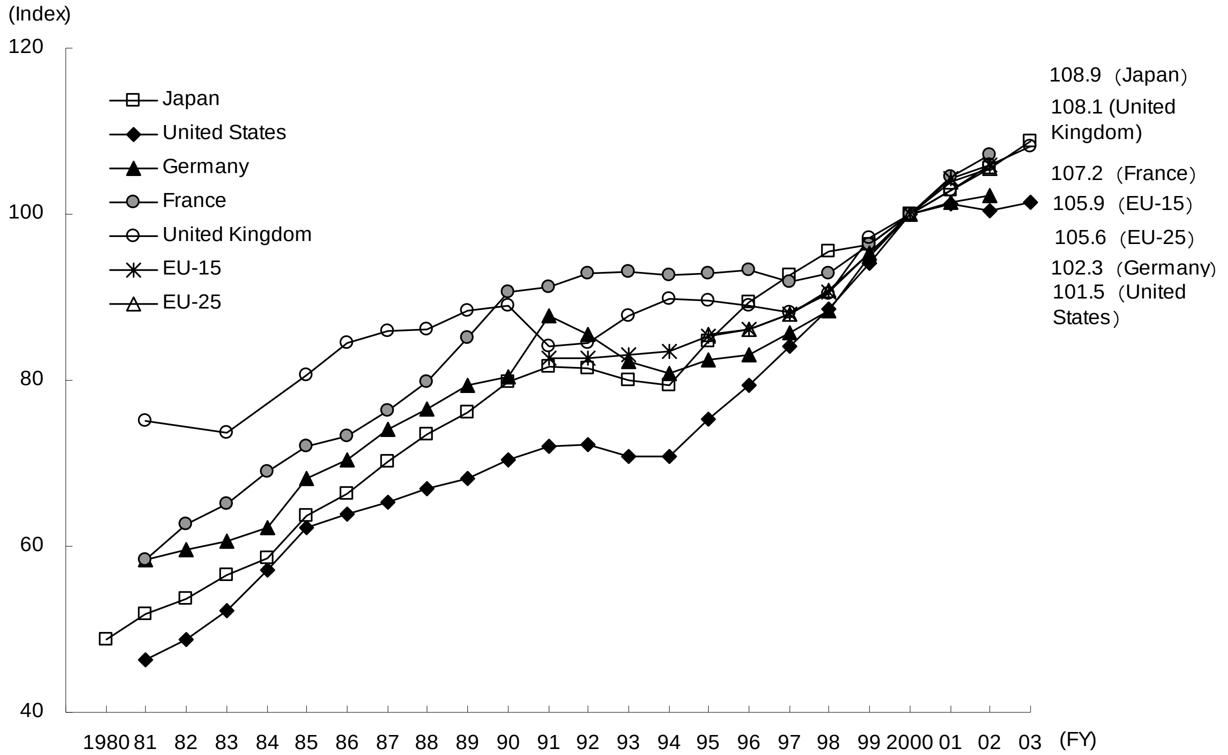


Figure 2-1-4 Growth of R&D expenditures (in real terms) in selected countries, with FY1995 as 100

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities.
2. Japan added industries as new survey targets in FY1996 and FY2001.
3. U.S. figure for 2002 is provisional.
4. EU figures are Eurostat estimates.
Source: France, Germany - OECD. "Main Science and Technology Indicators"
Others - Same as in Figure 2-1-3.

2.1.1.3 Expenditures as a Percentage of Gross Domestic Product (GDP)

Taking a look at the ratio of research expenditure to GDP as an indicator of nationwide R&D investment level, although decreases were observed in all countries in the early 1990s, the ratio started to increase in Japan and the United States in FY1995 and in European countries a little later. Japan continues to maintain the highest standard among the major advanced nations, at 3.35% of GDP in FY2003 (3.13%, using the FTE) (Figure 2-1-5).

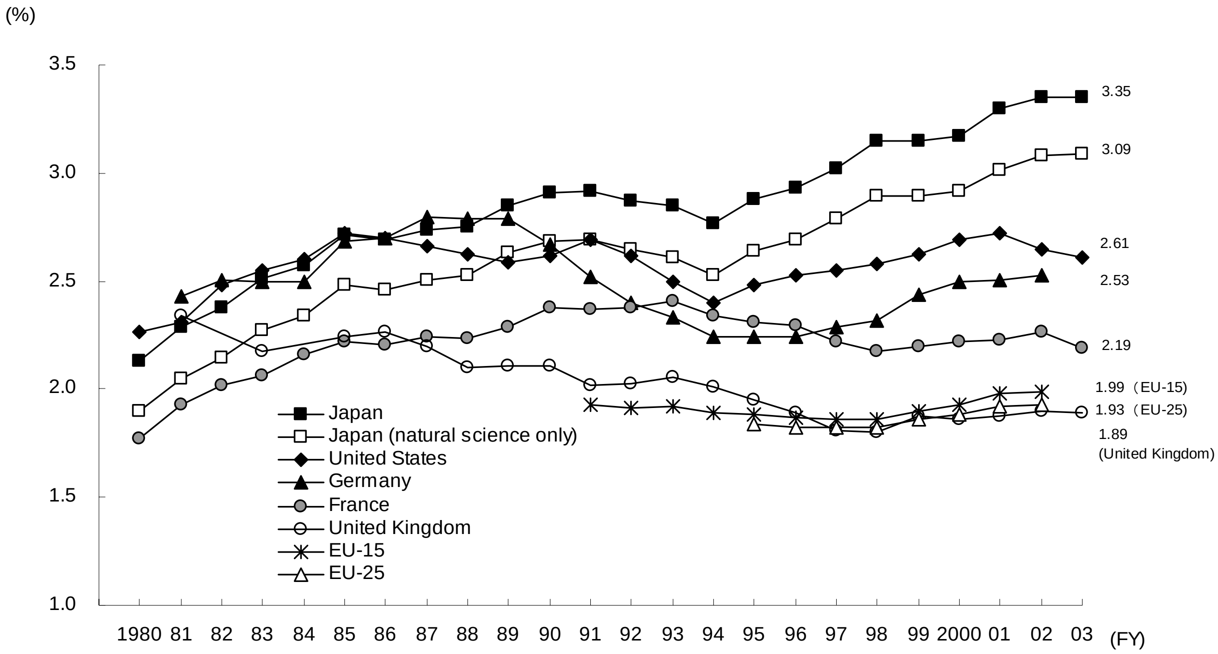


Figure 2-1-5 R&D expenditures as a percentage of GDP in selected countries

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities. The figures for Japan show also the amount for natural sciences only.
2. Japan added industries as new survey targets in FY1996 and FY2001.
3. U.S. figures for 2002 is provisional.
4. French figure for FY2003 is provisional.
5. EU figures are Eurostat estimates.

Source: Same as in Figure 2-1-3.

2.1.2 R&D Expenditures by Financing and Performance

R&D expenditures can be characterized by the financing and performance aspects of categorized sectors. The statistics compiled by the OECD categorize sectors into government[10], industry, universities and colleges, private research institutions, and overseas. Shares of R&D expenditures by financing and performance in selected countries are compared by OECD-categorized sectors.

2.1.2.1 Share of R&D Expenditures

A look at the share of total research expenditures held by governments shows France with the highest percentage, at about 40% of expenditures. Japan's share shows the lowest level among selected countries, a figure that is probably affected by such factors as the extremely low share held by defense research and by the large amount of activity in the private sector (Figure 2-1-6). The large share of R&D expenditures carried by the private sector means that the figures tend to be easily swayed by fluctuations in the business environment (Figure 2-1-7).

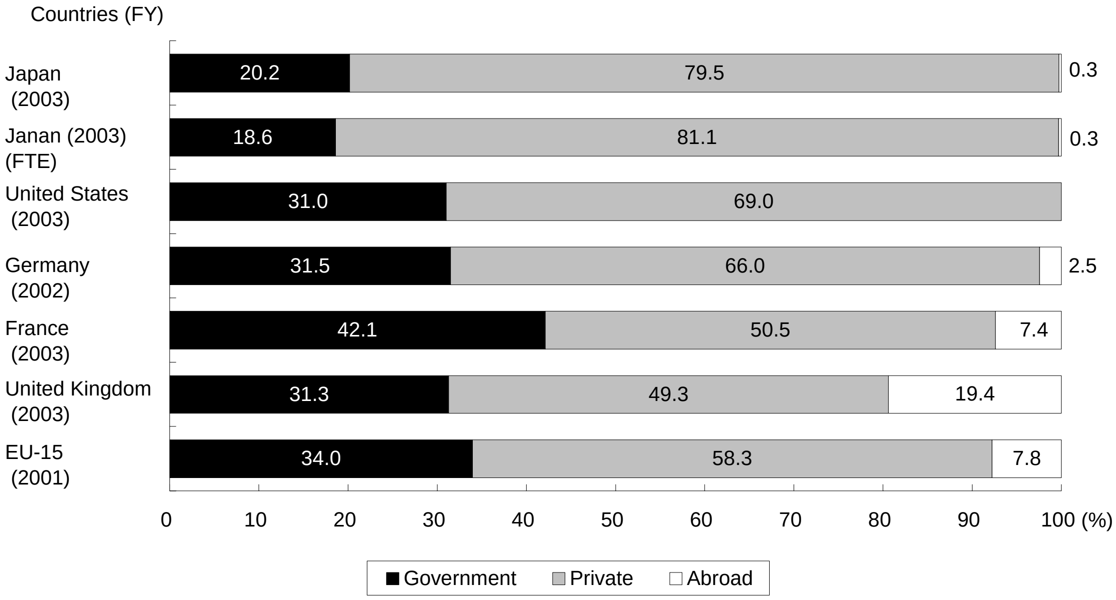


Figure 2-1-6 Share of R&D expenditures by financing sector in selected countries

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities. The figure for Japan includes the FTE value.
2. Japan's FTE value is calculated by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) based on the Statistics Bureau data.
3. U.S. and France figures are provisional.
4. Everything other than government and abroad is classified as private sector.
5. EU figures are OECD estimates.

Source: EU - OECD. "Main Science and Technology Indicators"
Others - Same as in Figure 2-1-3.

10 Government: In Chapters 2.1 and 2.2, when research expenses and numbers of researchers are expressed, "governments" means central governments and local governments (in the case of Japan, local public bodies).

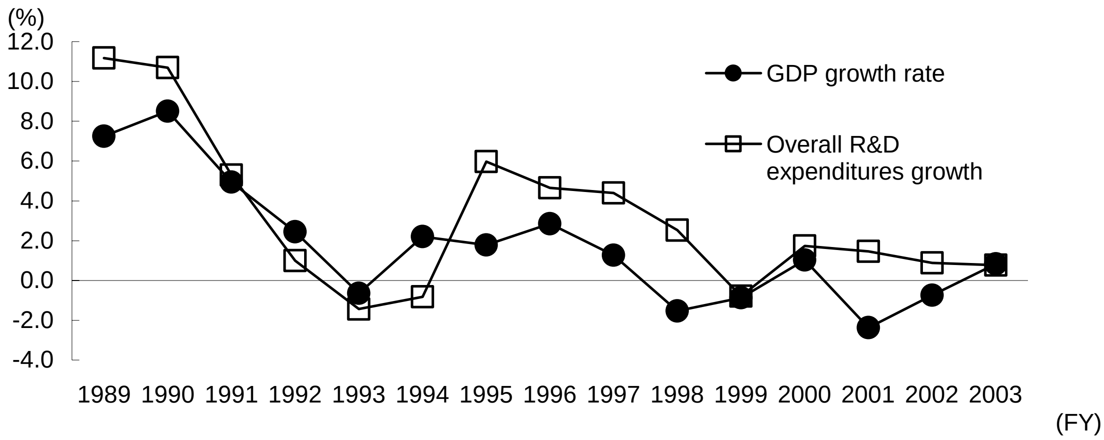


Figure 2-1-7 Trends in overall growth in R&D expenditures, and gross domestic product (GDP) growth rates

Source: Cabinet Office, Economic and Social Research Institute. "Annual Report on National Accounts", "Quarterly Estimates of GDP (preliminary Report)"
Statistics Bureau. "Report on the Survey of Research and Development"

The decline in defense-related R&D expenditures since the end of the Cold War structure has resulted in a gradual, continuous decline in the share of R&D expenditures financed by governments in other countries, although it has been on the rise in the United States and France in recent years. The share of R&D expenditures financed by the Japanese government has declined slightly for the fourth straight year (Figure 2-1-8).

For the government share of expenditures in relation to gross domestic product (GDP), France had the highest percentage, followed in order by the United States, Germany, Japan, and the United Kingdom. The shares for the United States, Germany and France have been increasing, while that for Japan has remained flat (Figure 2-1-9).

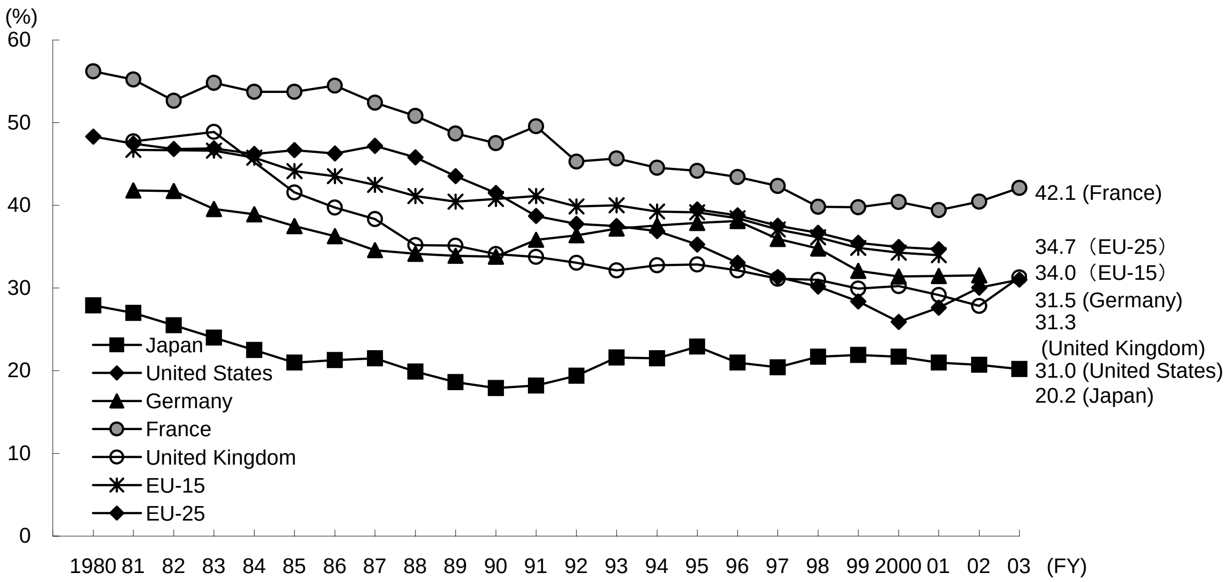


Figure 2-1-8 (1) Trends in government-financed R&D expenditures — Share of R&D expenditures financed by government

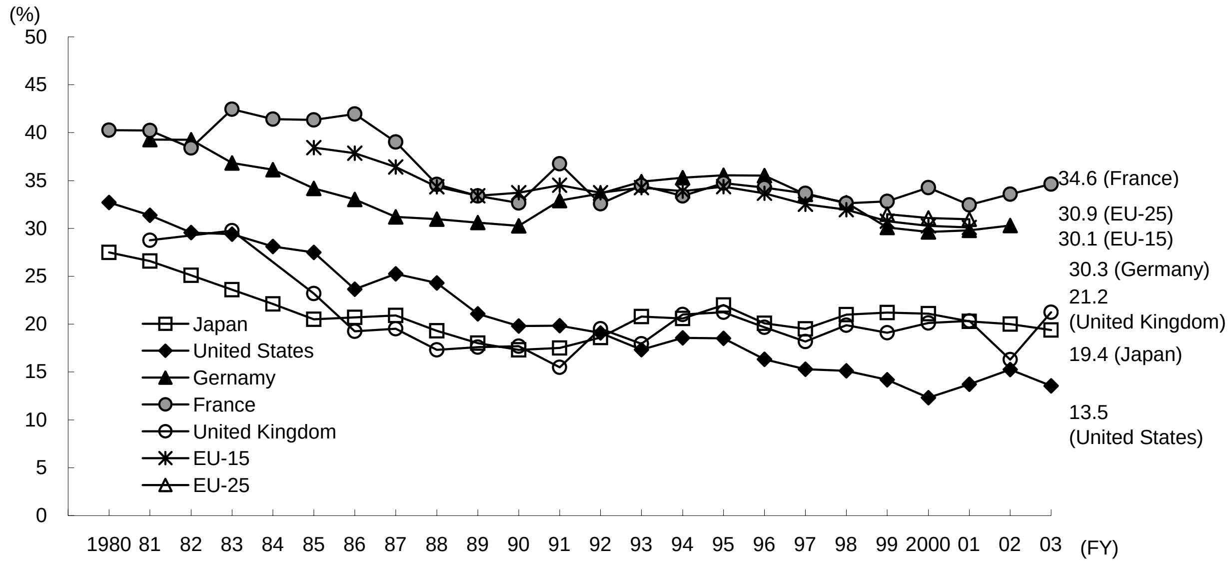


Figure2-1-8 (2) Trends in government-financed R&D expenditures － Share of R&D expenditures exclusive of defense-related R&D expenditures

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities.

2. Government percentages exclusive of defense-related research expenditures are calculated by the following equation.

$$\frac{\text{(Government - financed R \& D expenditures)} - \text{(Defense - related R \& D expenditures)}}{\text{(R \& D expenditures)} - \text{(Defense - related R \& D expenditures)}} \times 100\%$$

The national budget for defense-related R&D was used to derive the defense-related R&D expenditure. Therefore, this indicator should only be treated as a reference. It should be noted that the results of defense-related R&D often not only affect defense but also contribute to the development of science and technology for the civil welfare.

3. Japan added industries as new survey targets in FY1996 and FY2001.
4. U.S. figures for FY2002 and later are provisional.
5. French figure for FY2003 is provisional.
6. EU government share is OECD estimates.

Source: Defense-related R&D expenditures in Japan － MEXT. "Budget for Science and Technology".

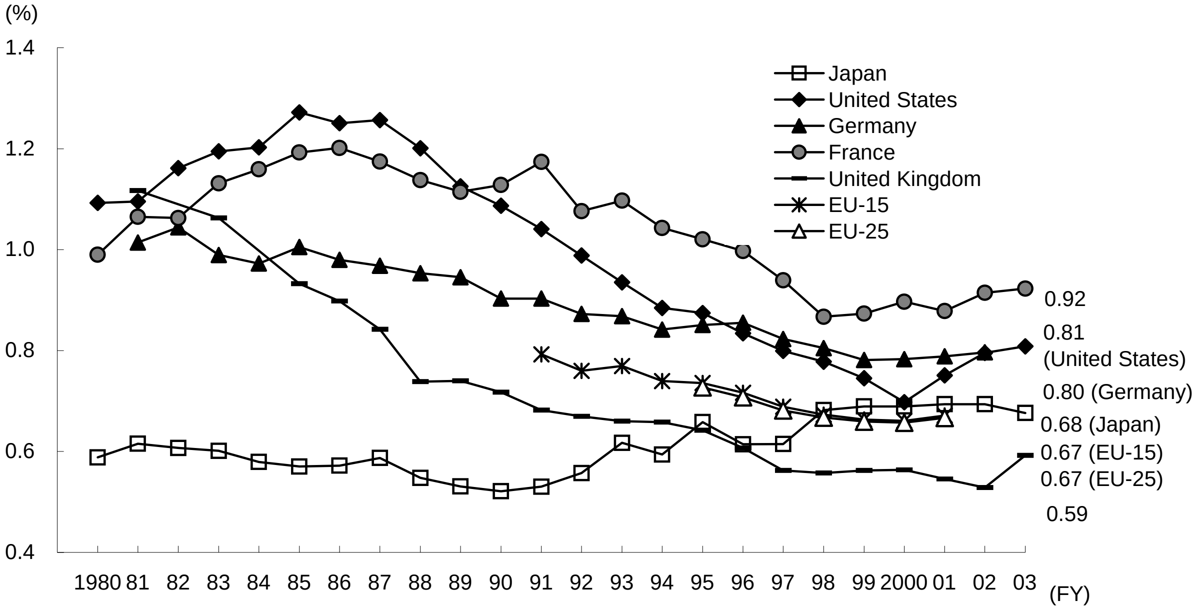


Figure 2-1-9 Trends in the proportion of government-financed R&D expenditures to gross domestic product (GDP) in selected countries

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities.
2. Japan added industries as new survey targets in FY1996 and FY2001.
3. U.S. figures for 2002 is provisional.
4. French data for FY2003 is provisional.
Source: Same as in Figure 2-1-3.

2.1.2.2 Share of R&D expenditures by performance

Industry spends approximately two-thirds of total R&D expenditures in all selected countries, demonstrating just how large a role private-sector companies play in research and development. Among the selected countries, government research institutions' share of R&D expenditures was highest in France (Figure 2-1-10).

In the selected countries, the trends in real R&D expenditures by type of organization reveals that industry has contributed the most greatly in all countries to growth in R&D expenditures (Figure 2-1-11).

In Japan, a look at the contribution by type of organization to year-on-year growth of R&D expenditures (in real terms) shows that R&D expenses at private companies have a large effect on trends in Japan's R&D expenses. For the degree of contribution, private companies made a positive contribution from FY1995 to FY1998, but then fell into a negative contribution for FY1999. Private companies returned to a positive contribution in FY2000 (Figure 2-1-12).

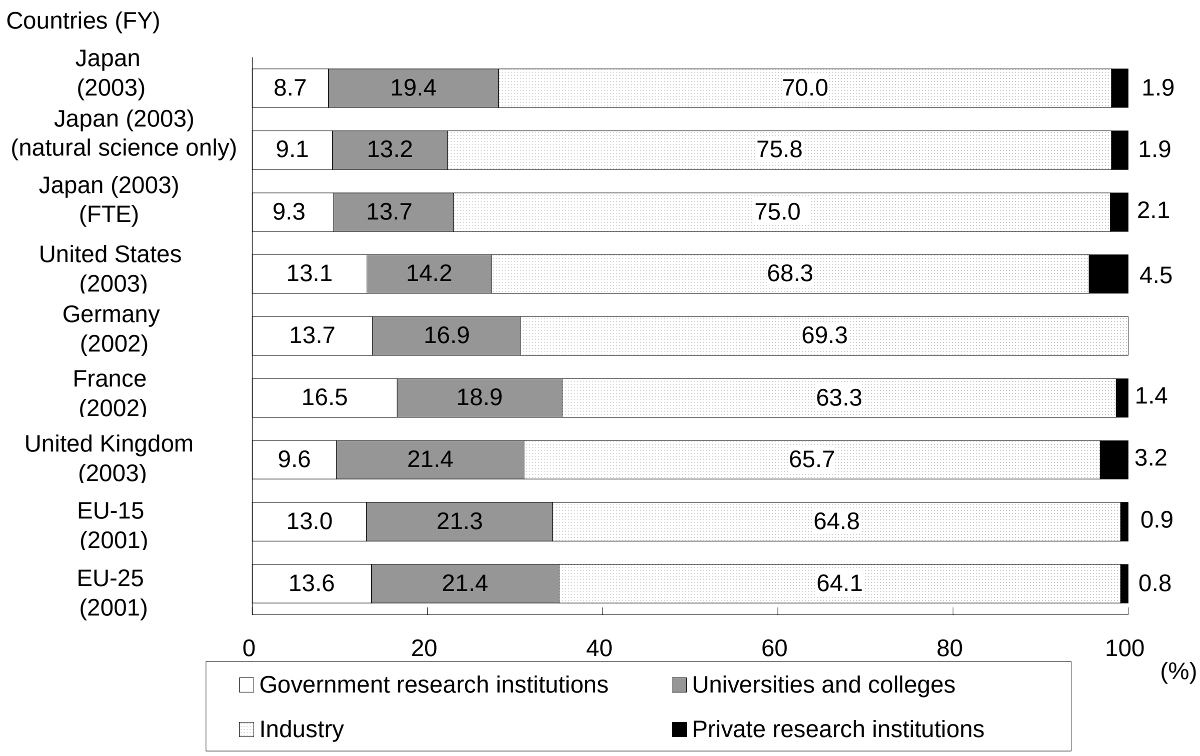


Figure 2-1-10 Share of R&D expenditures by performance sector in selected countries

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities.
The figures for Japan show also the amount for natural sciences only and FTE value.
2. Figures for Japan's FTE value are prepared from the Statistics Bureau data.
3. U.S. figures are provisional. In addition, Germany's re-search expenditures at "private research institutions" are included in "government" research institutions.

Source: France - OECD. "Main Science and Technology Indicators"
Others - Same as in Figure 2-1-3.

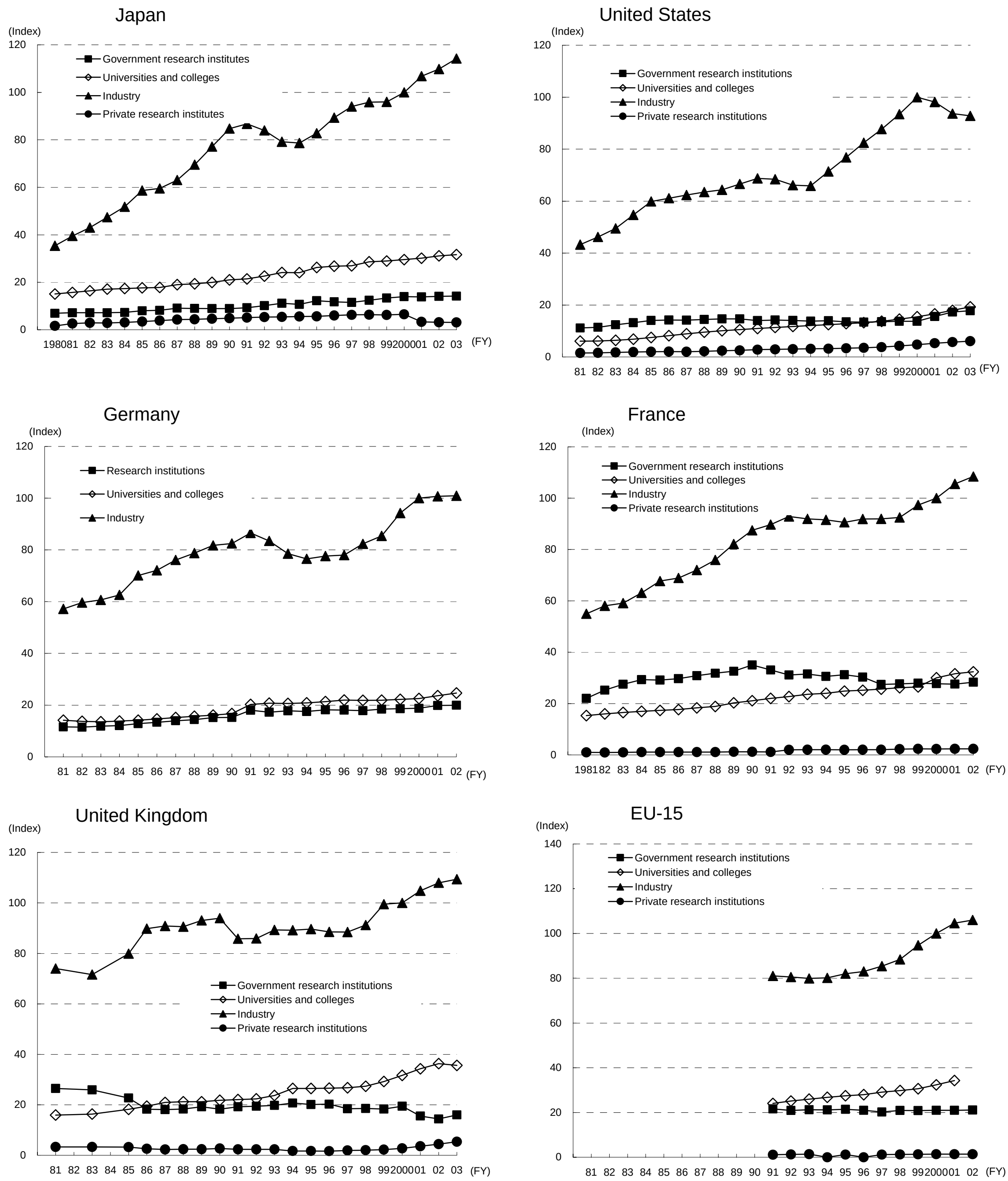


Figure 2-1-11 R&D expenditures growth (in real terms) by sector in selected countries

Notes:
1. All countries include social sciences and humanities for purposes of international comparison. In addition, industry's real research expenditures for FY2000 are set at 100.
2. U.S. data are for FY2002 is provisional.
3. Since no differentiation has been made between "government research institutions" and "private research institutions" in Germany, they are listed simply as "research institutions."
4. Japan added some industries as new survey targets in FY1996 and FY2001.
5. EU figures are Eurostat estimates.

Source: France, Gernany - OECD. "Main Science and Technology Indicators"
Others - Same as in Figure 2-1-3.

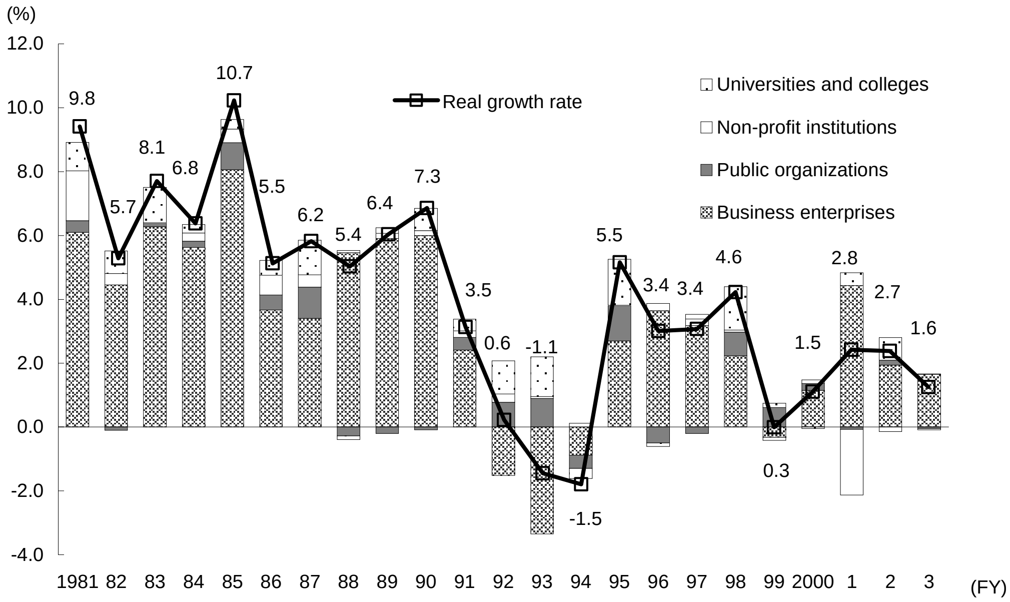


Figure 2-1-12 The contribution by organization to the year-on-year growth rate in Japan's real R&D expenditures

Notes: 1. The deflation referring for each sector is based on FY1995.
2. Japan added some industries as new survey targets in FY1996 and FY2001.
3. Survey coverage categories were changed in FY2001; figures up to FY2000 are for the following categories:

FY2005	Up to FY2004
Companies	Business Enterprises
Private research	Non-profit institutions
Government research institutions	Public organizations

Source: Statistics Bureau. "Report on the Survey of Research and Development", data of Statistics Bureau

2.1.2.3 R&D Expense Flows

Japan's R&D expense flows between sources of funding and sectors of performance reveal that about 49% of government funding goes to universities, about 42% to government research institutions, and about 9% to the private sector. In private-sector funding, by contrast, about 98.6% goes to the private sector, with about 1.0% to universities and about 0.3% to government research institutions.

Comparing flows of R&D expenditures between the financing and performance sectors shows that in Japan there is a lesser flow of R&D expenditures between sectors (government, industry, universities and colleges) than exists in other countries. The ratio of private sector R&D expenditures funded by government is high in the United States and in France. The United Kingdom is characterized by a large proportion of R&D expenditures being borne from abroad (Figure 2-1-13).

On the reason why R&D expenses flow from government to the private sector, and from the private sector to universities, are so low in Japan, it can be pointed out that research and development in Japan often relies more on private-sector activities than it does in other countries. The large flows from government to the private sector in the United States, France, and elsewhere are due to the large flows of aerospace research and defense research funds. Moreover, a major reason for the large flow of research funds from foreign countries into the

United Kingdom is likely the existence in that country of many foreign-capitalized corporations with research and development centers in operation, which would therefore be sending R&D funds to the United Kingdom from their own home countries.

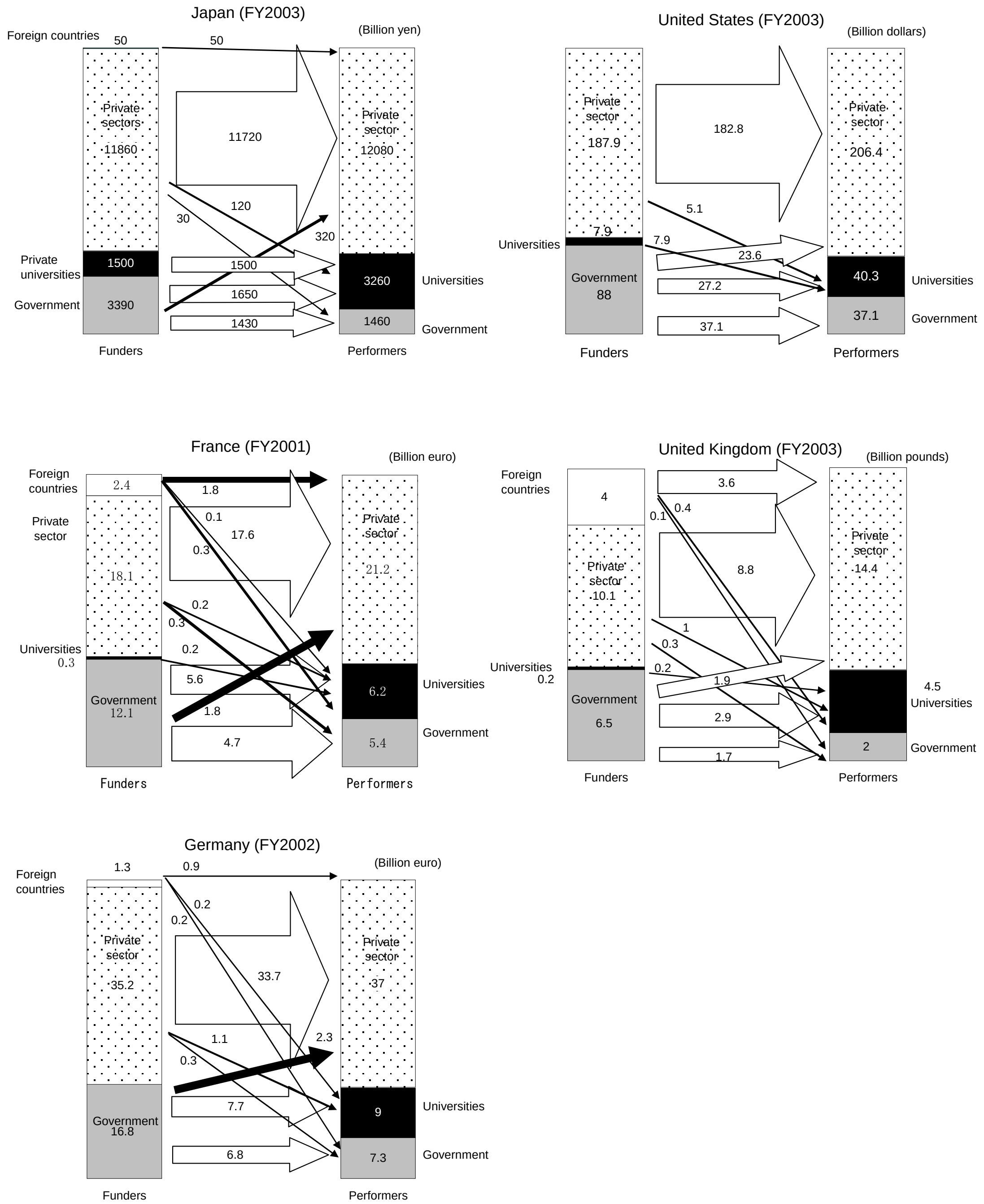


Figure 2-1-13 R&D expense flows in selected countries

Notes: 1. For comparison, statistics for all countries include research in social sciences and humanities.
2. U.S. figures are for calendar years and provisional.
3. In Germany, data from private research institutions are included in the government figures, and in the other countries are included in the private sector.

Source: France - OECD. "Basic Science and Technology Statistics"
Other countries - Same as in Figure 2-1-3.

2.1.3 R&D Expenditures per Researcher

Because of differences in how researchers are targeted, in survey methods used, and in ex-change rates, simple comparisons between countries of R&D expenditures per researcher may not be pre-cise. Nevertheless, a look at statistics for five major countries shows Japan ranked fourth when the yen was converted to the IMF exchange rate, and ran-ked last when the OECD's purchasing power parity conversion rate was used (Figure 2-1-14).

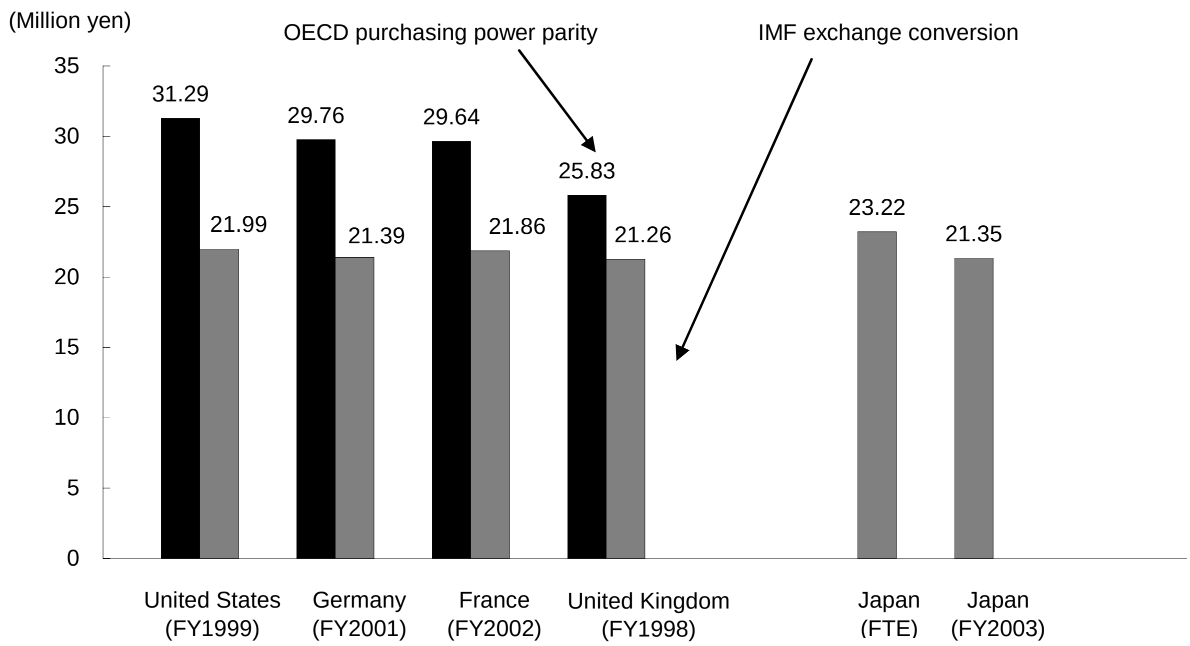


Figure 2-1-14 R&D expenditures per researcher

Notes: 1. For comparison, figures for all countries include social sciences and humanities. The figure for Japan includes the FTE value.
2. The FTE values for Japan were estimated by the Ministry of Education, Culture, Sports, Science and Technology based on data issued by the Statistics Bureau of the Ministry of Internal Affairs and Communications.
Source: Numbers of researchers in France and UK -- OECD "Main Science and Technology Indicators"
Others - Same as in Figure 2-1-3.

Japan's R&D expenditures per researcher have been hovering around 22 million yen in recent years.

For R&D expenditures per researcher by type of organization in FY2003, public organizations and non-profit institutions with high ratios of non-personnel R&D expenditures also registered high R&D expenditures per researcher, while universities and colleges, where the ratio of non-personnel R&D expenditures were low, registered lower expendit-ures per researcher (Figure 2-1-15).

If we limit the R&D expenditures per researcher at universities and colleges to those invested in those teachers, then the national universities with particularly high non-personnel R&D expenditures have the highest expenditures per researcher, follo-wed by private universities and other public uni-versities. By specialty (academic field), the ranki-ngs were, in order, physical science, engineering, agricultural sciences, and health sciences (Figure 2-1-16).

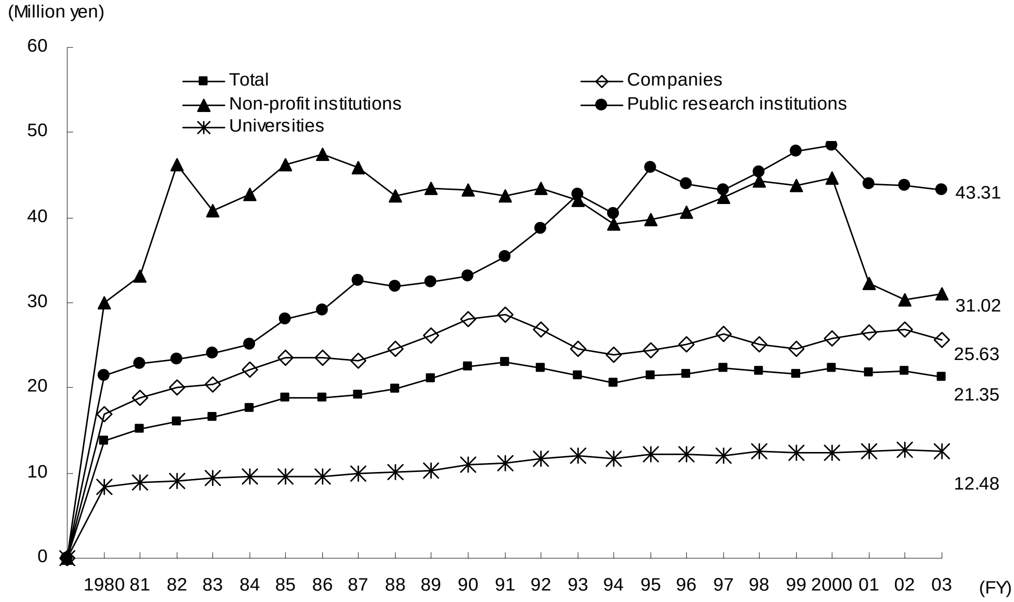


Figure 2-1-15 (1) Trends in R&D expenditures per researcher (in nominal terms)

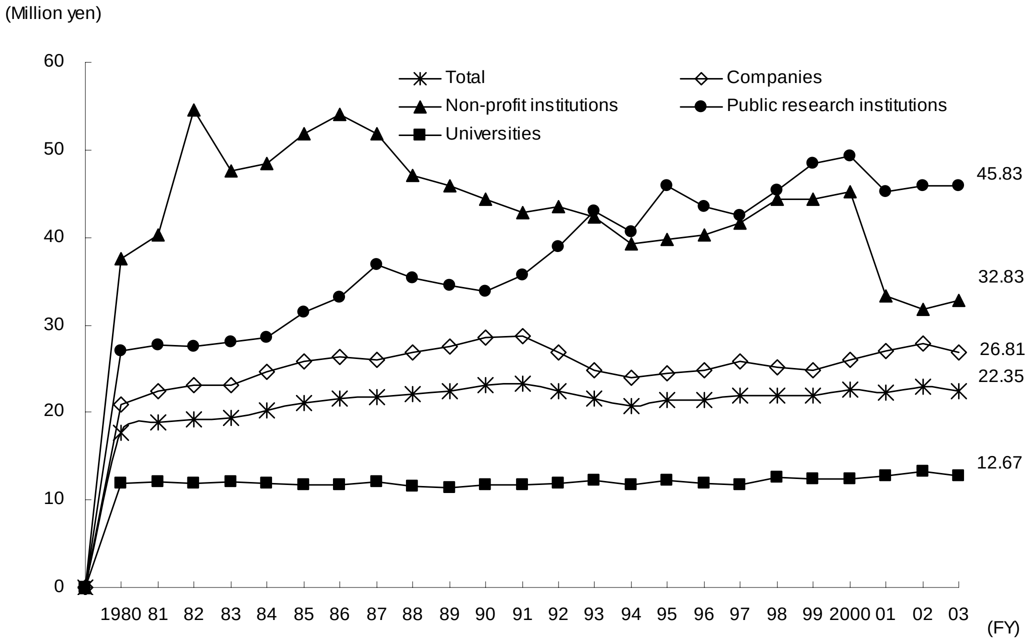


Figure 2-1-15 (2) Trends in R&D expenditures per researcher (in real terms)

Note: 1. Survey coverage categories were changed in FY2001; figures up to FY2000 are for the following categories:

FY2003	Up to FY2002
Business enterprises	Companies
Non-profit institutions	Private research institutions
Public organizations	Government research institutions

2. Figures in real terms are converted in constant FY1995.

Source: Statistics Bureau. "Report on the Survey of Research and Development", Data of the Statistics Bureau

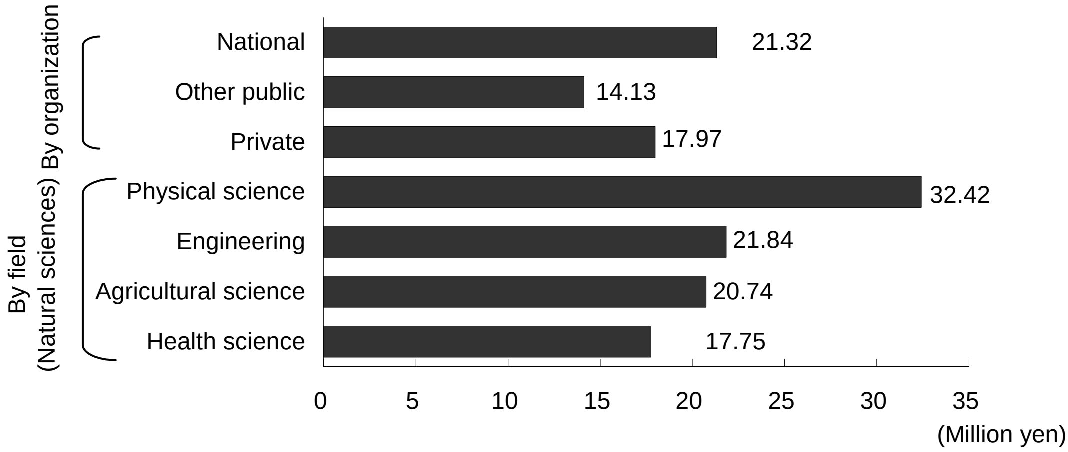


Figure 2-1-16 R&D expenditures per researcher at universities and colleges (FY2003)

Notes: 1. Figures by organization include the humanities and social sciences.
2. Figures are for faculty members only, out of all researchers.
3. The number of researchers is as of March 31, 2004.
Source: Statistics Bureau. "Report on the Survey of Research and Development"

2.1.3.1 R&D expenditures per Researcher, by Type of Industry

For the R&D expenditures per researcher at companies by type of industry, the top five industrial categories were led by the telecommunications industry, with its high purchase rates of large machinery, equipment, facilities, and other tangible fixed assets, and followed by the broad-cast industry, the pharmaceutical industry, academic research institutions, and the transportation industry (Figure 2-1-17).

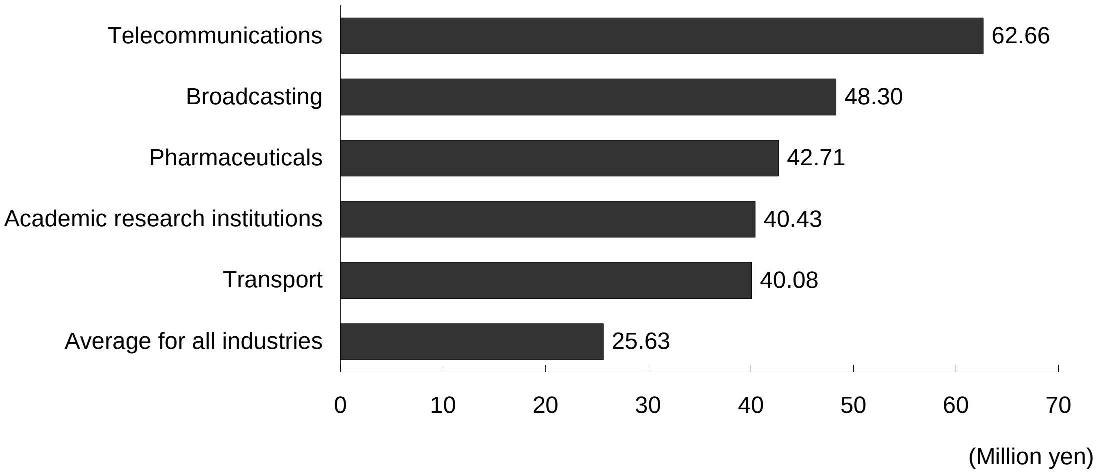


Figure 2-1-17 R&D expenditures per researcher, by industry (top five industrial categories) (FY2003)

Note: The number of researchers is as of March 31, 2004.
Source: Statistics Bureau. "Report on the Survey of Research and Development"

2.1.4 R&D Expenditures by Character of Work

Classification into basic research, applied research, and development[11], may differ from country to country. Although it is difficult to make a comparison due to differences in distinctions between the three among the countries concerned, R&D expenditure data by character of work generally reflects the R&D activity of each country.

Recent stati- stical data for Japan, the United States, Germany and France shows that France and Ger-many spend more on basic research, and that Japan spends less on basic research (Figure 2-1-18).

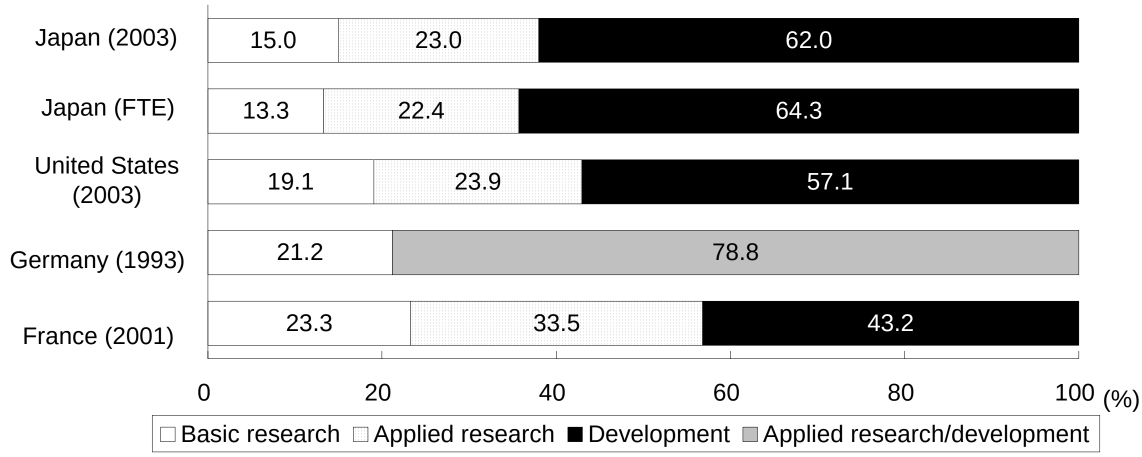


Figure 2-1-18 R&D expenditures by character of work in selected countries

Notes: 1. Figures for Japan's FTE value are prepared from Statistics Bureau data.
2. There is no distinction in Germany between applied research and development.
Source: Japan, U.S. - Same as in Figure 2-1-3.
Germany, France - OECD. "Basic Science and Technology Statistics"

A look at the trend for the share held by basic research in selected countries shows that Japan's allotment for basic research began rising in FY1991, but then turned downward in FY1996 and rose again in FY1998. The United States, while showing some minor fluctuations, has generally increased its share of basic research since FY1986 (Figure 2-1-19).

In Japan, research expenses in the different types of organizations, classified into companies, research institutions, and universities and colleges, are clearly differentiated in structure. For companies, development plays an extremely important role due to their corporate business functions, and this trend has become even more intensified in recent years. On the other hand, universities and colleges place emphasis on basic research and applied research. Non-profit institutions and public organizations, meanwhile, both exhibit intermediate trends (Figures 2-1-20, 21).

11 Research classification: "Report on the Survey of Research and Development" by the Statistics Bureau defines research by type of characteristics as follows:
- Basic research: Basic or experimental research conducted with no direct consideration for specific applications or uses, in order to form hypotheses or theories, or to obtain new knowledge about phenomena or observable reality.
- Applied research: Research that utilizes knowledge discovered through basic research to confirm the feasibility of commercialization for a specific objective, and research that searches for new applications for methods that have already been commercialized.
- Experimental development: Research that utilizes knowledge obtained from basic research, applied research, or actual experience for the objective of introducing new materials, devices, products, systems, processes, etc., or of making improvements to those already existing.

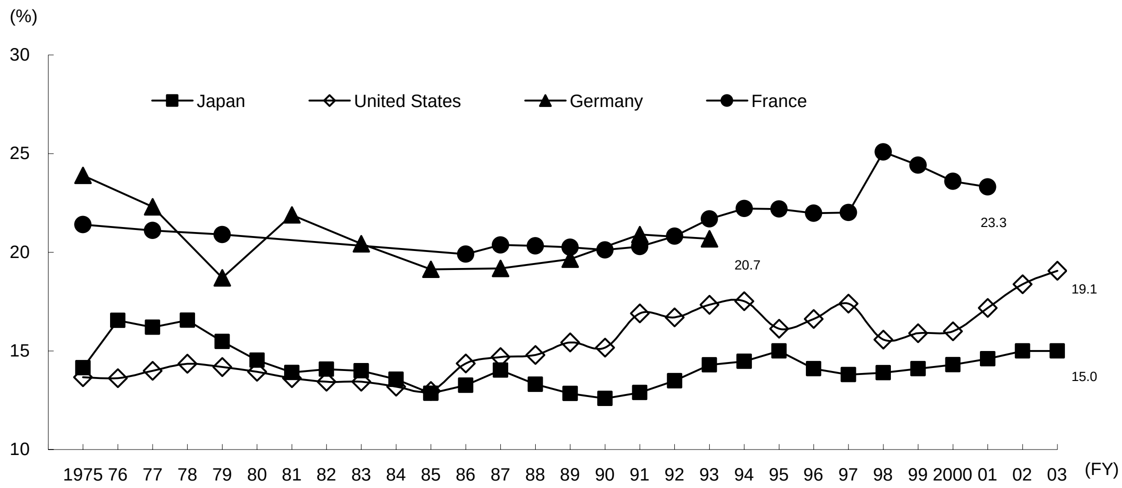


Figure 2-1-19 Trends in the proportion of basic research expenditures in selected countries

Source: Japan, United States - Same as in Figure 2-1-3.
Germany, France - OECD. "Basic Science and Technology Statistics"

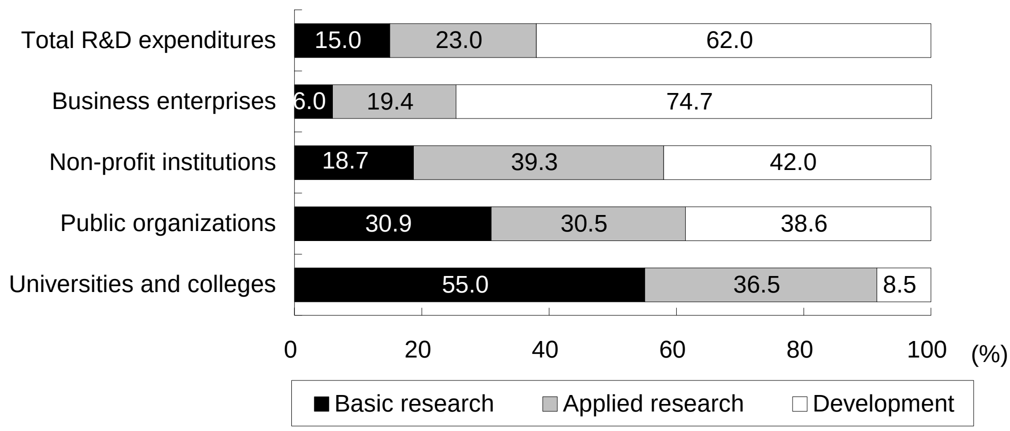


Figure 2-1-20 Composition of R&D expenditures by character of work by sector in Japan (FY2003)

Note: The figures are for the composition of R&D expenditures by character of work in the natural sciences (physical science, engineering, agricultural science, and health science).
Source: Statistics Bureau. "Report on the Survey of Research and Development"

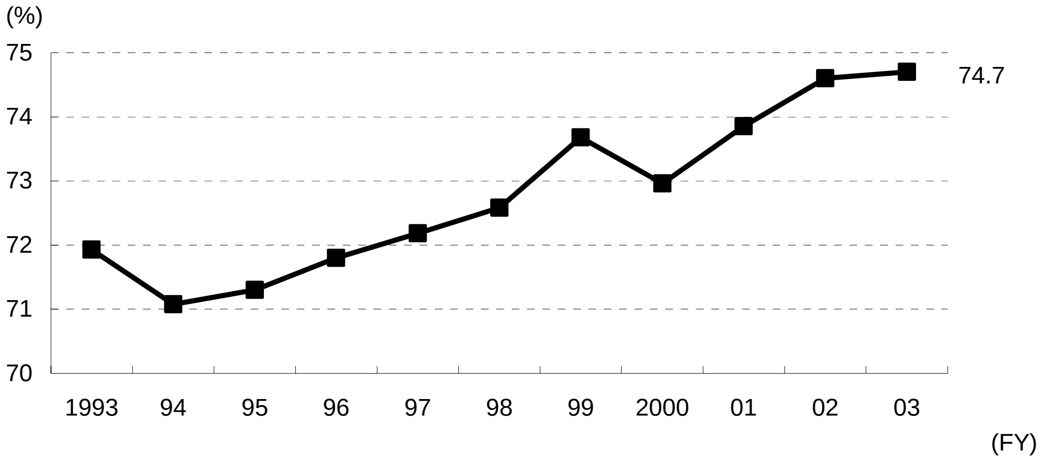


Figure 2-1-21 Trend in the share of development expenditures out of total research expenditures of companies

Note: The share of research expenditures in only for the natural sciences.
Source: Statictics Bereau. "Report on the Survey of Research and Development"

2.1.5 R&D Expenditures by Industry

2.1.5.1 R&D Expenditures by Industry

While the statistical survey range varies from country to country, making simple comparisons difficult, it is plain that research expenses in the service industry have been increasing in all countries since the mid-1980s, in response to the shift of industrial structure from manufacturing to ser-vices in major countries. The figures for services are particularly high in the United States and the United Kingdom (Figure 2-1-22).

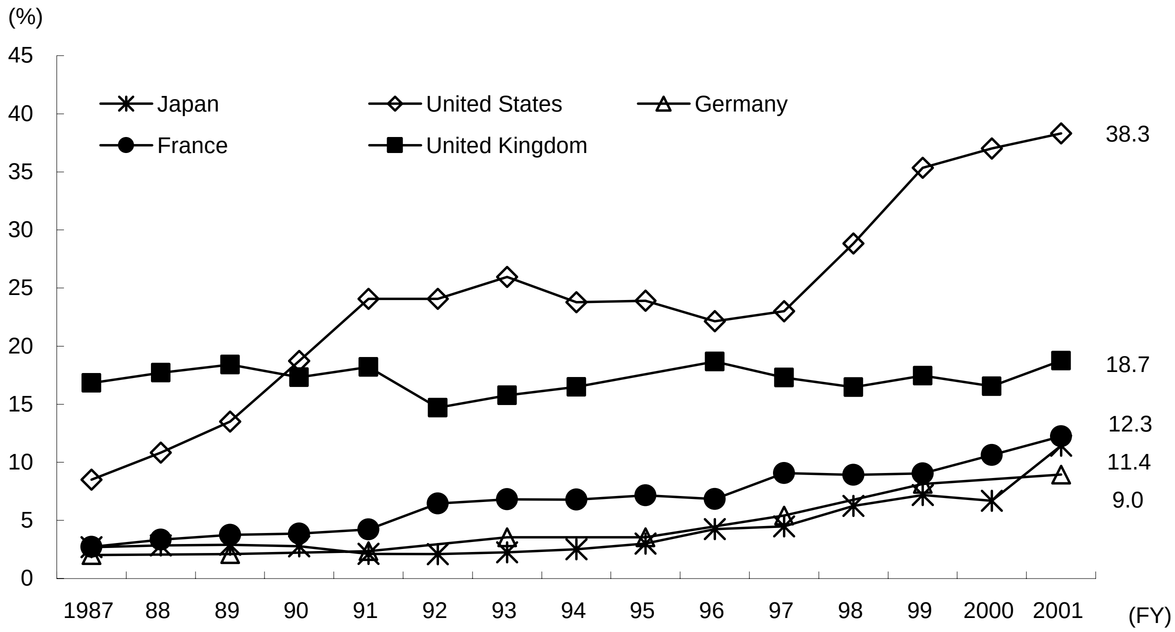


Figure 2-1-22 Share of services industry in total R&D expenditures

Notes: 1. For purposes of international comparison, the figures for each country include the humanities and social sciences.
2. Japan added some industries as new survey targets in FY1996 and FY2001.
Source: OECD. "Basic Science and Technology Statistics"

2.1.5.2 R&D Expenditures by Type of Manufacturing Industry

For the top six R&D expenditure manufacturing industry sectors in major countries, all countries showed high ratios for the electronics industry, the automobile industry, and the pharmaceuticals industry, which are all subject to severe competition internationally. For the total share of the top three industries, the information and telecommunications machinery and equipment industry, the automobile industry, and the electrical machinery and apparatuses industry accounted for 48.0% of the total in Japan; in the United States, the chemical industry, the precision instrument, and the automobile industry accounted for 49.6%; in Germany, the automobile industry, the electronics industry, and other machinery industries accounted for 55.5%; in France, the automobile industry, the electronics industry, and the pharmaceuticals industry accounted for 47.7%; and in the United Kingdom, the pharmaceuticals industry, the aerospace industry, and the electronics industry accounted for 53.2% of the total. In all major countries, therefore, R&D expenses are concentrated in the top-ranking industries (Figure 2-1-23).

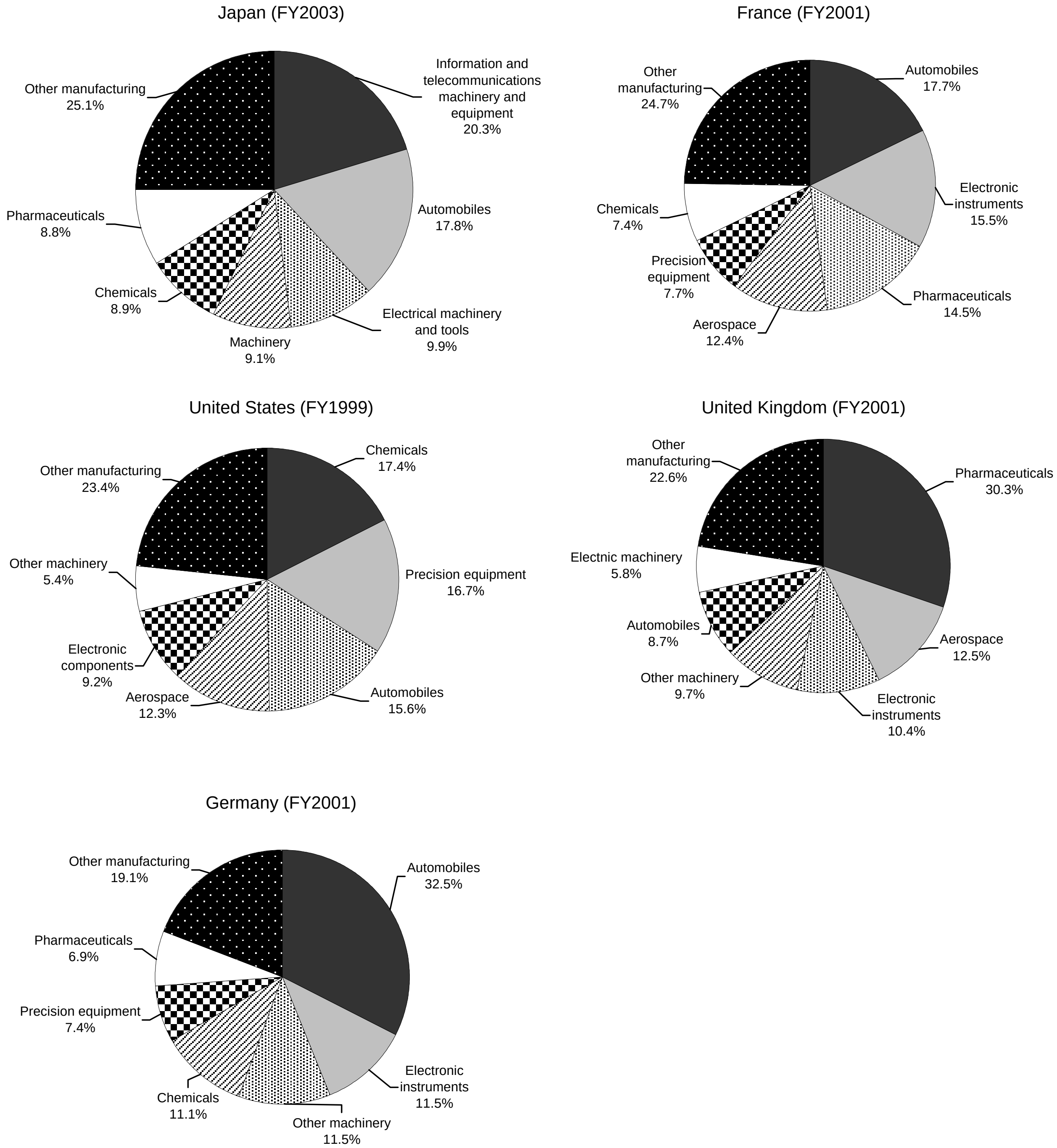


Figure 2-1-23 Manufacturing industry research expenditures in selected countries, by Industry

Source: Japan - Statistics Bureau. "Report on the Survey of Research and Development"
Other countries - OECD. "Basic Science and Technology Statistics"