Chapter 2 Progress in R&D System Reforms in Other Countries and Other Issues

1 Progress in R&D System Reforms in Other Countries

1 Shifts toward International Competitiveness- and Innovation-oriented S&T Policies

Struggling to win in the modern age of megacompetition, other countries assign high priority to policies that encourage innovation and create new social and economic value based on S&T achievements in order to maintain and enhance competitiveness. Efforts are being made at the national level to reform R&D systems and reinforce R&D budgets and other research resources in order to effectively encourage innovation.

When the US, the world champion in S&T, and the EU countries, as well as the rapidly growing new economies of China and Russia, are fully committed to the creation of science and technology-driven innovation, it is necessary for Japan to do the same with a genuine sense of urgency.

Of particular note is the rapid establishment of S&T and innovation policies of the US, starting from the publication of the *Innovate America: Thriving in a World of Challenge and Change* report (or the *Palmisano Report*) in 2004 to the enactment of the America COMPTES Act. In the course of this series of moves, proposals were made for new initiatives to radically increase the budgets of research-related institutions as represented by the doubled budget of the National Science Foundation (NSF), increasing and expanding high-risk research projects, and reforming the R&D system, including fostering scientists and engineers. Moreover, there were also additional proposals for shaping measures to encourage new innovation, and establishing "services science". These proposals have begun to have a significant influence on S&T policymaking in the US and other countries.

2 Enactment of the America COMPETES Act, Revision of China's Science and Technology Progress Law, and Other Issues

This subsection outlines some of the recent major activities of foreign governments that typically signify the shift toward S&T policies with a strong orientation toward international competiveness and the creation of innovation:

(1) Enactment of the America COMPETES Act

In the US, the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (or the America COMPETES Act) was enacted in August 2007. This epoch-making act comprehensively provides for the creation of R&D-driven innovation and investment in human resource development, with a radically increasing government budget for these purposes to ensure that the US maintains a competitive edge in the context of increasingly intense international competition from the rapid economic growth of China and India.

1) Background to the enactment of the America COMPETES Act

The rapid development of newly emerging counties and the intensification of global competition in recent years have led to the strong recognition of the need to build competitiveness, prompting industry and academia to present many bills to enhance S&T. The *Palmisano Report* in 2004, and the *Augustine Report* presented proposals for enhancing US competitiveness and urged Congress to develop individual proposals to sharpen the US competitive edge. Prompted by such a series of moves, the White House drafted the American Competitiveness Initiative (delivered in the 2006 Presidential State of the Union Address), which was the impetus for the enactment of the Act (Table 1-2-1).

a) The Innovate America

The process leading to the enactment of the America COMPETES Act was triggered by a report titled the *Innovate America* (the *Palmisano Report*) compiled in December 2004 by the Council on Competitiveness's National Innovation Initiative (Co-Chair: Samuel J. Palmisano, Chairman and CEO of IBM Corporation). Concluding that "Innovation will be the single most important factor in determining America's success," the report proposed policymaking from three perspectives, namely, talent, investment, and infrastructure, as a strategy for turning American society into an optimum environment for innovation. Moreover, out of an awareness that insufficient efforts had been made for R&D concerning new forms of innovation or service industries that account for a large portion of GDP or employment, the report made such proposals as the promotion of Services Sciences, Management and Engineering (SSME). These suggestions gave rise to active discussions.

b) Rising Above the Gathering Storm

The *Palmisano Report* led to active discussions in various quarters of American society regarding the enhancement of competitiveness. The House and Senate, and S&T policymakers of both the Republican and Democrat Parties requested the National Academies to study strategies for the US government to ensure that the US will succeed in the 21st century in terms of international competitiveness, prosperity, and security. As a result, the National Academies prepared a report titled the *Rising Above the Gathering Storm* (or the *Augustine Report*).

The *Augustine Report* was compiled in October 2005 by the Committee on Prospering in the Global Economy of the 21st Century (Chair: Norman R. Augustine, Retired Chairman and CEO of Lockheed Martin Corporation). The report says: "The United States has enjoyed the economic and strategic leadership since World War II; however, it has begun to lose its strength in markets and S&T fields over recent years. Urgent and comprehensive measures must be taken." Paying particular attention to China and India, the report proposes for the improvement of math and science education at elementary and secondary schools, the enhancement of science and engineering research, the improvement of science and engineering in higher education, and the creation of pro-innovation environments in order to meet the challenge from the two countries.

c) The American Competitiveness Initiative

The publication of the *Augustine Report* further invigorated discussions in Congress. In response, President George W. Bush announced in the 2006 Presidential State-of-the-Union Address, the American Competitiveness Initiative, which calls for the doubling of the government-funded budgets of the National Science Foundation (NSF), the Department of Energy's Office of Science (DOE/SC), and the National Institute of Standards and Technology (NIST) over a ten-year period, permanentization of corporate R&D tax exemptions, and fundamental enhancement of math and science education.

Table1-2-1 Major Initiatives for Enhancing the US Competitiveness

	Innovate America Council on Competitiveness (December 2004)	**Rising Above the Gathering Storm** National Academies (October 2005)	**American Competitiveness Initiative** Domestic Policy Council Office of Science and Technology Policy (February 2006)
Talent	• Build a National Innovation Education Strategy. • Catalyze the Next Generation of American Innovators. • Empower Workers to Succeed in the Global Economy.	• Annually recruit 10,000 science and mathematics teachers • Strengthen the skills of 250,000 teachers through training and education programs at summer institutes • Increase the number of students aiming to obtain degrees	• Enhance math and science education at elementary and secondary schools. • Enhance workforce training programs. • Comprehensive plan for immigration reform to attract and retain talented foreign nationals
Investment	• Revitalize Frontier and Multidisciplinary Research. • Energize the Entrepreneurial Economy. • Reinforce Risk-Taking and Long-Term Investment.	• Increase funding for long-term basic research by 10% annually • Research grants for outstanding early-career researchers • Establish a National Coordination Office for Advanced Research Instrumentation and Facilities • Institute a “Presidential Innovation Award”	• Double investments in physical science and engineering research at NSF, DoE SC, and NIST over 10 years.
Infrastructure	• Create National Consensus for Innovation Growth Strategies • Create a 21st Century Intellectual Property Regime. • Strengthen America's Manufacturing Capacity • Build 21st Century Innovation Infrastructures – the Health Care Test Bed	• Enhance the patent system that underlies the emerging knowledge economy • Enact a stronger research and development tax credit • Provide special tax provisions for US-based innovation • Ensure ubiquitous broadband Internet access	• Strengthen the environment for innovation • R&D tax incentives • Efficient system protecting intellectual property

Source: Center for Research and Development Strategy, Japan Science and Technology, cited by MEXT

COLUMN 7

US Competitiveness Policies Seen in *Global Competition: The New Reality (The Young Report)*

There had also been a time in the past when, alarmed at changes at home and abroad, the US implemented measures for strengthening its S&T and innovation policies. Having fallen into a massive trade deficit because of competition with Japan and other countries in such fields as the automotive, steel, and semiconductor industries in the 1980s, the US implemented a variety of different countermeasures, a representative example of which is the *Global Competition - The New Reality (the Young Report)* presented by the Council on Competitiveness in 1985. Alarmed at the huge trade and budget deficits, or the so-called Twin Deficit, the industrial circle took the initiative and invited experts from industries, academia, and government to organize a Council on Competitiveness, and this council presented to President Regan the report calling for measures for strengthening the national competitiveness.

The report made proposals for expanding R&D tax incentives, exempting joint research activities from the Antitrust Act, enhancing protection of intellectual property rights, eliminating deficits, and providing opportunities for productive dialogues between government, industries, and labor unions; it left a significant influence on the subsequent S&T and innovation policies of the US.

Following the publication of the *Young Report*, Massachusetts Institute of Technology (MIT) established the MIT Commission for Industrial Productivity, and, in 1989, published *Made in America: Regaining the Productive*

Edge, which contained a benchmark analysis of the competitiveness of Japanese, American, and European automotive, semiconductor, computer and other industries, and recommendations on future US industrial policies.

At the same time, the US accelerated efforts to explore the frontier of new cutting-edge technology. As shown by such examples as the National Information Infrastructure (NII) Initiative announced by the Clinton administration in 1993, the US implemented strong measures for promoting R&D in such new fields as IT and biotechnology. Consequently, the US is far ahead of the rest of the world in these fields today.

Four Subject Areas

Subject	Issues	Recommendations
1) Creation, application, and protection of technology	• Spillover of efforts from defense and space research to commercial applications is needed • Shortage of private sector R&D • Shortage of university faculty personnel • Little interest in manufacturing process including quality controls • Lack of protection of intellectual property rights against copy products and other forms of infringements • Regulator impediments	• Create a cabinet-level Department of Science and Technology • Permanent tax credits to stimulate more industry R&D • Exempt joint research activities from the Antitrust Act • Commercialize new technologies by improving manufacturing technologies • Enhance protection of intellectual property rights • Balance the needs of industrial competitiveness and regulations
2) Increase in the supply of capital available for investment and reduction of its cost	• Inappropriate capital supply due to such factors as a low savings rate • Soaring capital costs of American firms • Capital flow distorted by wrong tax and regulation policies	• Cut the deficit • Restructure the tax system • More stable monetary policy • Remove impediments to efficient capital flow
3) Development of a more skilled, flexible, and motivated work force	• Conflict of views among parties involved in policymaking • Traditional labor-management hostility • Insufficiency of outplacement support for workers in sunset industries • Employee training opportunities insufficiently provided by employers • Capital shortage and obsolete facilities in universities • High elementary and secondary school dropout rates, and delay in computer education	• Productive dialogues between government, industries, and labor unions • Harmonization of labor-management relationship • Enhancement of employee incentives including stock options • Support for laid-off workers • Support for technical education at universities and institutions • Support for vocational schools • Federal and private cooperation in education • Encouragement of teaching-skill building efforts
4) Trade as a national priority and strengthening of the world trading system	• Inconsistency in trade policy decision-making process • Lack of trade policy against unfair foreign trade practices, and incompatibility of the Antitrust Act with the reality of international competition • Various export control regulations • Insufficiency of subsidies to export enterprises • Defects in the General Agreement on Trade and Tariff (GATT) (absence of service and investment-related provisions, existence of inappropriate provisions on agricultural product trade, and lack of applicability to nontariff measures, including foreign-funded	• Improve trade and investment policies • Revise domestic trade laws against unfair foreign trade practices • Amendments in the direction of relaxing the Antitrust Act • Amend the Export Control Act in the direction of relaxing export controls • Relax the COCOM regulations to the levels of other countries • Expand export subsidy systems • Disseminate trade information • Promote export loans through export-import banks • Enact the establishment of international trading houses • Promote multinational trade system

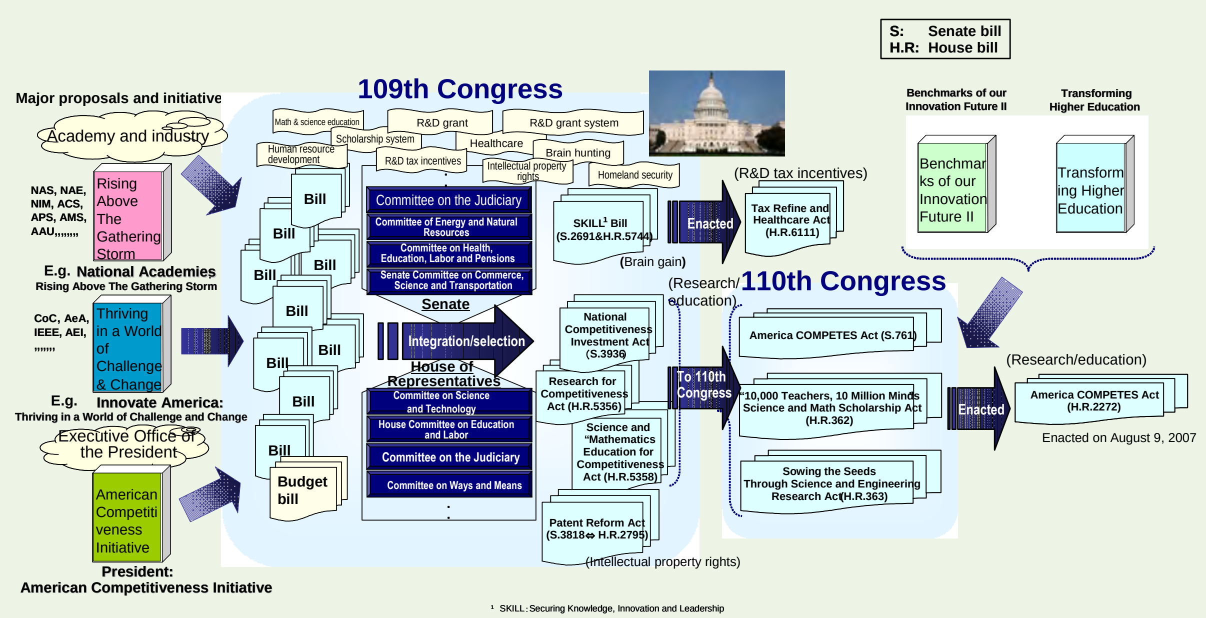
	industrial project promotion, relaxation of antitrust laws, R&D subsidies, and foreign investment regulations)	

Source: Development Bank of Japan *Industry Report Vol. 3*

2) Process toward the establishment of the America COMPETES Act

The announcement of the American Competitiveness Initiative attracted much congressional attention, and led to the presentation of a number of related bills for the enhancement of competitiveness during the 109th Congress (2006). These many bills paved the way for the submission of the bill for the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act to the Senate and the bill for the 21st Century Competitiveness Act of 2007 to the House of Representatives, respectively, during the 110th Congress in 2007. In July 2007, the House and Senate Joint Committee put the bills together into the America COMPETES Act. The Act was signed by the president and made effective on August 9, 2007 (Figures 1-2-2 and 1-2-3).

Figure 1-2-2 Enactment Process of America COMPETES Act in the US Congress



Source: Center for Research and Development Strategy, Japan Science and Technology

Figure 1-2-3 Bills Submitted to the 109th Congress

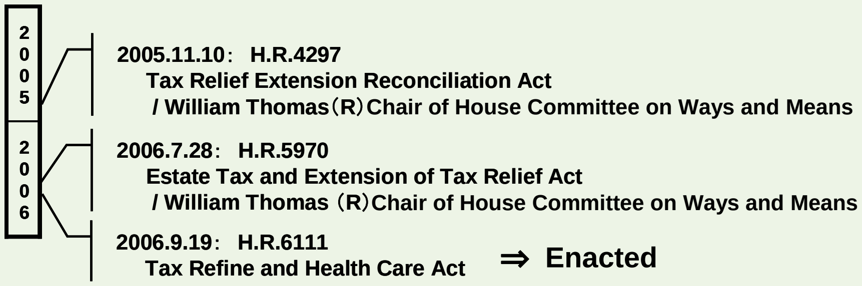
[Education & Research]

- 2005.10: Rising Above the Gathering Storm / National Academies
- 2005.11.15: Innovation Agenda / House Democrat
- 2005.12. 6: National Innovation Summit
- 2005.12. 6: H.R.4434、H.R.4435
  2005.12.16: H.R.4596
  House Innovation Bills / Bart Gordon (D)
- 2005.12.15: S.2109
  National Innovation Act / Joe Lieberman (D) John Ensign (R)
- 2006. 1.25: S.2197, S.2198, S.2199
  PACE Act / Lamar Alexander (R) Jeff Bingaman (D) Pete Domenici (R) Barbara Mikulski (D)
- 2006. 1.31: America Competitiveness Initiative / President
- 2006. 2 : America's Pressing Challenge – Building a Stronger Foundation / NSB
- 2006. 3. 1: H.R.4845
  The Innovation and Competitiveness Act / Bob Goodlatte (R) Lamar Smith (R) Sherwood Boehlert (R)
- 2006. 3. 2: S.2357
  Right Time to Reinvest in America's Competitiveness and Knowledge Act / Edward Kennedy (D)
- 2006. 3. 8: H.R.4906
  21st Century Innovation Act / Harold E. Ford Jr. (D)
- 2006. 3.15: S.2423
  Securing Excellence in Education for our Kids in Math and Science Act / Rick Santorum (R)
- 2006. 3.15: S.2450
  Homeland Security Education Act / Daniel K. Akaka (D)
- 2006. 3.16: S.2454
  Securing America's Borders Act / Bill First (R)
- 2006.3.30: H.R.609 (Passed House)
  College Access and Opportunity Act / House Committee on Education and Labor
- 2006.5.11: H.R.5356, H.R.5357, H.R.5358
  Early Career Research Act , Research for Competitiveness Act
  Science and Mathematics Education for Competitiveness Act / House Committee on Science and Technology(R)
- 2006.5.15: S.2802
  American Innovation and Competitiveness Act / Senate Committee on Commerce, Science and Transportation
- 2006.6.7: H.R.5356, H.R.5358
  Research for Competitiveness Act、Science and Mathematics Education for Competitiveness Act /
  House Committee on Science and Technology
- 2006.6.8: S.3483
  National Innovation Education Act – College Pathway Act / Joe Lieberman (D) John Ensign (R)
- 2006.6.13: S.3502
  New National Defense Education Act / Edward Kennedy (D) John Kerry (D) Hillary Clinton (D)
- 2006.6.21: H.R.5656
  Energy Research, Development, Demonstration, and Commercial Application Act / House Committee on Science and Technology(R)
- 2006.9.26: S.3936
  National Competitiveness Investment Act / Bill First (D) Cosponsored by many influential senators

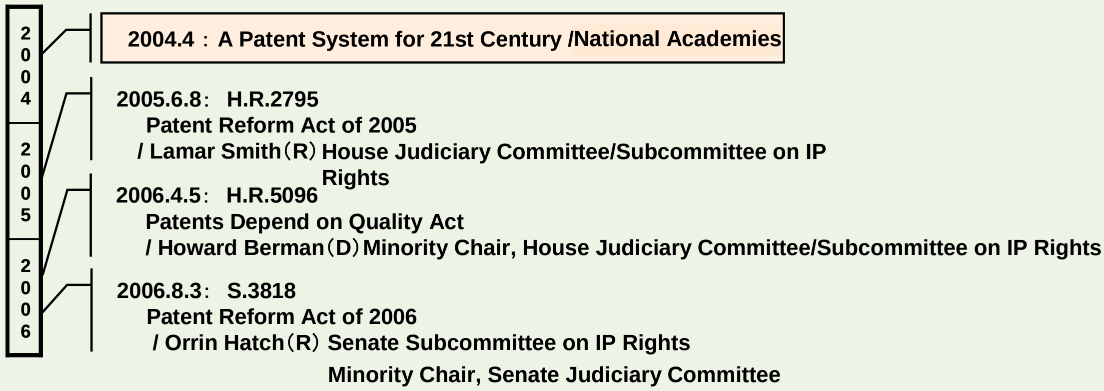
[Visa (Brain Gain)]

- 2005.12.6: H.R.4437
  The Border Protection, Anti-terrorism, and Illegal Immigration Control Act of 2005
  / Jim Sensenbrenner (R) Chair of House Committee on the Judiciary
- 2006.4.7: S.2611
  Comprehensive Immigration Reform Act
  / Arlen Specter (R) Chair of House Committee on the Judiciary
- 2006.5.2: S.2691
  Securing Knowledge Innovation and Leadership (SKILL) Bill
  / John Cornyn (D) Minority Chair, House Judiciary Subcommittee on Immigration, Border Security, and Claims
- 2006.6.26: H.R.5744
  Securing Knowledge Innovation and Leadership (SKILL) Bill
  / John Shadegg (R)

[Tax System]



[Intellectual Property Rights]



Source: Center for Research and Development Strategy, Japan Science and Technology

3) Main features of the Act[fn.1]

The Act extensively covers not only the proposal by the American Competitiveness Initiative for front-loading the expansion of the budgets of NSF, DOE/SC and NIST, but also other measures for promoting general public support for math and science education, promoting service science, and encouraging high-risk research. The main features of the Act are as follows:

a) Convening of the National Science and Technology Summit

Representatives of S&T interests from diverse quarters of society, including industrial quarters and state and federal governments, shall be convened to cross-governmentally consider the health and directions of American activities in the scientific, technological, engineering, and mathematical fields. After the conclusion of the Summit, the President shall present to Congress a report on the government policy for federally funded research and technology programs for the following five years.

b) Radical increase of budgetary allocation to research institutes

There are provisions for radically increasing the budgetary allocation to the aforementioned three organizations. For further details, refer to Figure 1-2-6.

c) Promotion of high-risk research

Any federal governmental agency in charge of fund allocation to scientific, technological, engineering, and mathematical fields shall set a target value for the ratio of high-risk research budget to the basic research budget every year and shall report to Congress the target value and the resulting achievements. Moreover, an Advanced Research Projects Agency-Energy (ARPA-E) shall be newly

fn. 1 Cited from http://crds.jst.go.jp/kaigai/report/TR/US20071002.pdf established within the Department of Energy to tackle long-term and high-risk technological barriers in the development of energy technologies.

d) Investigation of impediments to innovation, and promotion of service science

The Office of Science and Technology Policy in the Executive Office of the President shall collaborate with the National Academies to conduct investigations to consider techniques for identifying and reducing new business and financial risks that may potentially affect innovation creating capabilities. The federal government shall strategically treat service science and provide through the National Academies support to research, education, and training for service science. "Service science" is defined as a newly emerging interdisciplinary field integrating computer science, business studies, industrial engineering, business strategies, management science, and legal studies[fn.2].

e) Promotion of general public support for math and science education and S&T

In order to enhance the national competitiveness of the US, it shall be understood that quality education is essential. Consequently, all students should receive education at higher education institutes. Support shall be provided to improve the quality of teachers and make use of research achievements in order to ensure effective scientific, technological, engineering, and mathematical education.

f) Effective appointment of young and female scientists engineers

Early career grants, fellowship grants, and other forms of support shall be provided to young scientists and engineers.

g) Promotion of manufacturing technologies

Locally-based industry-academia joint projects shall be promoted, and manufacturing technology-related joint research shall be supported.

COLUMN 8

Funding Mechanism for High-risk Research in the US

1. What is high-risk research?

High-risk research (or high-risk/high-impact research) means research[Note] that involves high risks of success or failure in achieving the research objective but has quite a high potential for producing high impact results, if successful, and significant influences such as contribution to advances of the relevant field.

As mechanisms for supporting creating innovation, high-risk research funding has been widely used in the US. There have been such funding mechanisms under the Defense Advanced Research Projects Agency (DARPA) and the Howard Hughes Medical Institute (HHMI), both traditionally committed to high-risk research. Since 2004, similar research funding systems have been in place and run by the National Institutes of Health (NIH) and NSF. The following paragraphs outline the role of such funding systems with a focus placed on the one run by DARPA.

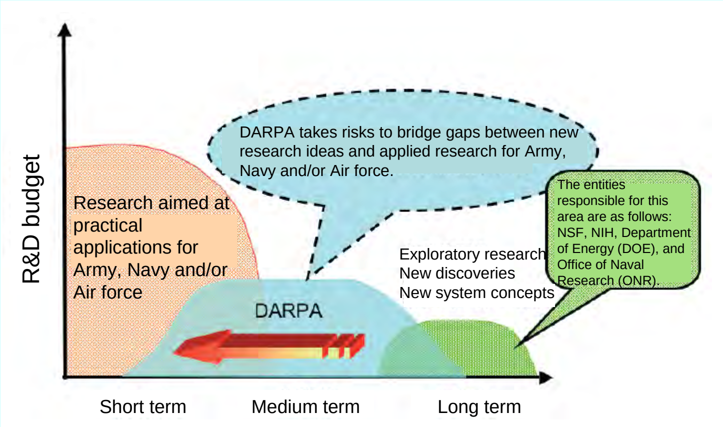
2. Funding mechanism run by DARPA

DARPA is an organization subordinate to the Department of Defense. It was established in 1958 to ensure US military technical superiority and national security. The establishment of the Agency was a reaction to the so-called Sputnik Shock, the shocking success of the Soviet Union in launching the world's first artificial satellite *Sputnik* in 1957.

fn. 2 For the specific details of practices in the US, refer to Part 1, Chapter 2, Section 2, 3 (1).

DARPA does not have its own dedicated research facilities. Its research programs are actually carried out under the leadership of publicly hired program officers at corporate and university research facilities. Thus, DARPA is similar in substance to a funding agency. DARPA provides funding to (i) high-risk research the purpose of which is not limited specifically to the Army, Navy, or Air Force, and (ii) R&D, which is non-urgent but may be necessary for US forces when viewed from the medium- to long-term perspectives. Among typical examples of such research achievements is the Advanced Research Projects Agency Network (ARPAnet), which was the predecessor of today's Internet.

Role of DARPA



Source: JST-CRDS

It is pointed out that the management of DARPA is characterized by its flat organizational structure and the wide latitude of discretion of program managers. First of all, DARPA has a flat organizational structure, and there are only three levels in the decision-making process, which starts from publicly hired program managers, each in charge of an individual program, then to the heads of the individual laboratories, and to the director of DARPA. Second, program managers are vested with broad discretionary authority over the entire process of a research project from planning to scheduling, management, and implementation, and are expected to have strong leadership and capabilities of achieving meaningful results in short terms.

3. High-risk research programs at NSF and NIH

While high-risk research programs at DARPA have made excellent achievements, it has come to be considered that, in fields where basic research should be pursued at NIH, NSF, and DOE based on long-term perspectives, productivity-oriented research projects have been proposed and adopted to earn higher review scores. Along with a suspicion that research results may not necessarily contribute to the advancement of relevant fields, there developed a momentum toward funding system reform. Thus, in 2004, NSF and NIH established a new funding system for promoting high-risk research.

Note: Center for Research and Development Strategy, Japan Science and Technology (http://crds.jst.go.jp/output/pdf/05or03.pdf)

(2) Revision of the Law of the People's Republic of China on Science and Technology Progress

1) New developments in S&T policies in China

In recent years, China has pursued S&T policies with a basic orientation toward the development of sciences and technologies and the creation of innovation, as can typically be seen in such slogans as "Nation building through science and education (make the nation prosperous through science and education) (*kejiao xing guo*)," [fn.3] "Scientific view of development (a concept of achieving China's

fn. 3 "Nation building through science and education" originally proposed in 1995 by Zhu Rongji, former Premier of the People's Republic of China.

continuous development through science, technology and scientific ways of thinking),"fn.4 and "Innovation through self-developed technology (China's original innovation)."fn.5

Committed to economic growth to transform itself from a planned economy into a market economy, China had pursued the promotion of S&T under the Science and Technology Progress Law established in 1993. In December 2007, the Law underwent a major revision to include clearer provisions for promoting "innovation through self-developed technology" and those for developing related systems and implementing incentive measures.

Currently, China's S&T policies are implemented under the Five-Year Plan, which is the national comprehensive plan that spells out specifics and action items, and the National Medium- to Long-Term Science and Technology Development Plan (2006-2020), which provides the guiding principles for national S&T policies. The latter Plan specifies short term and medium-/long-term investment target areas in line with the guiding principles of "carrying through with the scientific view of development," "nation building through science and education/strategic human resource development for strong nation building," and "independent innovation."fn.6

One of the noteworthy characteristics of S&T promotion policies in China is that a US-style competitive system was introduced instantaneously to persistently execute R&D system reform. For example, the wholesale introduction of competitive funds and establishment of spin-off companies from national research institutes have promoted the introduction of US-style competition systems (Table 1-2-4). It can be said that the rapid expansion of government R&D investment and the successful establishment of such an excellent R&D system increase the possibility that China will become a candidate for one of the world's innovation centers.

Table 1-2-4 Top 10 Universities in Terms of Gross Sales of S&T Enterprise (2005)

Ranking	University	Sales volume (100 million RMB)
1	Peking University	264.49
2	Tsinghua University	189.90
3	Zhejiang University	52.26
4	Northeastern University	34.88
5	China University of Petroleum (East China)	28.70
6	Wuhan University	22.69
7	Tongji University	21.07
8	Harbin Institute of Technology	19.45
9	Fudan University	19.07
10	Xian Jiaotong University	15.69

Science and Technology Development Center, the Ministry of Education of the People's Republic of China
Source: Center for Research and Development Strategy, Japan Science and Technology

2) Main Features of the Science and Technology Progress Law

The Science and Technology Progress Law regards S&T as the "Primary Production Capacity" and preferentially promotes S&T to contribute to economic development for state building (construction of a modern socialist state)fn.7. The law revised in 2007 includes such aspects as development of relevant

fn. 4 "Scientific view of development" explicitly stated at the 17th National Congress of the Communist Party of China in 2003. In 2007, it was adopted as one of the guiding principles of the Chinese Communist Party and included in the Party Constitution.

fn. 5 The concept of "Innovation through self-developed technology" is included in the 10th Five-Year Plan.

fn. 6 Source: JST-China Research Center (CRC) *Overseas Trend Report*

fn. 7 Source: JST-CRDS *Global Science and Technology Trends* systems and incentive measures [fn.8], with priorities on the encouragement of independent innovation and the construction of an innovation-oriented state. Thus, many specific action items are included.

a) Enhancement of S&T through budgetary, financial, and taxation measures

There are provisions for tax incentives for imported foreign products for R&D use and those for preferential financial services provided by government-funded financial institutions to high-tech and other industries.

b) Arrangements for high-risk research, and punitive actions for fraudulent research

It is stipulated that, in order to promote high-risk research, any researcher involved in high-risk research shall be tolerantly treated even if the researcher fails to complete the research, as long as the person diligently performed all assigned duties. On the other hand, there are also provisions for the prohibition of and penalties for dishonest research.

c) Incentives for luring competent expatriate researchers back home

There are provisions for preferential treatment of outstanding expatriate researchers who will return to China. Such returnee researchers shall be given priority for permanent resident status in China.

d) Revision and rapid implementation of state-sponsored intellectual property rights

It is stipulated that intellectual property rights obtained through government-funded S&T projects shall be granted to those who carry out relevant R&D, unless such intellectual property rights may affect national security, national interests, or important public interests of society and hence belong to the country.

It is also stipulated that intellectual property rights obtained shall first be used in mainland China, and that exclusive licensed use of such intellectual property rights by foreign organizations or individuals shall be subject to permission by relevant project management organizations.

e) Construction of corporate innovation systems

There are provisions for the promotion of corporate-driven innovation. These provisions relate to promotion of corporate R&D tax incentives and voluntary R&D theme selection.

f) Promotion of sharing of S&T resources

There are provisions for export control practices for S&T-related resources such as rare biological species resources and genetic resources.

g) Provisions for introduction of large equipment

It is stipulated that the purchase and construction of any large scientific equipment and facilities shall be planned with a view toward innovation.

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fn. 8 Source: JST-CRC http://crds.jst.go.jp/CRC/newsflash/beijing/b080111.html
http://www.jetro-pkip.org/upload_file/2008011576744857.pdf

COLUMN 9

China's Manned Space Flight and Moon Exploration Project

One of typical examples that illustrate the rapid development of China's S&T is aggressive space exploration. The manned space flight in 2003, in particular, attracted much attention from around the world.

China's manned space flight program, the *Shenzhou Project* (*Project 921*), started in 1992 under the Jiang Zemin regime. In 2003, *Shenzhou V* was launched manned by an astronaut, making China the third country to succeed in launching a manned spacecraft after Russia (the now-defunct Soviet Union) and the US. Then, in 2005, China successfully launched the two-manned spacecraft *Shenzhou VI.*

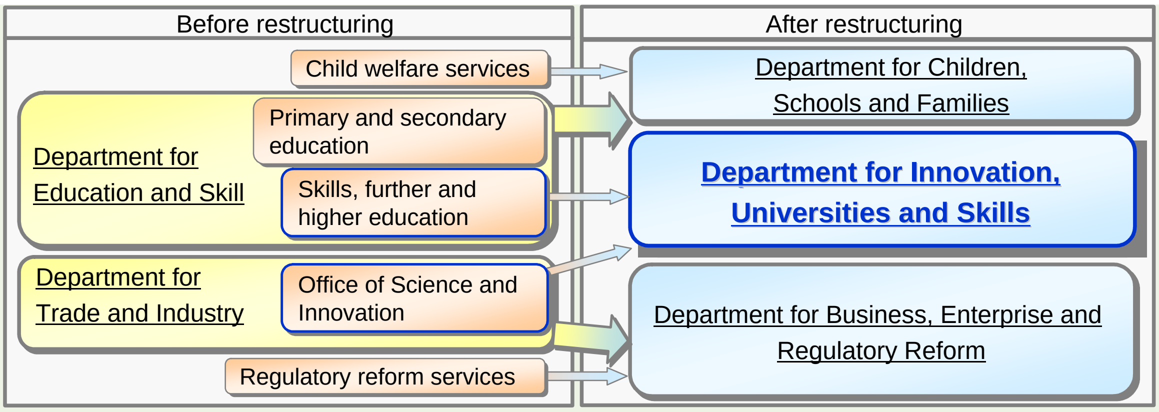
Moreover, China has been aggressively pursuing a long-term unmanned lunar probing program, including the launch of its first lunar probe satellite *Change I* in October 2007. On March 11, 2007, the Commission of Science, Technology and Industry for National Defense announced a project aimed at lunar observation using a soft-landed probe by around 2012 and the return of small capsules containing samples back to the Earth by around 2017.

(3) United Kingdom: New establishment of the Department for Innovation, Universities, and Skills through reorganization of Departments

The Department for Innovation, Universities, and Skills (DIUS), newly established in the reorganization of government Departments by the Brown Administration in June 2007, is a representative example of efforts toward S&T-driven innovation in the UK (Figure 1-2-5). The DIUS brings together the functions of the former Office of Science and Innovation under the former Department for Trade and Industry with the further skills and higher education section under the former Department for Education and Skill. This new Department is epoch-making in that it was established as a powerful innovation promotion system with responsibilities ranging from human resource development to S&T and innovation.

The efforts made by DUIS include human resource development through higher and life-long education, the construction of the top world-level research infrastructure, and the maintenance of a dual subsidy system for universities (operational subsidies and competitive research funds). In November 2007, the Department presented a policy for raising the ending age of compulsory education from the current 16 years to 18 by 2015.

Figure 1-2-5 UK Departments Before and After Reorganization



Source: Cabinet Office, Government of Japan

COLUMN 10

Russia Turned toward Innovation-oriented S&T Policies

As a part of its current economic structure reform, Russia has been pursuing a shift to innovation-oriented S&T policies to secure the international competitiveness of Russian industries. At the Expanded Meeting of the State Council on February 8, 2008, President Putin (then) wrapped up his two-term eight-year presidency with a speech, in which the President proposed strategies for Russian development for the years up to 2020. In his speech, the President declared that Russia had come out of critical situations before his inauguration, revived as an international power, and joined the world's top seven economies, and that Russia would take diverse and comprehensive development strategies for a whole range of agendas, including the economy, industry, education, science, population, health, safety, political economy, regional economy, and national security. The specifics of these strategies are currently under consideration.

Of special note regarding the speech is that it placed particular emphasis on the "necessity for development through technological innovation."

In the speech, the President argued, "Russia is still positioned as no more than an energy supplier. Having achieved an eight consecutive year economic growth, Russia is technologically lagging behind advanced industrialized countries. Should this situation be left unchanged, Russia would have no choice but to remain dependent on imported industrial products and technologies. To terminate this situation and ensure improved national economy and quality of life," the President continued, "it is necessary to develop high-tech industries toward the establishment of a technology-driven country." The agendas to be addressed to achieve it include making a better use of the abundant Russian human resources for development of cutting-edge technologies and more dynamic promotion of innovations, improving the national standard of living, expanding the middle class, and correcting economic disparities.

It should also be noted that the speech spelled out other goals, such as quadrupling the productivity of the key sectors of the Russian economy in twelve years, establishing national innovation systems, building and growing new globally competitive sectors including high-tech industries, and developing IT, medical, and other cutting-edge technologies.

A typical example of such innovation-oriented political measures is promotion of the nanotechnology field. In order to construct effective R&D systems and increase foreign investments in the nanotechnology field, Russia established the Russian Corporation of Nanotechnologies in July 2007 to strongly support innovations in the field with a view to application to the aircraft manufacturing, shipbuilding, and rocket and space industries, nuclear and medical technologies, and housing and public facilities.

3 R&D Budget Increase Plans in Other Countries

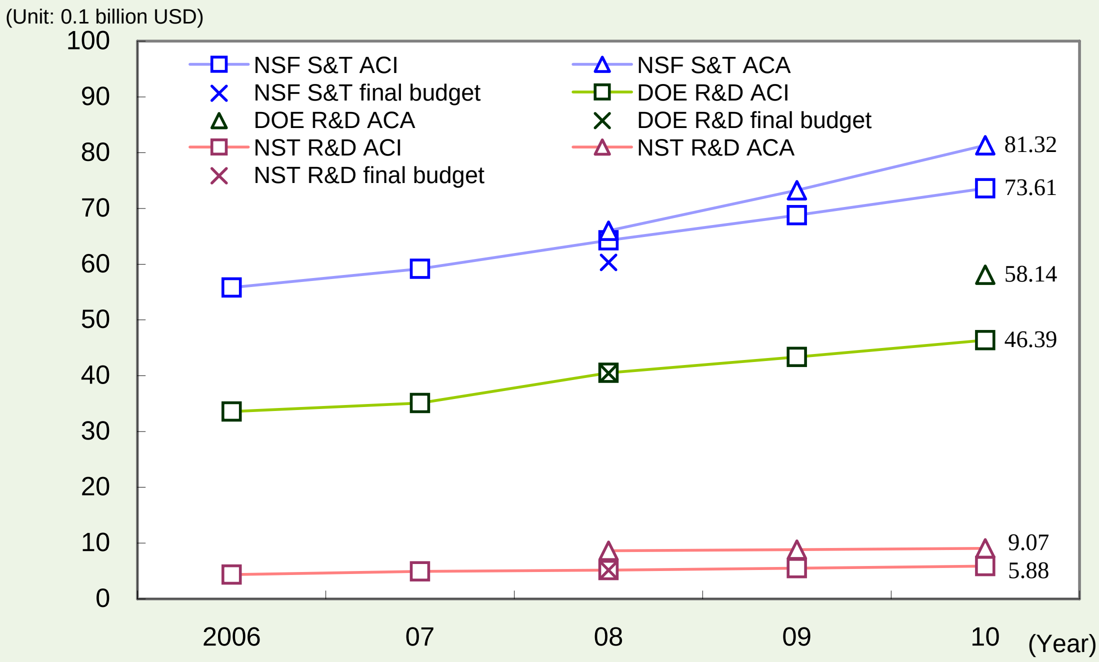
What is of note about the S&T policies of other countries is that they all plan not only R&D system reform, but a radical increase in R&D expenditures as a strategic investment in the future, toward creation of innovation through S&T. Specifics of such plans are provided in the following sections:

(1) United States

Major American research institutions responsible for encouraging the creation of innovations include NSF, DOE/SC, NIST, NIH, and the National Aeronautics and Space Administration (NASA). Among these, NSF, DOE/SC, and NIST are designated by the American Competitiveness Initiative to have their R&D budgets doubled over 10 years from 2006, and by the America COMPETES Act to have their budgets increased for the years up to 2010. Figure 1-2-6 compares the target budgets projected in the Act and the Initiative with the final ones for FY 2008 fn.9.

Note that the NIH budget had actually been doubled from US$ 13.1 billion in 1998 to US$ 26.4 billion in 2003, which provided a powerful driving force for human genome deciphering and medical technology development.

Figure 1-2-6 Trends in Budget of the US Three Selected R&D Institutions



Source: See footnote 9

(2) China

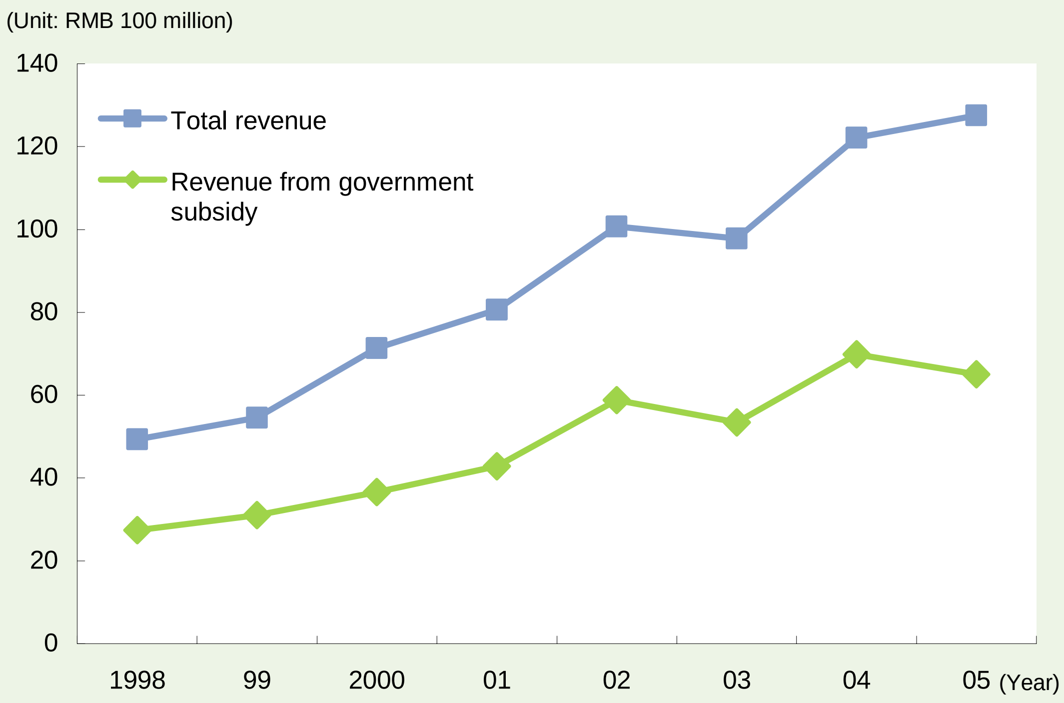
In the National Medium and Long Term Program for Science and Technology Development (February 2006), China set the goal of increasing the ratio of R&D expenditures to GDP up to 2.5% in 2020, approximately doubled from the level at the time when the plan was drafted fn.10. Figure 1-2-7 shows the trends in research expenditures in China's largest R&D institution, the Chinese Academy of Sciences (CAS). The chart reveals that the institute had its budget increased by approximately RMB 6 billion during the period between 1998 and 2005. As the Chinese GDP has been rapidly expanding, note should be taken that the planned R&D budget increase will be huge on an actual amount basis.

fn. 9 The final budgets of NSF, DOE/SC, and NIST for FY 2008 are shown below along with the target S&T budgets allocated to the three institutes by the America COMPETES Act and the American Competitiveness Initiative for FY 2008.

- NSF: US$ 6.032 billion (final budget), US$ 6.6 billion (America COMPETES Act), US$6.429 billion (American Competitiveness Initiative)
- DOE/SC: US$ 4.045 billion (final budget), US$ 4.052 billion (American Competitiveness Initiative)
- NIST: US$ 0.515 billion (final budget), US$ 0.862 billion (America COMPETES Act), US$0.514 billion (American Competitiveness Initiative)

fn. 10 An annual average GDP growth rate of 7.5 % is planned for the 11th Five Year Plan period.

Figure 1-2-7 Trends in Research Budget in Chinese Academy of Sciences



Source: Center for Research and Development Strategy, Japan Science and Technology

(3) United Kingdom

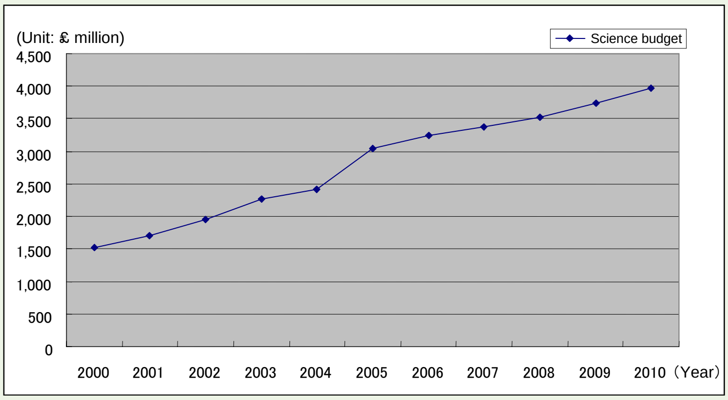
The UK S&T budget policy for the next three years is presented in the Comprehensive Spending Review (October 2007), which is the de facto manifest of Brown Administration. According to this policy, the UK will increase the S&T budget from £5.4 billion (2007) to £6.3 billion (2010), and the higher education and skills development budget from £14.2 billion (2007) to £16.4 billion (2010).

In 2004, the UK established the Science and Innovation Investment Framework 2004-2014, a S&T basic plan for the next ten years. This plan stipulates that the ratio of the total R&D expenditures to GDP shall be increased from the current 1.9% to 2.5% by 2014 to strengthen the UK science infrastructure.

Figure 1-2-8 illustrates the trends in the budget of the Research Council (RC), the principal research funding organization of the UK, and that of the Government Office for Science[fn.11].

fn. 11 An organization under DIUS. According to the 2007 edition of JST-CRDS *European Science and Technology Trend Report (UK)*, the DIUS Science and Innovation Group has taken over authority over the functions of science budget review and research management from its predecessor organization. These functions are reportedly reduced to some extent.

Figure 1-2-8 Trends in the UK Science Budget



Note:

1. The science budget is the total of the Research Council (RC)'s budget and that of Government Office for Science (GOS: former OSI).
2. The figures for 2004 and before are actual values. The figures for 2005 to 2007 are estimates. The figures for 2008 and after are projected values based on the Comprehensive Spending Review (CSR).

Source: SET & DIUS Comprehensive Spending Review cited by the Center for Research and Development Strategy, Japan Science and Technology

(4) France

In 2006, France established the Research Planning Law (*la Loi de Programme pour la Recherche*) to improve the efficiency of publicly sponsored research and enhance the international competitiveness of the country. The law stipulates that the national R&D investment shall be increased from €19 billion (2004) to €24 billion (2010).

(5) Germany

In August 2006, the German government under Prime Minister Merkel established the High-Tech Strategy for Germany (die Hightech-Strategie für Deutschland), a comprehensive strategy for the Federal Government-sponsored R&D and innovation projects. The Strategy covers diverse issues ranging from research funding to R&D systems. It also contained initiatives for achieving the R&D investment-to-GDP ratio of 3% by 2010 as agreed in the EU Lisbon Strategy.

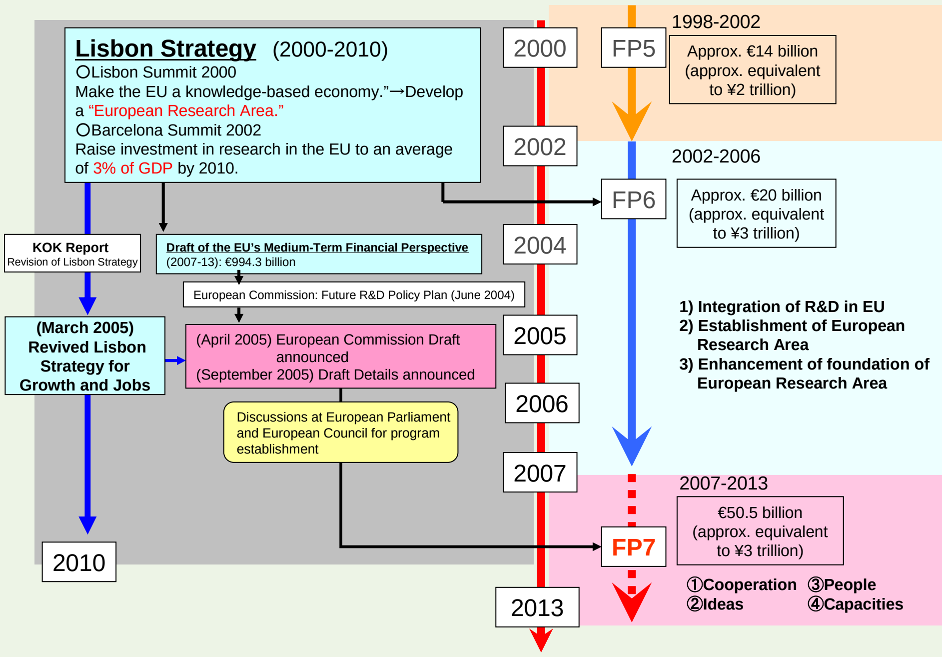
(6) EU

Upholding the banners of "a Europe attractive for investment and business," "knowledge and innovation for growth," and "qualitative and quantitative improvement of employments," the New Lisbon Strategy stipulates that the ratio of European R&D expenditures to GDP shall be increased from 1.9% (2000) to 3.0% (2010).

Based on, among other things, the Strategy, the Seventh Framework Programme (FP7) established in 2005 provides that a total budget of approximately ¥7 trillion equivalent for the seven years up to 2013 shall be used to cover research grants to industry-academia-government joint projects with participation from three or more EU countries (up to 50% of each project budget to be covered by EU) as well as to subsidize basic research projects, promote human resource development, and develop research infrastructure toward the establishment of an European Research Area (ERA) (Figure 1-2-9).

Moreover, in order to achieve the "Growth and Jobs" objective of the New Lisbon Strategy, the Competitiveness and Innovation Framework Programme (CIP) was established in 2007 with a total budget of ¥500 billion equivalent for the seven years up to 2013. The Initiative focuses on the "exit strategies" for research and innovation programs, and consists of an innovation support program for small and medium-sized enterprises, an information and communications policy support program, and a renewable energy program.

Figure 1-2-9 The Seventh Framework Programme (FP7)



Source: Center for Research and Development Strategy, Japan Science and Technology

(7) Russia

Pursuant primarily to the Basic Principles of the Russian Federation Policy in the Field of Development of Science and Technologies for the Period up to 2010 and Further Perspective (Presidential Decision, March 2002), Russia expends its national R&D budget according to multi-year budget plans. Moreover, according to the presidential annual state-of-the-nation address delivered in April 2007, a total amount of 130 billion rubles will be additionally spent in the nanotechnology field over the years up to 2015.

(8) India

India intends to increase the ratio of R&D investments to GDP to 2%, the numerical target set forth in the Science and Technology Policy 2003, during the 11th Five-Year Plan period from FY 2007 to 2011.

(9) South Korea

The draft of the Second Science and Technology Basic Plan starting from 2008 included a goal of increasing the ratio of R&D investments to GDP from 3.23% (2006) to 3.5% (2012). During his presidential campaign, President Lee Myung-bak pledged to increase the ratio of R&D investments to GDP to 5%. There may later be readjustments of the R&D investments-to-GDP ratio.

4 Global Competition for Human Resources

While international competition for human resources intensifies as globalization advances, many counties are actively moving to retain talents, the wellspring for the creation of innovation. The following paragraphs provide descriptions of global recruitment activities pursued by other countries.

(1) United States: Human resource policy through immigration regime reform

For a long time, a constant inflow of competent researchers from countries around the world has given the US the edge in creating innovation. Now out of fear that it may become difficult to maintain the inflow of talents from other countries because of the economic development of the BRICs and other countries, the US has implemented aggressive measures aimed at recruiting human resources from other countries to reinforce domestically developed researchers.

Specifically, the above-mentioned presidential initiative has made proposals for methods of human resource development and recruitment. These methods are the improvement of math and science education at elementary, junior high, and senior high schools, and immigration control system reform aimed at facilitating visa issuance to competent engineers and researchers from around the world and their settlement in the US.

(2) China: Incentives for returning researchers

China is aggressively promoting incentives for its competent researchers in foreign countries to back home in a spirit of improving the level of the country's S&T and catching up with advanced countries (Figure 1-2-10). There are analyses that such returnee researchers are now playing central roles in R&D activities in China. Moreover, China has started to invite outstanding foreign researchers to China[fn.12]. The details on such incentives are as below.

• Overseas Student Pioneer Parks (Incubators) (since 1994)

This is an incentive measure for luring Chinese students studying abroad or Chinese researchers working abroad back home. Returnees can receive entrepreneurial start-up support.

• Spring Sunlight Program (since 1996)

This program is implemented by the Ministry of Education to provide support to returnees with oversea study experience and facilitate their service to the country. Eligible recipients of support under this program are primarily returnees with an overseas doctoral degree and a history of remarkable academic achievements in their expertise.

• Chinese Academy of Sciences (CAS), One Hundred Outstanding Young Chinese Scientists (since 1994)

This is the first of the high-target, high-standard, high-power researcher recruitment and development programs that China has implemented. The standard term of fellowship is three years. Fellows are entitled to receive salary, medical insurance, and other allowances.

• Changjiang Scholarship Program (since 1998)

This is a program aimed at inviting outstanding scholars from home and abroad to higher education institutions in China in order to domestically develop internationally first-rate human resources. This program provides preferential treatment in terms of insurance, position, and salary to 45-year-old or younger scholars active at home or abroad in scientific research or science education.

• Plan 111 (since 2006)

This plan is such that more than 1,000 scientists will be invited from the world's top 100 universities and research institutions to organize approximately 100 joint research teams with prominent domestic researchers. The plan intends to establish globally competitive S&T intelligence introduction bases at first-rate universities in China to facilitate active use of top-notch foreign researchers on the S&T front line in the country.

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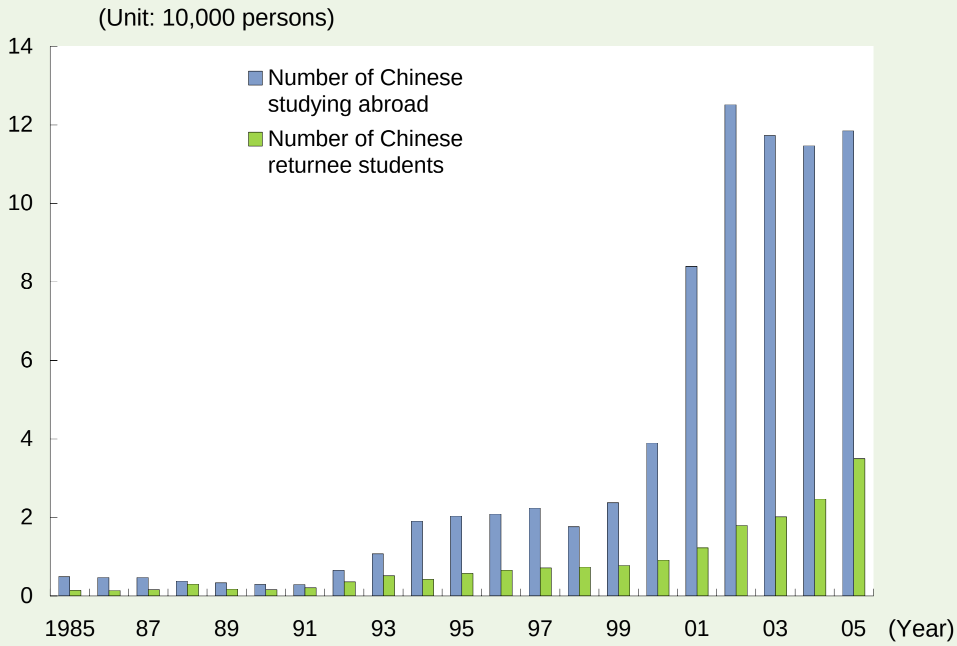
fn. 12 Source: JST-CRC

Figure 1-2-10 Trends in Number of Chinese Students Studying Abroad and Chinese Returnee Students



Source: Center for Research and Development Strategy, Japan Science and Technology (http://crds.jst.go.jp/CRC/plan/m4-3.htm)

5 Implementation of Flexible and Effective R&D Systems

As described above, other countries are working on R&D system reform to facilitate the creation of innovation. Unlike in Japan, there are already flexible and smooth-running R&D systems established in many other countries for coordinating research funds. These systems are one of significant driving forces for creating innovations. While the differences in the accounting system and other things between Japan and other countries should be taken into account, foreign examples will provide Japan with some useful suggestions for its future research system reform.

(1) Flexible spending of research funds

NSF, a leading competitive US research funding organization, allocates both multi-year and single-year budget competitive research funds. The former, over half of the overall competitive research funds, has no concept of year-to-year carryover of an unspent budget. As for single-year competitive funds, researchers can carry over up to 20% of unspent funds to the next fiscal year without permission. In its practices of high-risk research promotion, DARPA has the following special personnel measures and special accounting rules to ensure appointment of highly competent managers and funding to optimum institutions.

[Special Personnel Measures and Special Accounting Rules at DARPA]

Number of personnel	Highly qualified, up to 40 scientists/engineers (supernumerary)
Salary	Rewarded with the base salary applicable to senior staff or higher, plus additional salaries as appropriate
Provisions on funding	More flexible contractual provisions than required by law available. Awarded for the development of outstanding technologies as a form of subsidy independently of normal funding.

UK research funding systems are basically run on the one-year accounting basis. The Research Council, a representative UK research funding organization, also has its own system of multi-year budget funds.

(2) Background of management improvement of competitive US research funding systems

About 20 years ago in the US, a cooperative initiative called the Federal Demonstration Partnership (FDP) was jointly established by universities and federal agencies such as NSF, to reduce the administrative burdens associated with research grants and contracts. Specifically, the purpose of FDP was to streamline the process of research funding management by granting some discretion to institutional recipients of federal funds on the basis of their fund management capabilities. So far, qualified institutional recipients have been granted authority over research fund allocation prior to the start of the research period, less than one-year extension of research periods, and year-to-year carryover of unspent research funds.

These measures are characterized by the process of generalization. In this process, agencies and institutional recipients meet in a place and exchange frank opinions on improvements on research funding systems, and analyze model projects to demonstrate improvement effects (e.g.: increase in the time devoted by researchers to research activities).

Initially, these measures has been begun as an experiment between universities in Florida and federal agencies , and then have been expanded to all over the country along with gradual addition of other measures [currently underway as Phase IV (2002-2008) (with the participation of 10 federal agencies and 98 institutional agencies)]. Thus, it is considered that these measures have contributed significantly to the realization of flexible research funding systems in the US.

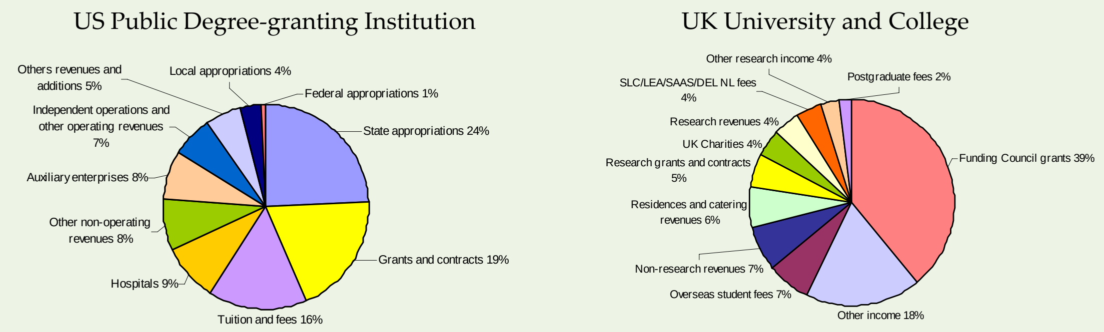
Figure 1-2-11 Overview of Federal Demonstration Partnership (FDP) Activities

A report on FDP activities
For further details, visit the FDP website at http://thefdp.org/.

(3) Promotion of externally funded R&D projects

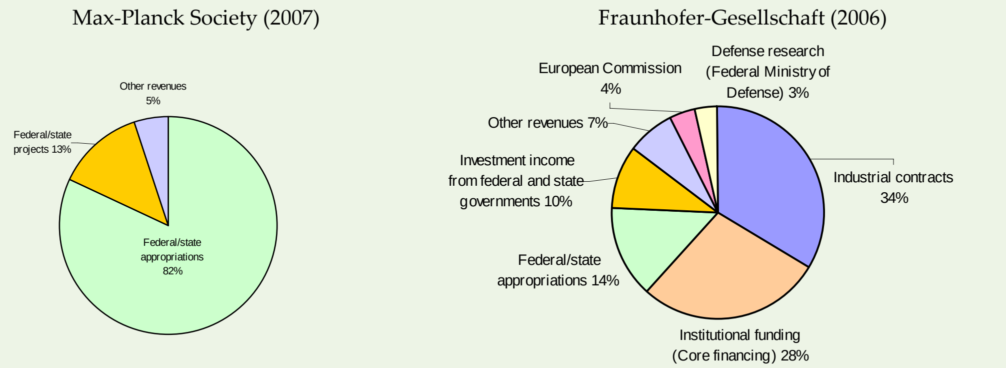
In many other countries, not only state-sponsored grants but external funds from various sources, including private sectors, support R&D projects at universities and other public research institutions. An analysis of revenue structures of US state universities, UK universities, and German research institutions reveals that they receive not only public financial aids but funding from diverse sources including those in private sectors (Figure 1-2-12).

Figure 1-2-12 Sources of Total Revenue of the US Public Degree-granting Institutions, UK Universities and Colleges, and German Research Organizations



* Auxiliary enterprises are business enterprises within universities to provide the campus community with specified services such as meals, stationeries and groceries.

German Research Organizations



* The institutes of the Max Planck Society perform basic research, while the Fraunhofer-Gesellschaft undertakes applied research.

Source: Prepared by MEXT

6 Enhanced Measures for Intellectual Property Rights Protection and International Standardization

(1) Enhanced measures for intellectual property rights protection

In response to the ongoing globalization of corporate activities, there are moves toward global protection of intellectual property rights. Accordingly, many other countries are revising their domestic patent systems to ensure international harmonization of their intellectual property rights systems. In order to promote international harmonization of its patent system, a US Patent Reform Act of 2007 has been submitted to the House and the Senate, the purpose of which is to replace the current *first-to-invent* system with the *first-to-file* system and abolish the provisions on restrictions on the *first-to-file* right of foreign applicants (after passing the House in September 2007, the bill is under consideration in the Senate). In Europe, the revised European Patent Convention EPC 2000 came into force in December 2007. The Convention is intended to strengthen the patent applicant rights, including the right to file patent applications in any native language. Furthermore, China is working on the revision of the Patent Law, including adoption of the absolute novelty rule as the basis for determination of novelty (under the current version of the Chinese Patent Law, protection is granted on the basis of having not been previously disclosed and/or used in China).

(2) Enhanced measures for international standardization

Seen from the perspective of "exit strategies" for applying the fruit of innovation to the market needs, it goes without saying that standards for products and services have a critical importance in shaping the course of competition. Following the effectuation of the World Trade Organization's (WTO) Agreement on Technical Barriers to Trade (TBT Agreement) in 1995, the WTO member states are obliged to harmonize multinational standards and government technical standards, in principle, with ISO standards. Traditionally, Europe has made good use of international frameworks, such as the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), to establish de jure standards[fn.13] as means of strategic market domination.

Following the effectuation of the TBT Agreement, the US has reversed its traditional de facto standard-oriented stance[fn.14] to a de jure standard-oriented one, and fundamentally reinforced its efforts to ensure that US standards will be adopted as ISO standards and other international standards. According to the Department of Commerce Standards Initiative launched in March 2003, the US has been committed to enforcing measures aimed primarily at dealing with trade barriers attributable to standards and certification policies of other countries. One example of such measures is to increase the number of standards attachés stationed at US diplomatic establishments in China and other countries.

Moreover, China also regards protection of intellectual property rights strategies and technical standards strategies as *priority policies and actions* according to the National Medium and Long Term Program for Science and Technology Development established in February 2006. Thus, while promoting adoption of Chinese standards as international standards, China has been enhancing international standardization activities, including integration of scientific research, development, design, and manufacturing into the process of standardization. In the past, China has made proposals to ISO and IEC for Wireless LAN Authentication and Privacy Infrastructure (WAPI), a wireless LAN-related standard, and Intelligent Grouping and Resource Sharing (IGRS), a standard for home information appliances network.

When ISO member countries are compared in terms of the estimated ratio of international standardization activity-related and other standardization-related governmental budget to GDP for 2006, it is revealed that the German, US, and Chinese ratios are respectively approximately same size as, four times large as, and seven times large as that of Japan taken as the base of one (Table 1-2-13).

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fn. 13 De jure standard: "De jure" is a Latin phrase meaning "legally official." *De jure* standards are ones established according to procedures made explicit and public by ISO, IEC and other official organizations.

fn. 14 De facto standard: "De facto" is a Latin phrase meaning "in fact." De facto standards are so-called global standards, ones actually used in the international market. These standards have no legal bases but have won recognition through market competition.

Table 1-2-13 International Comparison of Standardization Budgets (Tentative Estimates)

Country	FY 2006 Standardization Budget (¥1 million or equivalent)	Proportional size of the standardization budget-to-GDP ratio of each country to that of Japan (Japan = 1) (NB)
South Korea	4,243	11.55
China	8,118	7.23
US	22,280	3.82
France	1,974	2.02
Germany	1,344	1.03
Japan	2,102	1.00

Note: Each country's GDP cited from *Oversea Economic Data for 2005* (Nov. 2006) compiled by Cabinet Office
Source: Ministry of Economy, Trade and Industry

2 Science and Technology-related Challenges Facing Japan

In the context of the age of megacompetition, as explained above, other countries have already started increasing government R&D investment for R&D system reform and creation of innovation. In order for Japan to compete up against the US and China without the advantage of physical assets such as natural resources and population, it is essential to continuously pursue aggressive and efficient R&D for creating innovation.

Science and technology in Japan, however, face a diverse range of challenges including: loss of comparative advantages relative to its Asian competitors, all sharply increasing S&T investments and rapidly improving research and technological standards; fear of the eroding foundation of Japanese human resources; internationally uncompetitive science-based industries and tertiary industries; weakness in "exit strategies" for technology management. Therefore, Japan must promote R&D system reform with such challenges in mind.

1 Indicators of Rapid Catch-up by Asian Countries

Japan's nominal gross domestic product (GDP) for 2006 was approximately ¥51.2 trillion, with a year-on-year increase of 1.6%. Meanwhile, after its R&D investment also increased for the seventh consecutive year, primarily in the business enterprises, up to approximately ¥1.85 trillion with a year-on-year increase of 3.5%, Japan's R&D investment-to-GDP ratio also rose by a year-on-year increase of 0.07% up to 3.61%. In addition, the number of researchers in Japan increased for the sixth year in 2007, and the total of Japan's research-related workforce also increased for the fourth year with assistant research workers, technicians, and others all included.

Thus, it is desirable that Japan is increasing its resource investment in R&D, even if piecemeal, upholding the national policy of an advanced science- and technology-oriented nation. Now, however, the US, the world's champion in S&T, EU countries, and BRICs countries are all rushing to increase their resource inputs in R&D, placing a high premium on innovation through S&T. In particular, Asian countries are continuously increasing their investments at rapid rates.

Furthermore, Asian counties have been increasing shares in research achievements, as can be seen from the recent significant increase in the share of Chinese-authored scientific papers or from the increased Chinese and South Korean presence in the number of patent applications. Moreover, Asian countries are making remarkable advances in industrial competitiveness. For example, recent years have seen the shrinkage of Japan's once overwhelming share in the global high-tech industry markets from the peak in the 1980s while China's share is rapidly expanding.

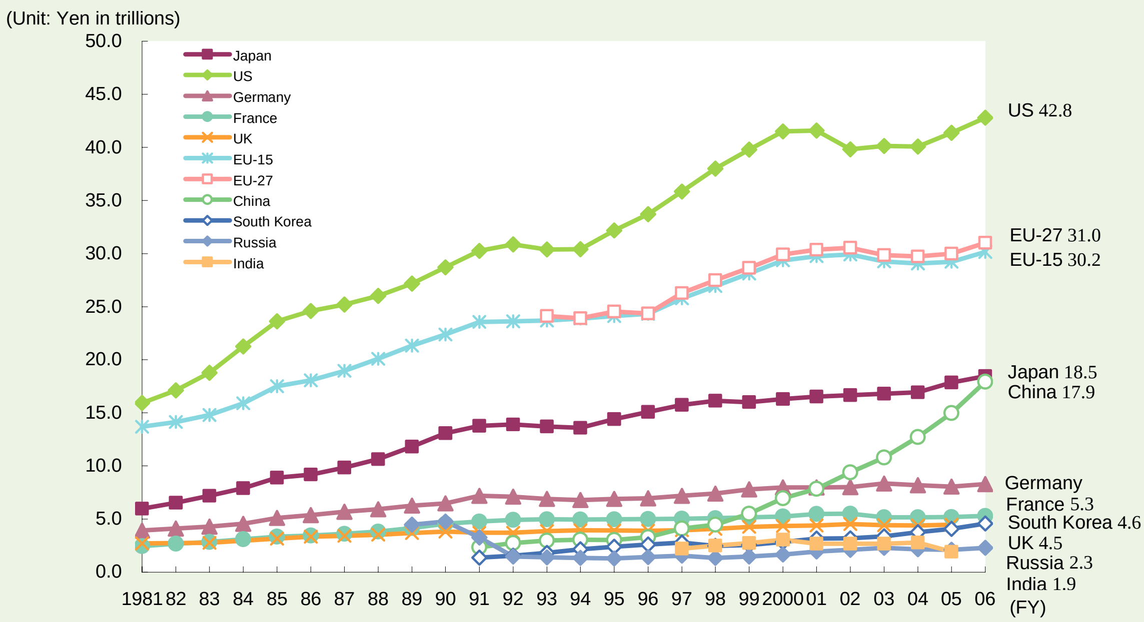
The following sections compare Japan with selected countries based on S&T indicators and relevant data, including: R&D resource input (research expenditures, research workforce, etc.); R&D output (scientific papers, patents, technological trade, etc.); high-tech industries' technological capabilities; and S&T capabilities of individual fields, in order to provide an overview of the current state of Japan's S&T activities.

(1) Resource input to R&D activities

1) Research expenditures

In terms of PPP-based research expenditures, the US ranks at the top with ¥42.8 trillion equivalent, followed far behind by EU-27 with ¥31.0 trillion equivalent (EU-15 with ¥30.2 trillion equivalent), Japan with ¥18.5 trillion, China with ¥17.9 trillion equivalent, and Germany with ¥8.3 trillion. Below these countries come France, the UK, and South Korea, each with a similar amount to the others. A closer look at these trends reveals that the US research expenditures are rapidly increasing and those of EU-27 are also on the increase. Japan lags far behind the US and EU-27 in terms of the increase rate of research expenditures, and the disparity has been widening significantly in recent years. Meanwhile, China has been increasing its research expenditures at a remarkable rate; it almost caught up with Japan in 2006 (Figure 1-2-14).

Figure 1-2-14 Trends in R&D Expenditures in Selected Countries/Regions (On PPP-basis)



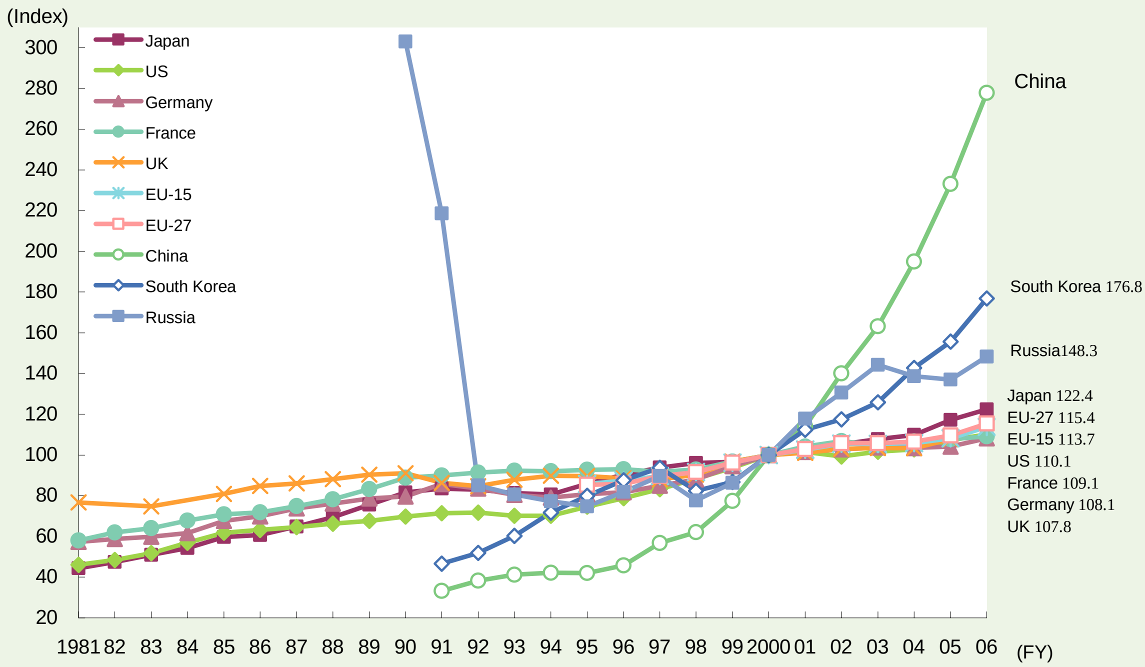
Note:

1. For international comparison, R&D expenditures of all countries other than South Korea include those of humanities and social sciences.
2. In FY 1996 and 2001, Japan increased industries surveyed.
3. The US figures for FY 2005 and after are provisional. The French and German figures for FY 2006 are provisional. The EU figures are estimates by the Organization for Economic Co-operation and Development (OECD).
4. Foreign currency conversion to yen is based on the OECD PPP list (figures for FY 2007 are estimates). Because the OECD PPP list does not cover India, the figures for India are cited from the World Bank PPP list.
5. The figures for India for FY 1999, 2000, 2004, and 2005 are estimates by Indian government. The R&D expenditures of India for FY 2005 are smaller than those for FY 2004 and before, because of the revision of the World Bank PPP index for 2005 (published in Dec. 2007).
6. EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, UK, Greece, Portugal, Spain, Austria, Finland, and Sweden)
7. EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania)

Sources: Japan: *Report on the Survey of Research and Development* compiled by the Statistics Bureau, Ministry of Internal Affairs and Communications
US, Germany, France, UK, South Korea, China, Russia: OECD *Main Science and Technology Indicators*
EU: Web-based database of Statistical Office of the European Communities (hereafter Eurostat), and OECD *Main Science and Technology Indicators*
India: UNESCO Institute for Statistics S&T database, and the World Bank *World Development Indicators CD-ROM - 2007*

Moreover, an international comparison was made in terms of real research expenditures, with FY 2000 taken as the base of 100, after removal of the influence of price fluctuations to grasp more clearly the recent state of the increase in research expenditures of the selected countries/regions. Among them, Japan's research expenditures have been steadily increasing over the recent 10-odd years, but not so dramatically as those of its neighbors, China and South Korea (Figure 1-2-15).

Figure 1-2-15 Trends in Real Research Expenditures Index in Selected Countries/Regions with Figures for FY 2007 as 100

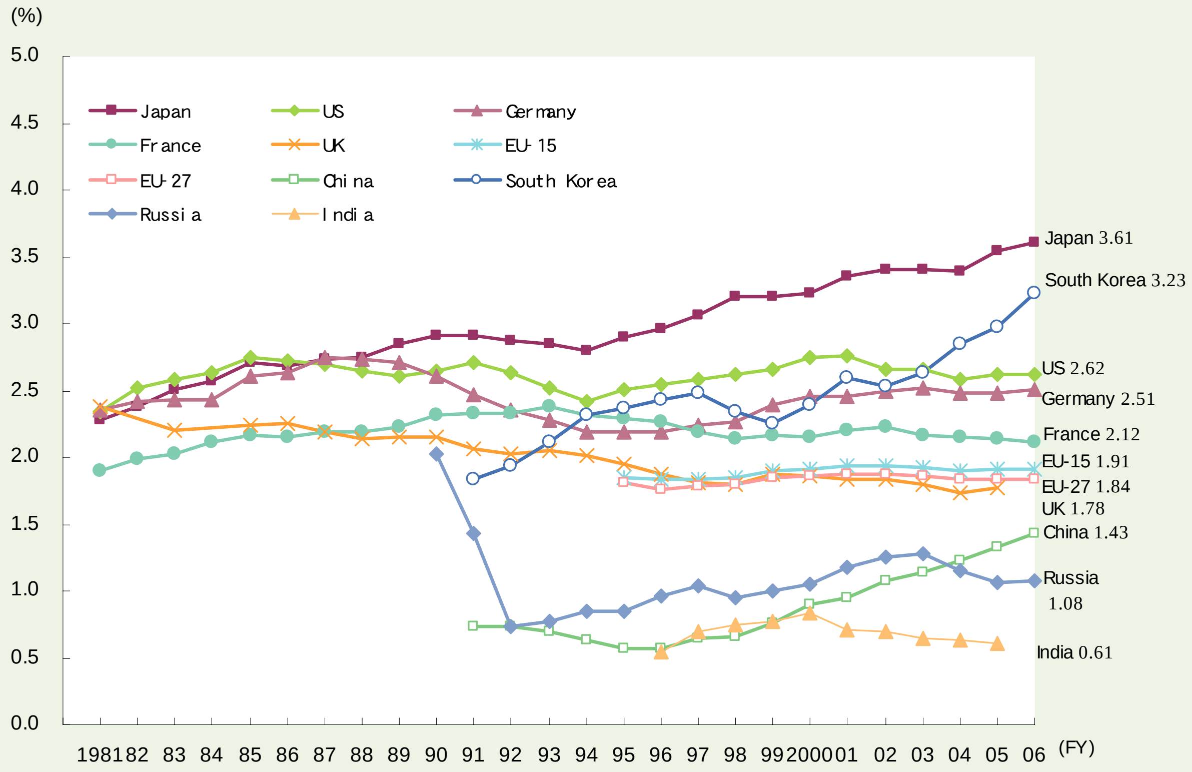


Note:
1. For international comparison, the figures of all countries other than South Korea include those of humanities and social sciences.
2. In FY 1996 and 2001, Japan increased industries surveyed.
3. The US figures for FY 2005 and 2006 are provisional. The French and German figures for FY 2006 are provisional. The EU-27 figures are estimates by the Organization for Economic Co-operation and Development.
4. The EU figures are estimates by Eurostat.
5. EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, the UK, Greece, Portugal, Spain, Austria, Finland, and Sweden)
6. EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania)

Sources: Same as those listed in Figure 1-2-14.

Next, the research expenditures-to-GDP ratios of the same countries are looked at with their economy size differences taken into consideration. After the selected countries'/regions' research expenditures-to-GDP ratios dropped at the beginning of the 1990s, those of Japan and the US have been on the increase since 1995. Shortly after the two countries, European countries also resumed increasing theirs. Japan still maintains the highest level among them, with its research expenditures-to-GDP ratio for FY 2006 standing at 3.61%. It is of note that those of China and South Korea have been increasing sharply (Figure 1-2-16).

Figure 1-2-16 Trends in R&D Expenditures as a Percentage of GDP in Selected Countries/Regions



Note:

1. For international comparison, R&D expenditures of all countries other than South Korea include those of humanities and social sciences.
2. In FY 1996 and 2001, Japan increased industries surveyed.
3. The US figures for FY 2005 and after are provisional. The French and German figures for FY 2006 are provisional. The EU-27 figures are estimates by the Organization for Economic Co-operation and Development (OECD).
4. EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, UK, Greece, Portugal, Spain, Austria, Finland, and Sweden)
5. EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania)
6. The Chinese figures for 1999 and before are either underestimated or based on underestimated data. The figures for 2000 and after have no continuity from those for 1999 and before.

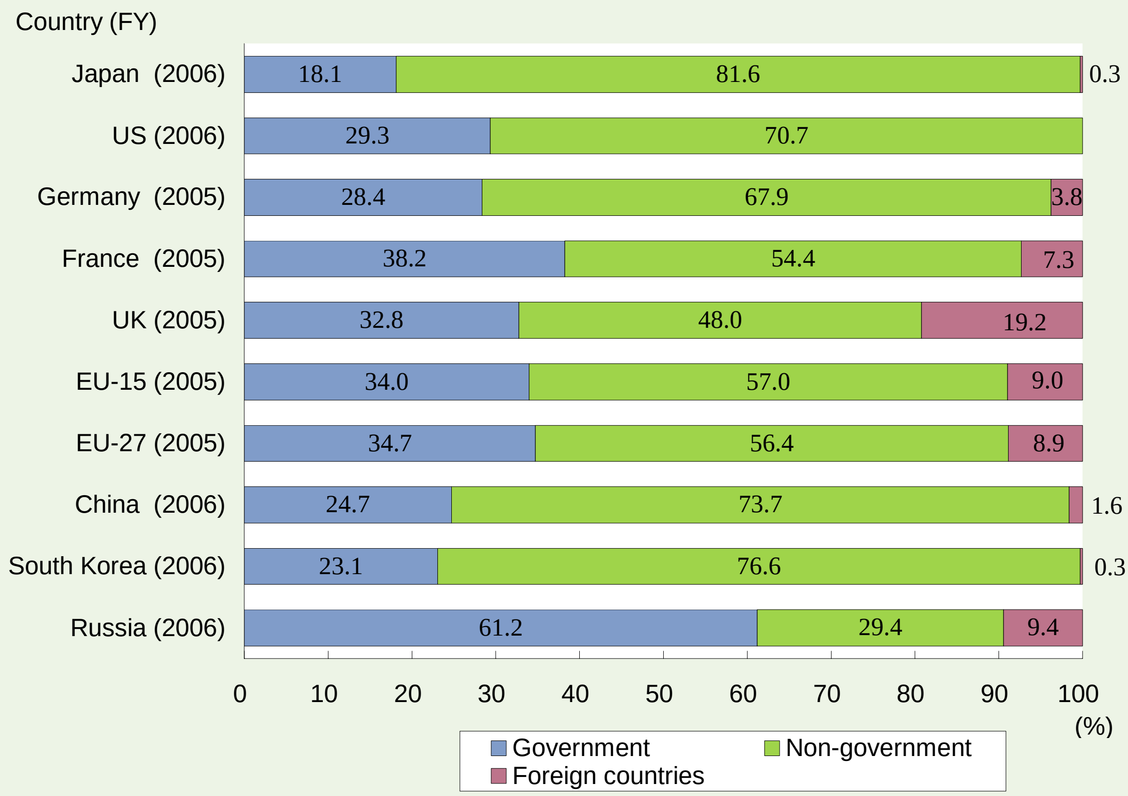
Sources: The figures for Japan are tentative estimates by MEXT, all based on the data compiled by the Statistics Bureau, Ministry of Internal Affairs and Communications and the Cabinet Office. The other countries' figures are based on the same sources as those of Figure 1-2-14.

2) Government R&D investment

Japan has a larger total amount of research expenditures relative to economic size than other countries. An international comparison of the R&D expenditure breakdown by payer reveals that an approximately 80% of the total amount of Japan's R&D expenditures are shouldered by the industrial sector, with the government's share of burden remaining at a lower level than in other countries (Figure 1-2-17). Thus, it is shown that Japan relies largely on private enterprises for research expenditures, while the government's burden relative to the economic size of the country is far from heavy.

The trends in PPP-converted government R&D budget of the selected countries/regions reveals that Japan has kept its R&D budget almost unchanged since 2000, whereas China, South Korea, and the US have been significantly increasing theirs during the same period and China's increase is particularly sharp. Moreover, Japan falls far behind its major competitors in terms of budget size; Japan's budget of ¥3.5 trillion (FY 2007) is dwarfed by ¥17.1 trillion equivalent (FY 2007) of the US, ¥12.1 trillion equivalent (FY 2005) of EU-27, and ¥10.1 trillion (FY 2006) of China (Figure 1-2-18).

Figure 1-2-17 Composition of R&D Expenditures by Financing Sector in Major Countries/Regions

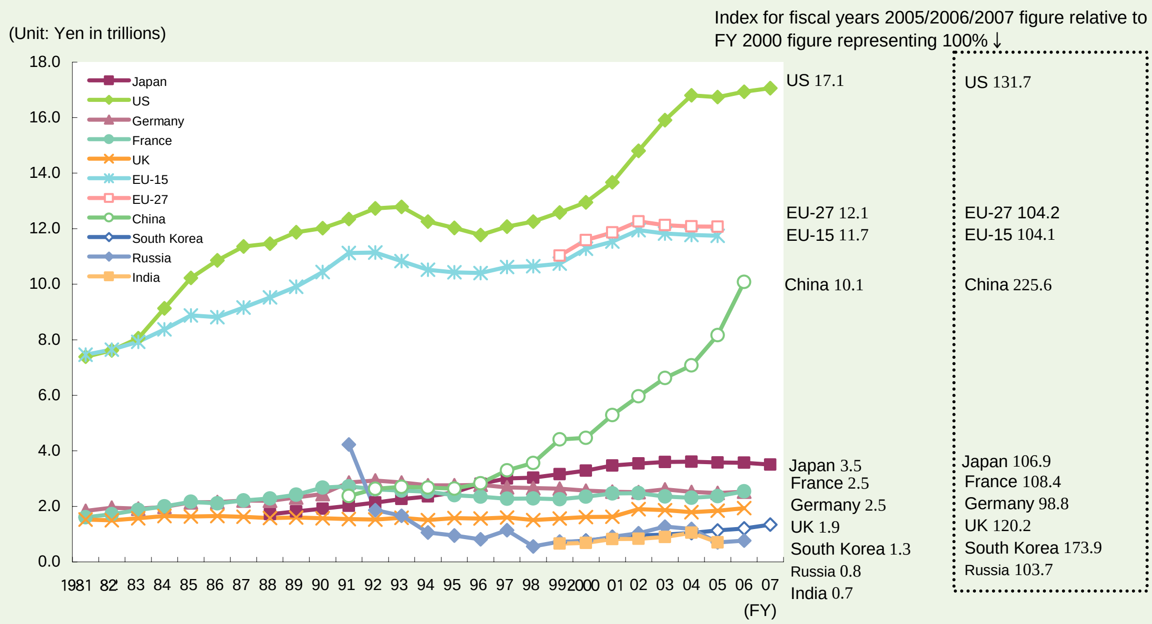


Note:

1. For international comparison, R&D expenditures of all countries other than South Korea include those of humanities and social sciences.
2. The US figures are provisional.
3. In each bar, all expenditures neither covered by the government nor foreign countries are lumped together into one portion labeled as "Non-government."
4. The EU figures are estimates by the Organization for Economic Co-operation and Development.
5. EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, UK, Greece, Portugal, Spain, Austria, Finland, and Sweden)
6. EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania)

Source: Same as in Figure 1-2-14.

Figure 1-2-18 Trends in Government R&D Budget in Selected Countries/Regions (On PPP-basis)



Note:

1. The US figure for FY 2007 is provisional. The French and German figures for FY 2006 are provisional.
2. The UK figures for FY 2005 and 2006 are provisional. The South Korean figures for FY 2006 and 2007 are provisional.
3. The EU figures are estimates by Eurostat. The Indian government R&D budget covers S&T expenditures as well as environmental expenditures.
4. Foreign currency conversion to yen is based on the Organization for Economic Co-operation and Development (OECD) PPP list (figures for FY 2007 are estimates). Because the OECD list does not cover India, the figures for India are cited from the World Bank PPP list.
5. The R&D budget of India for FY 2005 is smaller than those for FY 2004 and before, because of the revision of the 2005 World Bank PPP index in Dec. 2007. As for India, the index of FY 2007 R&D budget relative to that of FY 2000 taken as 100% was not calculated.
6. EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, UK, Greece, Portugal, Spain, Austria, Finland, and Sweden)
7. EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania)

Sources: Japan: MEXT Survey
US, Germany, France, UK, Russia, and South Korea: OECD *Main Science and Technology Indicators*
EU: Eurostat web-based database
China: *China S&T Statistics Data Book*
India: Ministry of Finance Union Budget 2008-2009, and the World Bank World Development Indicators CD-ROM - 2007

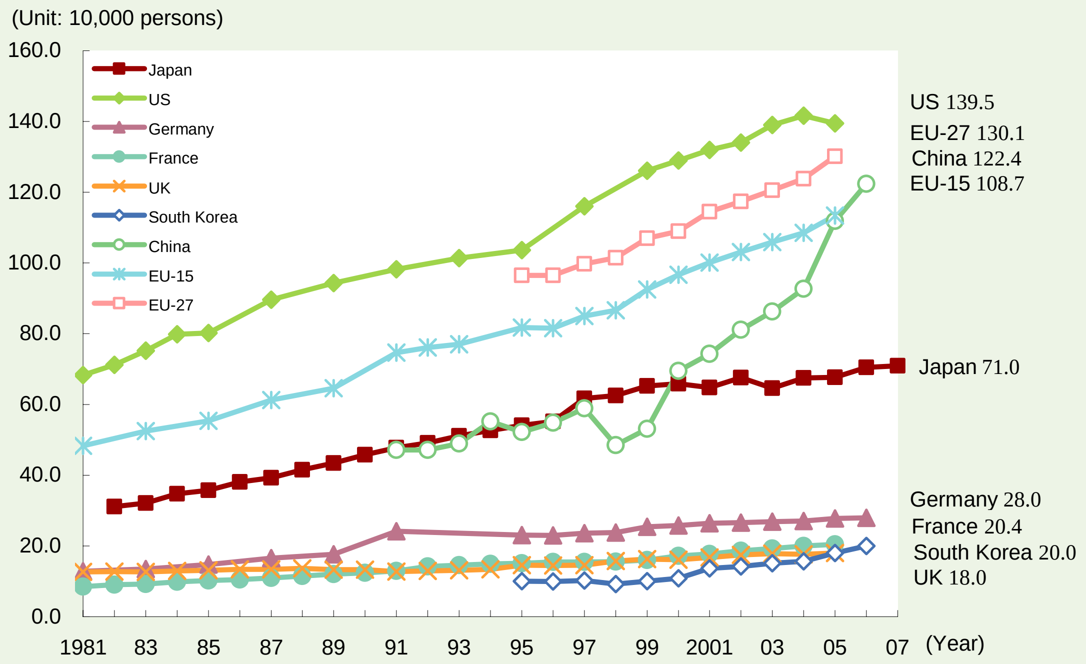
3) Number of researchers

The number of researchers in Japan for 2007 stood at 0.827 million persons, with a year-on-year increase of 0.8%. According to an international comparison with the selected countries/regions on an FTE basis[fn.15], which takes into consideration the proportion of time actually devoted to research activities, Japan has a researcher population of 0.710 million persons (2007), while the US and the EU-27 boast 1.395 million (2005) and 1.301 million (2005), respectively. Although it should be noted that

fn. 15 FTE: Acronym for full time equivalent. Used to indicate the proportion of actual hours worked for research activities. For example, if a researcher spends an average of 30% of his/her working hours for R&D duties and the rest for other activities (teaching, university administrative duties, student counseling, etc.), s/he is a 0.3 FTE researcher. A 1.0 FTE researcher employed for 6 months is counted as a 0.5 FTE researcher.

a direct international comparison of the number of researchers is impossible because of the difference in the counting method, there are a growing number of researchers in other selected countries/regions as well. Particularly of note is China, with as many as 1.224 million researchers (2006) or approximately more than 1.7 times more researchers than Japan. At this rate, China is expected to soon have more than twice more researchers than Japan (Figure 1-2-19).

Figure 1-2-19 Trends in Number of Researchers in Selected Countries/Regions



Note)
1. For international comparison, the figures of all countries other than South Korea include those of humanities and social sciences.
2. Japan's figures for 2001 and before are those as of April 1st. Its figures for 2002 and after are those as of March 31st.
3. Japan's figures for 1996 and before are estimates by the Organization for Economic Co-operation and Development (OECD). Its figure for 2007 is calculated based on *Report on the Survey of Research and Development (2007)* compiled by the Statistics Bureau, MIC.
4. Japan's figures include the software industry for years 1997 and after, and the wholesale industry for years 2002 and after.
5. The figures for EU-15 (following 15 EU countries: Belgium, Germany, France, Italy, Luxembourg, the Netherlands, Denmark, Ireland, UK, Greece, Portugal, Spain, Austria, Finland, and Sweden) are estimates by OECD.
6. The figures for EU-27 (EU-15 plus the following 12 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, and Romania) estimates by OECD.

Source: OECD *Main Science and Technology Indicators*

(2) R&D outputs

1) Shares of scientific papers published and cited

Figure 1-2-20 shows the trends in selected countries'/regions' shares of scientific papers published and cited[fn.16] in their total number of papers published in the world's most prominent scientific journals.

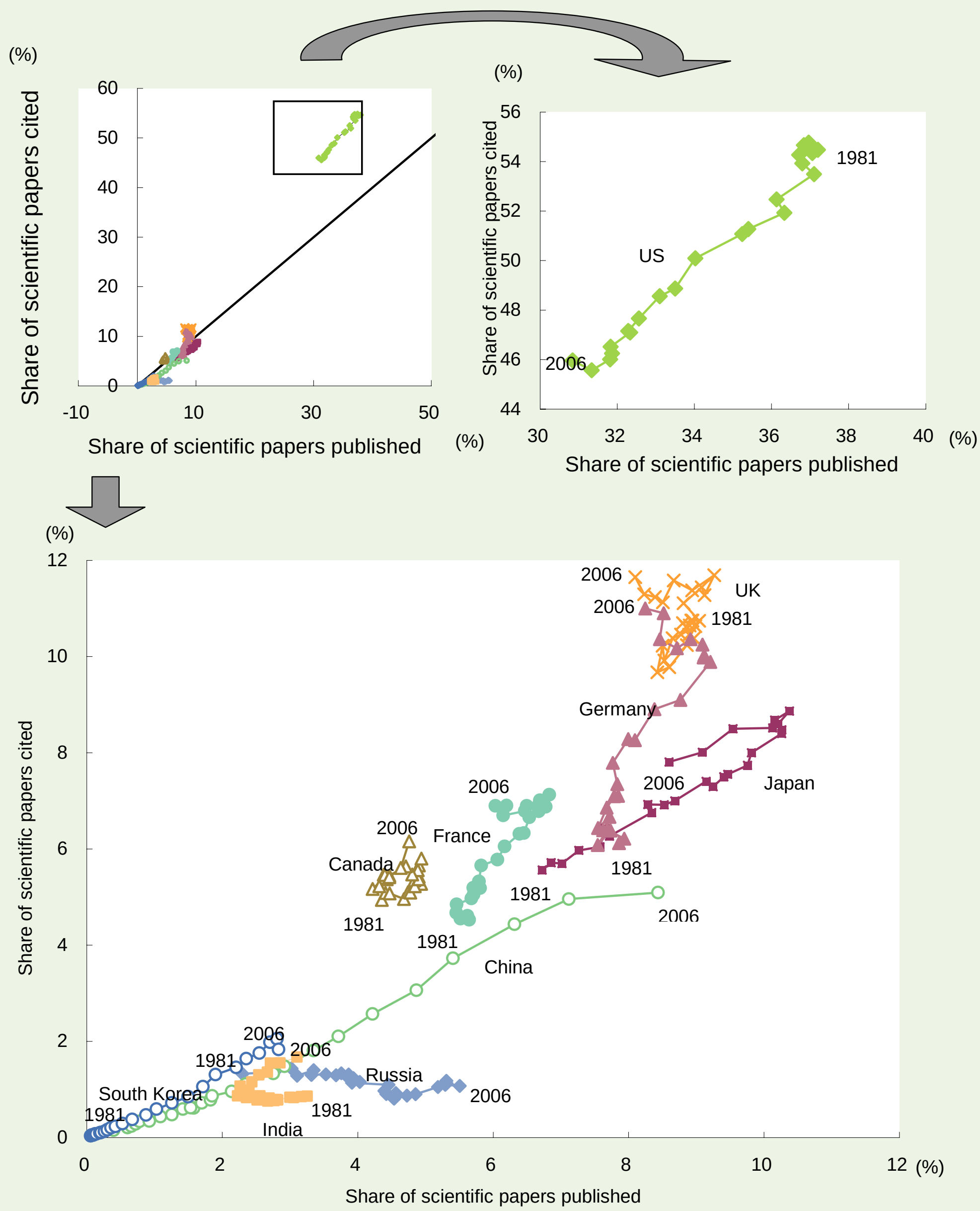
In 1981, Japan ranked fourth after the US, the UK, and Germany in terms of share in the world's

fn. 16 Generally speaking, excellent papers tend to be cited more frequently in other papers. Therefore, the number of times a paper has been cited can be used as an indicator of the quality of that paper.

total number of scientific papers published. Since having outstripped the UK in 1990, Japan has maintained second place. Meanwhile, when compared in terms of share of papers cited, Japan has ranked fourth after the aforementioned three countries since 1990 though its share has been on the rise year after year. Moreover, Japan's share of papers cited has remained low relative to its share of papers published.

The last several years have seen an increase in the number of Chinese-authored papers published. Now China has almost the same share of papers published as that of Japan, though China's share of papers cited has not increased at a rate comparable to its share of papers published.

Figure 1-2-20 Trends in Number of Scientific Papers and Number of Citations in Selected Countries



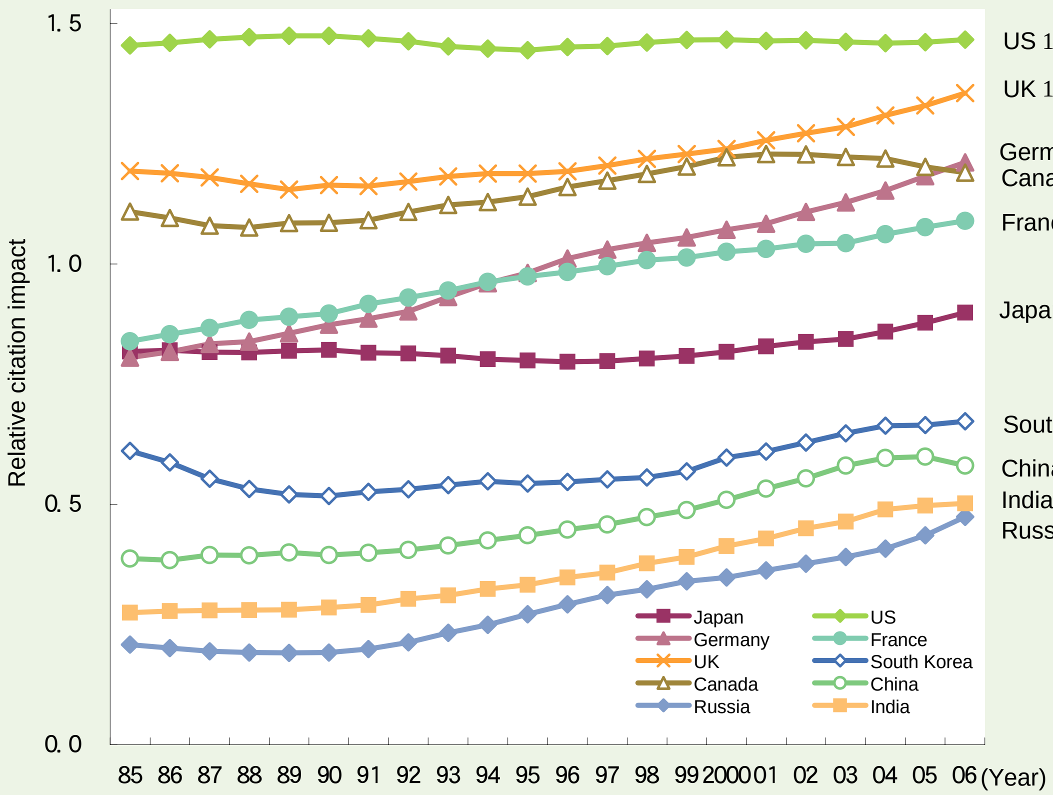
Note:
1. Papers in areas of humanities and social sciences excluded.
2. Multinationally co-authored papers are double-counted for inclusion in the figures of relevant countries.

Source: Compiled by MEXT based on Thomson Scientific *National Science Indicators, 1981-2006* (Standard version).

2) Relative citation impact of scientific papers

The frequency at which a paper is cited is indicated by the "relative citation impact[fn.17]." As shown by Figure 1-2-21, Japan's impact has remained low under 1.0, while those of the UK, Germany, and France have been stable at high levels, steadily moved upward and catching up with that of the US. Moreover, China and Russia has also been basically showing upward trends.

Figure 1-2-21 Trends in Relative Citation Impact, by Selected Country



Note)
1. Humanities and social sciences research papers excluded.
2. The figures for respective years are based on 5-year-window data to compare citation data on the same basis. For example, the figure for 1985 is based on that for years 1981 to 1985.
3. Multinationally co-authored papers are double-counted for inclusion in the figures of relevant countries.

Source: Compiled by MEXT based on Thomson Scientific, *National Science Indicators, 1981-2006* (Standard version)."

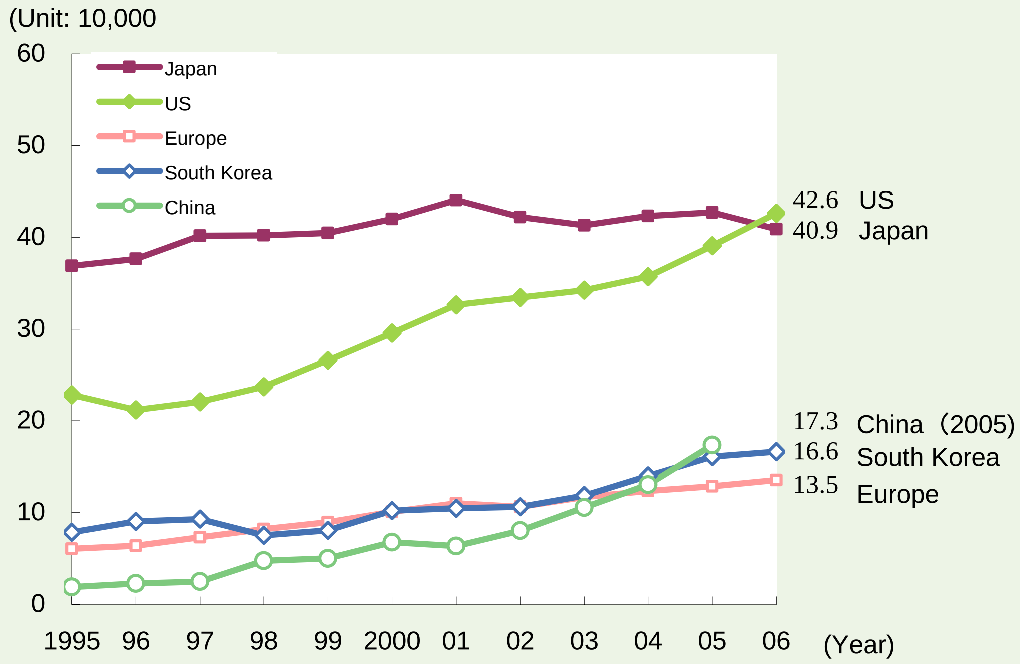
3) Patent market

A country where many patent applications are filed is an active locus of enterprise or organizational R&D activities. A country where many patent applications are filed from foreign countries is an important market or arena of competition for applicant foreign enterprises. Accordingly, it is considered that foreign enterprises make active efforts to obtain patents in such countries. An international comparison of the numbers of patent applications accepted by national and regional patent offices for years 1995 and after reveals that Japan remained the world's largest patent market up until 2006 with approximately 0.4 million applications per year. In 2006, however, the US came out on top with 0.426 million applications per year, followed by Japan with 0.409 million, China with 0.173 million (2005), South Korea with 0.161 million, and Europe 0.135 million in this order. As for the

fn. 17 The relative citation impact indicates how many per cent more or less citations the publications of a certain country have received in comparison with the citation impacts in the world (index=1).

growth rate for 2000 and after, Japan saw a 3% drop, while the US, Europe, China, and South Korea saw increases of 44%, 34%, 257%, and 163%, respectively. Thus, the Chinese and South Korean patent markets have shown particularly remarkable growth rates. As for the proportions of patent applications by applicant type, Japan has smaller proportions of applications filed by foreigners and PCT applications under transition to the national phase[fn.18] than the US and Europe (Figures 1-2-22 and 1-2-23).

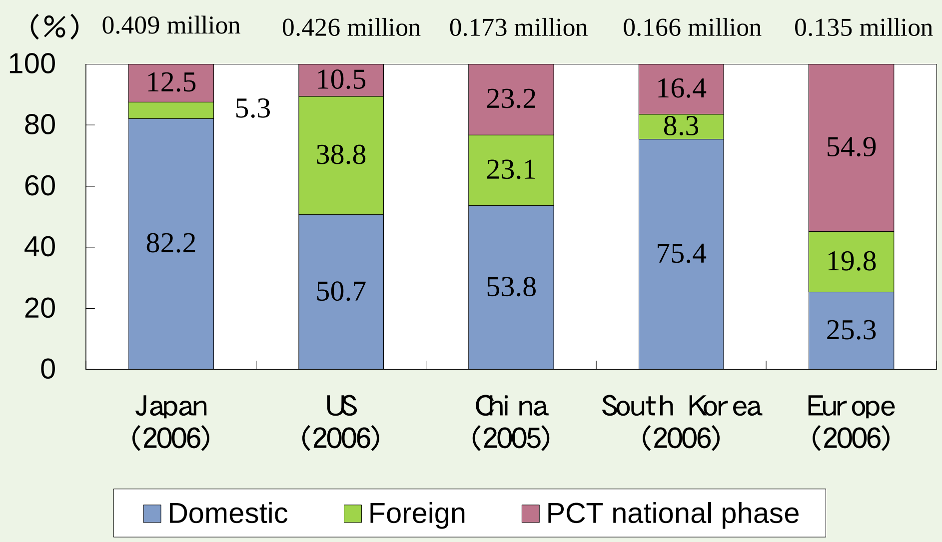
Figure 1-2-22 Trends in Number of Patent Applications Filed at Selected Countries'/Regions' Patent Offices



Note) The figures include the national/regional phase entries via PCT applications filed by residents or non-residents to each designated country.
Source: World Intellectual Property Organization *Patent Applications by Office 1985 to 2006* (revised on December 14, 2007)

fn. 18 The PCT application system is such that, pursuant to the Patent Cooperation Treaty (PCT), a patent application filed according to the due process specified by the Treaty shall be deemed as simultaneously filed in all PCT member countries (137 countries as of Mar. 2007). It should be noted, however, that the PCT application system is no more than a mechanism for international patent application filing. Whether an invention applied for an international patent can actually be patented in individual countries depends ultimately on a substantive patent examination (substantive examination) by the patent office of each country. Then, for a patent application to be substantively examined in individual counties, the applicant(s) must complete the "transition to national phase" procedure by a specified deadline to ensure that that application will be processed in those countries.

Figure 1-2-23 Patent Application Shares in Selected Countries'/Regions' Patent Offices



Note)

Resident: Number of resident patent applications filed (PCT applications excluded)

Non-resident: Number of non-resident applications filed (PCT applications excluded)

PCT national phase entries: Number of PCT national phase applications filed by residents or non-residents to each designated country

Source: World Intellectual Property Organization *Patent Applications by Office 1985 to 2006* (revised on December 14, 2007)

(3) Trends in high-tech industries

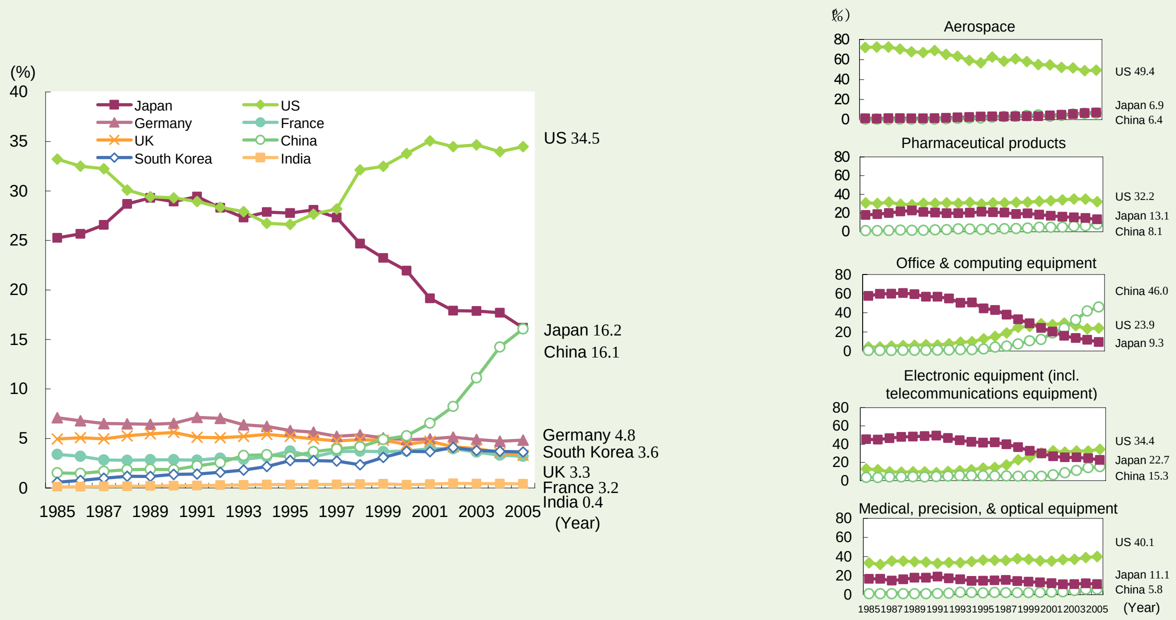
High-tech industries are defined as the top five industries (aerospace, office & computing equipment, electronic equipment (incl. telecommunications equipment), pharmaceutical products, and medical, precision & optical equipment) in terms of the proportion of the total R&D expenditures to the total manufacturing cost (according to the definition by OECD).

High-tech industries require massive R&D investments, and their product manufacturing processes involve highly advanced technologies. Therefore, the trends in a S&T-driven, high-tech industry in a country can be viewed as an indicator that reflects an aspect of the competitiveness of that industry. According to the National Science and Engineering Indicators 2008, the world's total revenue of high-tech industries expanded from US$1.1 trillion for 1986 to US$3.5 trillion for 2005, at an annual average growth rate of 6%, or at a rate more than twice faster than other industries, over the most recent 20 years, and its share increased from 10% to 18% of all manufacturing industries combined.

1) World shares of revenues of high-tech industries in selected countries/regions

In terms of the world shares of value-added revenues of the high-tech industries for 2005 (estimates), the US comes out on top with 35%, followed by Japan with the second largest share of 16.1%, a sharp drop from the peak of 29.4% for 1991. Meanwhile, China has rapidly expanding its share and come third place with 16.0%, only 0.1% below Japan's share. An industrial comparison reveals that Japan has seen drops in its global shares in four of the five industries, with the sharpest drop in the office & computing equipment industry from more than 60% share for 1986 down to 9.3% for 2005, whereas China has come to account for 46.0% (Figure 1-2-24).

Figure 1-2-24 World Shares of Value-added Revenues of High-tech Manufacturing



* "Value-added revenue" is gross revenue less the costs of raw materials purchased domestically or imported and those of intermediate inputs.

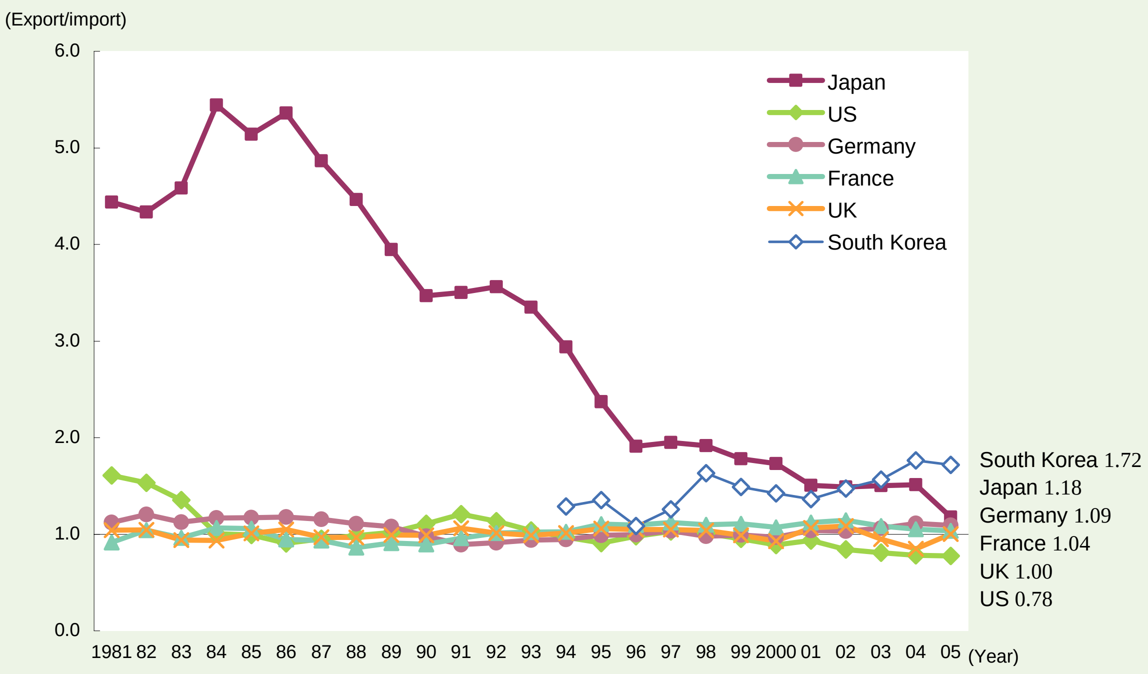
Source: Prepared by MEXT based on Appendix Tables 6-8, 6-9, 6-10, and 6-11 of National Science Foundation *Science and Engineering Indicators 2008*

2) Trade balances of high-tech industries

The trends in high-tech industry trade ratio[fn.19] in the selected OECD member countries reveal that, while the US, Germany, France, and the UK have maintained theirs around 1.0, Japan has seen a significant shrinkage of its ratio, albeit a large absolute amount, as viewed on a long-term basis. In 2003, Japan was outstripped by South Korea (Figure 1-2-25).

fn. 19 The figure of amount of high-tech industry export divided by that of high-tech industry import

Figure 1-2-25 Change in Trade Ratio of High-tech Industry in Selected OECD Member Countries



Source: Organization for Economic Co-operation and Development *Main Science and Technology Indicators*

2 Trends in S&T Capabilities by Field

(1) Trends in Japan's S&T capabilities and industrial competitiveness

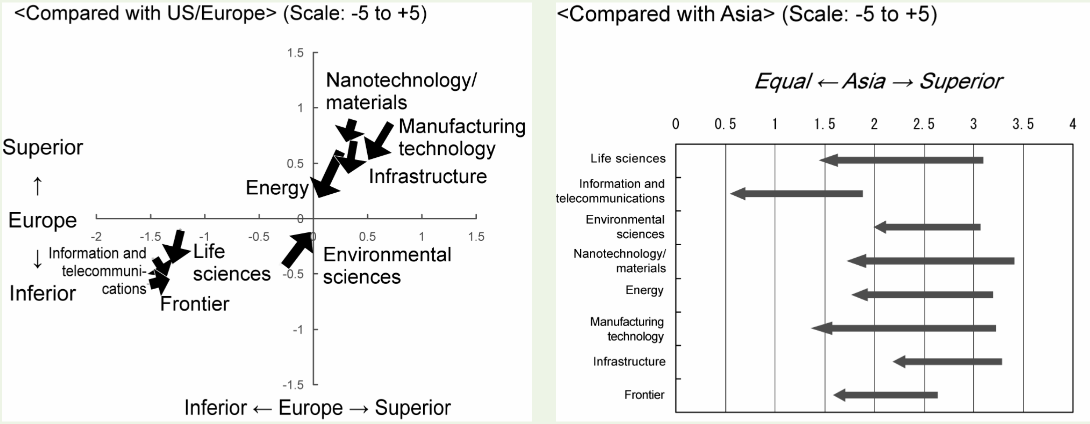
Some aspects of S&T capabilities and industrial competitiveness are difficult to evaluate based entirely on numerical data such as the volume of resource input, the number of scientific papers, or the number of granted patents. Therefore, the following paragraphs compare Japan's scientific, technological, and industrial competitive edges, field by field, with those of other countries on the basis of the result of an expert evaluation conducted by the National Institute of Science and Technology Policy (NISTEP) of MEXT. The following charts show six-level index evaluations of Japan's scientific, technological, and industrial competitive edges based on comparisons made by first-rate researchers in the relevant fields with those of the US, European and Asian countries (most advanced ones only).

It is considered that, on the whole, Japan still maintains a good scientific edge. When viewed with an eye to five years from now, however, it is feared that Japan may see an erosion of competitiveness in terms of technological prowess and social contribution (industrial applicability). In some S&T fields, Japan is feared to lose its relative technological superiority not only to the United States and Europe but to some Asian countries.

1) Scientific level

Japan is said to have a competitive edge over the US and Europe in the fields of manufacturing technology, nanotechnology/materials, and infrastructure. It is feared that, in five years from now, while likely to reduce the lag behind the US and Europe in environmental sciences and frontier, Japan may experience an overall drop in relative competitiveness in all other fields. It is also feared that Japan may lose some of its relative superiority over its Asian competitors. Especially in the field of information and telecommunications, it is expected that China, South Korea, and Taiwan will rapidly boost their technological capabilities up to a level high enough to challenge Japan (Figure 1-2-26).

Figure 1-2-26 Comparison of Japan's Scientific Level with the US, European and Asian countries

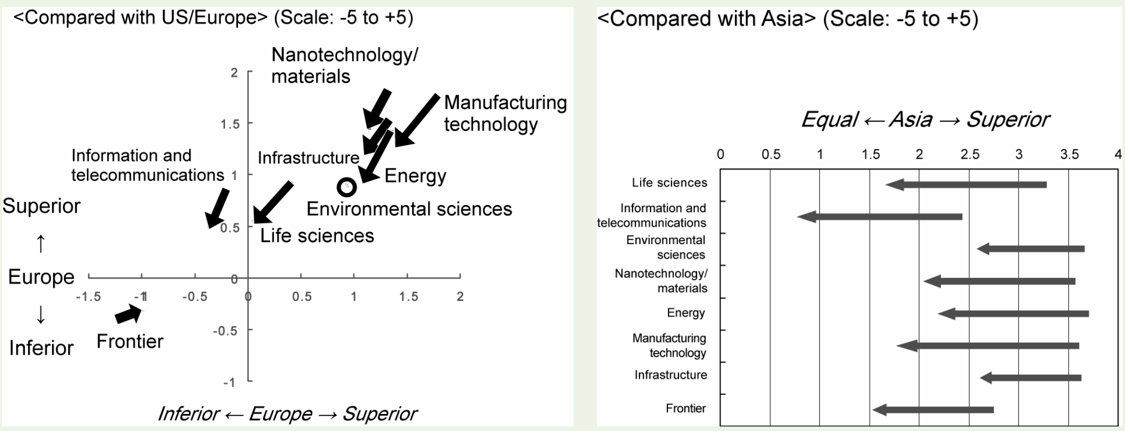


Note) 1. The tail end of each arrow in the charts above stands for "Present," and the head stands for "Five years after."
2. Higher scores indicate "higher levels of competitiveness" ("0" for "Equivalent").
Source: National Institute of Science and Technology Policy Report No. 109 *2006 Expert Survey on S&T Activities by Fields (Oct. 2007)*

2) Technological level

It is believed that, at present, Japan is technologically behind the US and Europe in frontier. Five years from now, Japan is expected to see an overall drop in relative competitiveness against the US and Europe in all fields other than environmental sciences and frontier. The same tendency applies to where Japan supposedly maintains global superiority. Even in the field of manufacturing technology, the expectation is that Japan will lose some of its competitive edge against the US and Europe. It is likely that, five years from now, Japan will lose much of its technological superiority over its Asian competitors in the field of information and telecommunications. The general tendency is similar to that of scientific competitiveness (Figure 1-2-27).

Figure1-2-27 Comparison of Japan's Technological Level with the US, European and Asian countries



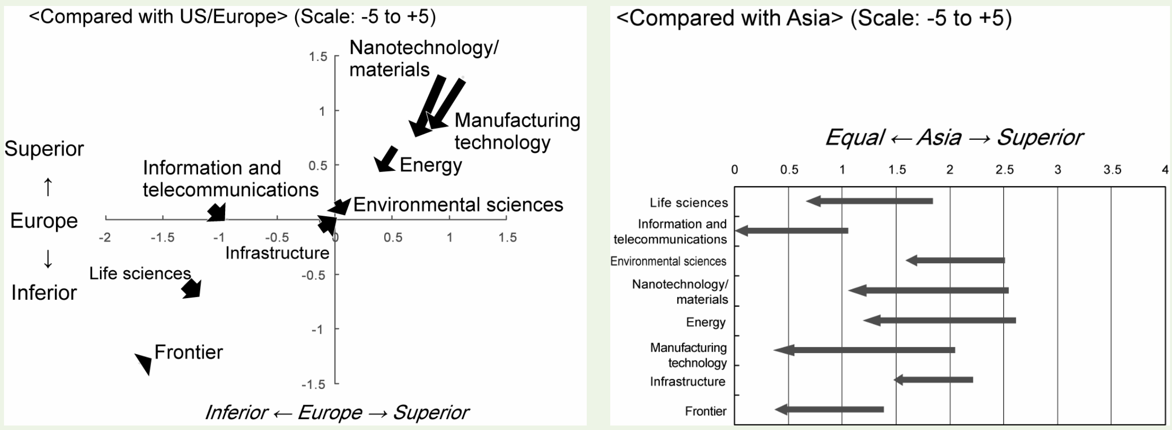
Note) 1. The tail end of each arrow in the charts above stands for "Present," and the head stands for "Five years after."
2. Higher scores indicate "higher levels of competitiveness" ("0" for "Equivalent").
Source: National Institute of Science and Technology Report No. 109, *2006 Expert Survey on S&T Activities by Fields (Oct. 2007)*

3) Industrial competitiveness level

Currently, it is considered that Japan maintains a good competitive edge over the US and Europe in the fields of nanotechnology/materials, and manufacturing. There is concern that, five years from now, Japan's lead may be trimmed. Today Japan is less competitive than the US and Europe in life sciences and frontier, and it its feared that the situation will remain the same with no improvement in five years from now.

The main worry is that Japan will suffer an overall decline in its competitiveness relative to its Asian competitors in all fields. This tendency is particularly evident in the field of information and telecommunications, and Japan is likely to lose most of its competitive edge over its Asian competitors in five years. Thus, it is considered realistic that the rising Asian competitors will rapidly catch up to Japan (Figure 1-2-28).

Figure 1-2-28 Comparison of Japan's Industrial Competitiveness with the US, European and Asian Countries



Note) 1. The tail end of each arrow in the charts above stands for "Present," and the head stands for "Five years after."
2. Higher scores indicate "higher levels of competitiveness" ("0" for "Equivalent").
Source: National Institute of Science and Technology Report No. 109 *2006 Expert Survey on S&T Activities by Fields* (Oct. 2007)

(2) Patent applications by technical field

One of the indicators for comparative analysis of the number of important patent applications by applicant's nationality with regard to the three countries/regions of Japan, the US, and Europe is provided by the number of triadic patent families (patent applications filed to JPO, USPTO, and EPO[fn.20]). A field-by-field breakdown of simultaneous patent applications filed in 2002 with a claim for priority[fn.21] to each patent office reveals that Japan surpasses the other two in terms of the number of patent applications for electronic parts and semiconductors; display and audio devices; and other electronics-related fields, whereas Japan ranks far below in life sciences-related fields such as genetic engineering; biotechnology; and pharmaceuticals (Figure 1-2-29). Thus, the trends in applications by technological field show that Japan outperforms the US and Europe in electronics-related fields but underperforms them in life sciences-related fields.

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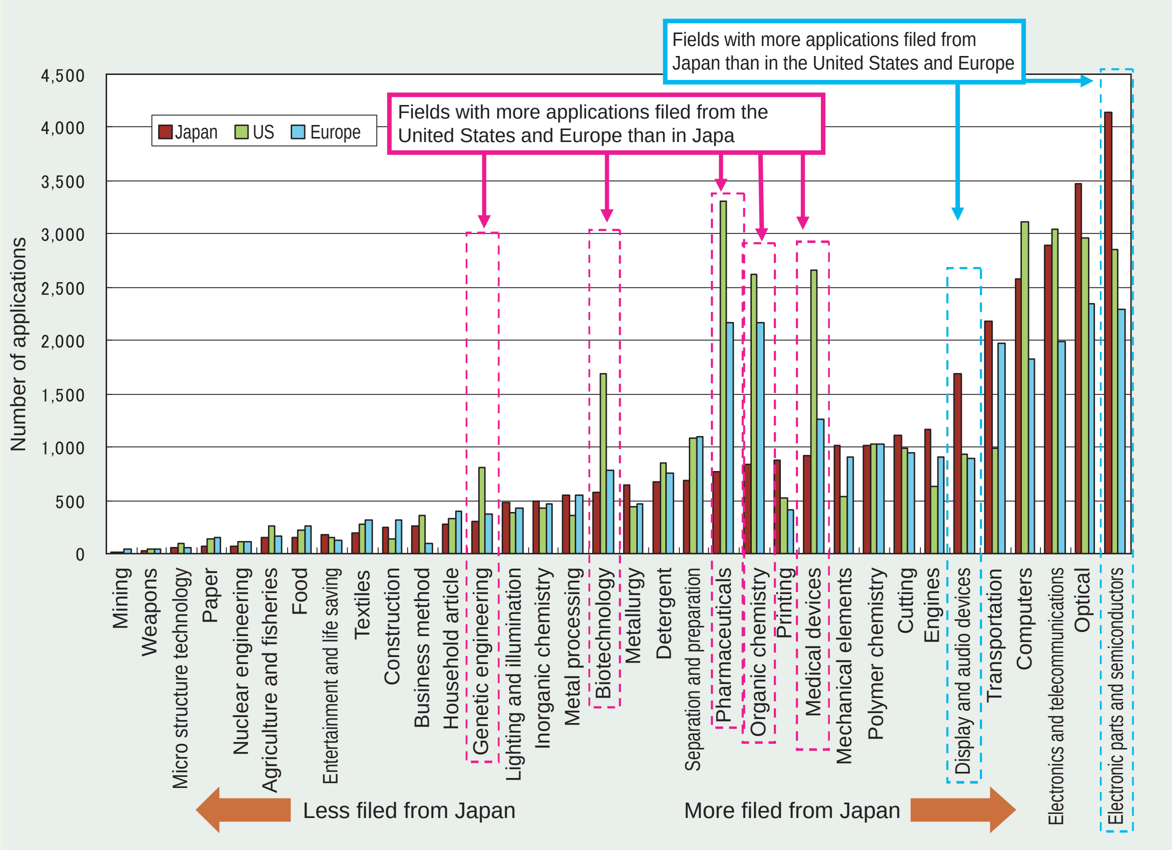
fn. 20 Triadic patent families: Patent application filed to JPO, USPTO, or EPO, upon which a claim of priority is based for a simultaneous application to the other two patent offices [International patent application filed under the Patent Cooperation Treaty: PCT or otherwise (Patent application filed directly with a specific patent office)]

fn. 21 If a claim for priority is presented during the pendency of the first filling of the patent application, the application will be deemed as having been filed in other countries on the same date as in the country of original filing.

Figure 1-2-29 Number of Triadic Patent Families, by Technical Field (2002)

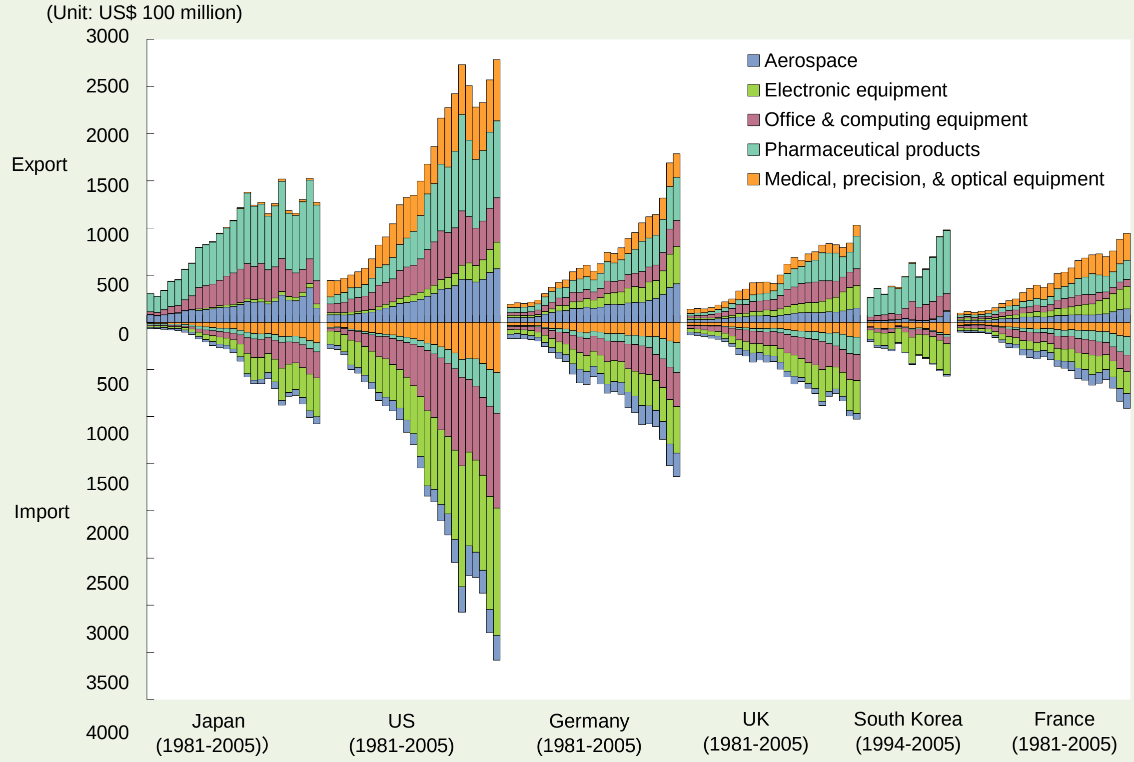


Source: Japan Patent Office *Annual Report 2007*

(3) Trends in high-tech industry trade value

While electronics-related industries (electronic equipment; and medical, precision and optical equipment) contribute to Japan's trade surplus, Japan runs trade deficits in aerospace and pharmaceuticals. The US, Germany, France, and the UK, unlike Japan, maintain stable export track records in aerospace and pharmaceuticals, without the sources of their competitiveness concentrated on the electronics industry (Figure 1-2-30).

Figure 1-2-30 Trends in High-tech Industry Trade Value in Major Countries



Source: Organization for Economic Co-operation and Development *Main Science and Technology Indicators*

3 Challenges concerning International Competitiveness of Tertiary Industries and Science-based Industries

(1) International competitiveness of tertiary industries

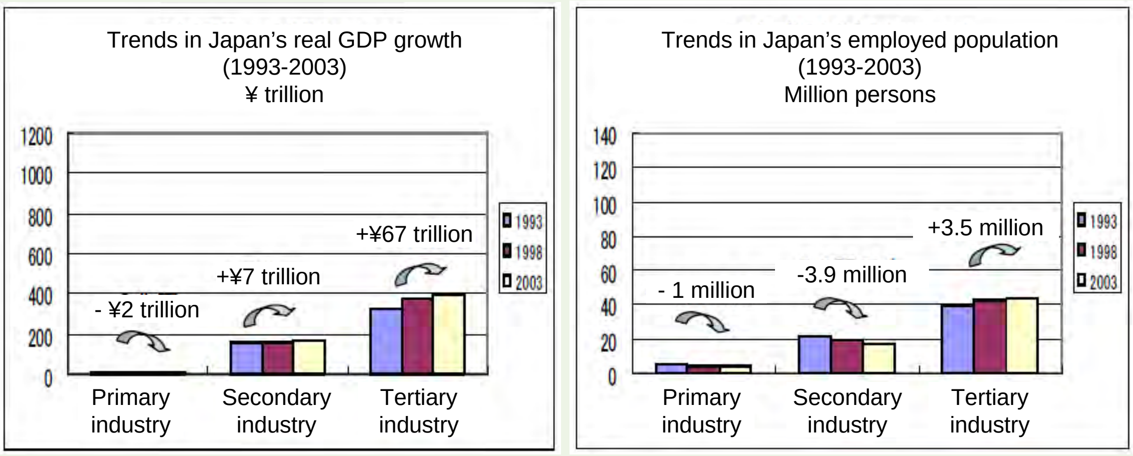
Year after year, the tertiary industry has been increasing its importance in the national economy, including employment, as Japan and other major developed countries undergo changes in their industrial structures. In fact, the tertiary industry accounts for an approximately 70% of Japan's GDP and approximately two-thirds of the total number of employments. It has been pointed out that, in business operations of manufacturing industries, service activities such as product support have been increasing their importance (Figure 1-2-31).

Therefore, to maintain its economic vitality, Japan must have a twin-economic engine driven by service/tertiary and manufacturing industries. Japan, however, generally ranks lower than the US and other competitors in terms of the labor productivity of tertiary industries. The labor productivity of tertiary industries remains low relative to that of manufacturing industries in Japan as compared with other developed countries (Table 1-2-32). While the improvement of such a low labor productivity of service industries and the development of new service industries are important agendas that Japan should address to sharpen its competitive edge, Japan's S&T investment in service industries remains extremely low as compared with that of the US (Figure 1-2-33).

In the US, there was awareness that systematic R&D was insufficient in the service sector despite the large share of services in economic activities in the country. In response to such awareness, the aforementioned *Palmisano Report* was published as a proposal for promoting services science defined as an interdisciplinary area of "computer science, operations research, mathematics, decision sciences, and social sciences." This publication and its proposal had a significant influence on the US industry and the government.

Following this sequence of events, the America COMPETES Act was enacted which defines services science as curricula, training, and research programs that "apply scientific, engineering, and management disciplines that integrate elements of computer science, operations research, industrial engineering, business strategy, management sciences, and social and legal sciences, in order to encourage innovation in how organizations create value for customers and shareholders that could not be achieved through such disciplines working in isolation" and stipulates that the government shall prepare a report in a period of one year, based on hearings from academics and industrial experts at the National Academies. Furthermore, in the US, NSF allocates services science-related competitive funds, and there are universities promoting services science-related programs (Table 1-2-34 and Figure 1-2-35).

Figure 1-2-31 Characteristics of Japan's Industrial Structure



Source: Ministry of Economy, Trade and Industry

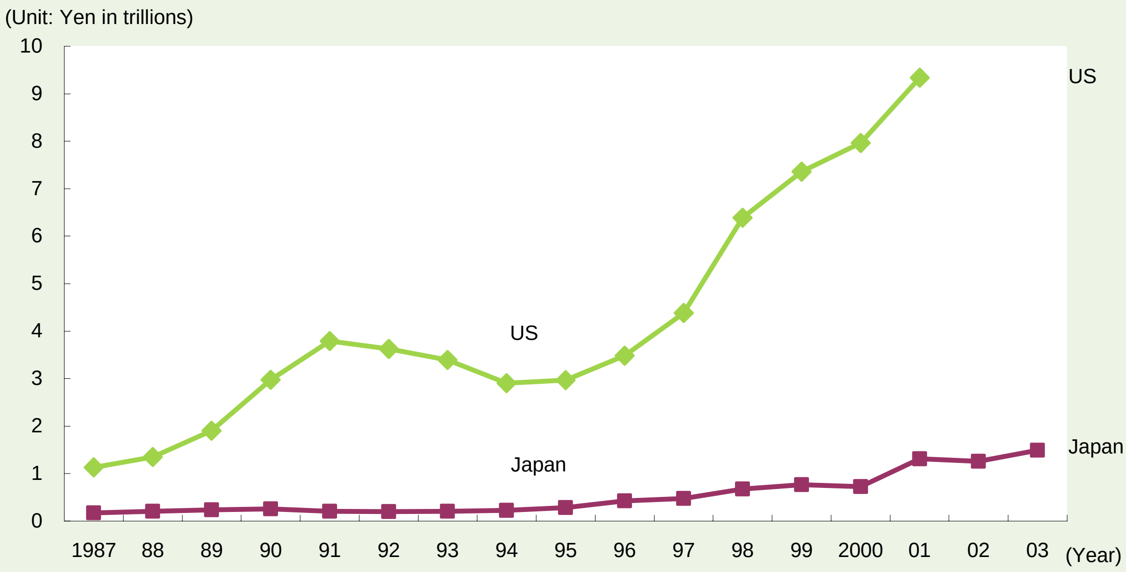
Table 1-2-32 Manufacturing- and Service-industry Labor Productivity Growth Rates, by Selected Country

Labor productivity growth rate (1995 to 2003)

	Manufacturing industry (%)	Service industry (%)
US	3.3	2.3
UK	2.0	1.3
Germany	1.7	0.9
Japan	4.1	0.8

Source: Prepared by MEXT based on Organization for Economic Co-operation and Development *Compendium of Productivity Indicator 2005*

Figure 1-2-33 Trends in the US and Japan's R&D Expenditures in the Service Sector



Source: Organization for Economic Co-operation and Development *Research and Development Statistics*

Table 1-2-34 Overview of Service Science-related Research Projects Awarded by National Science Foundation

Field	Research Title	Overview	Research Institute
Medical	Patient Scheduling for Primary Care Clinics: Theory and Implementation	The objective of the project is to develop and implement new clinical scheduling methods that accommodate the environmental complexities faced by clinic schedulers, such as patient no-shows (missed appointments) and patient walk-ins.	Purdue University
	Optimization Models and Algorithms for Emergency Response Planning	This project will develop better plans for the effective deployment of medical supplies in response to a large-scale infectious disease outbreak. The research also seeks to create models that develop adaptable decomposition and branching algorithms for large-scale mixed integer nonlinear programs.	University of Southern California
	Optimal Management of Expedited Placement Livers	The objective of the research is to fulfill the critical need for decision support in the management of expedited placement livers.	University of Pittsburgh

	Collaborative Research: Optimization of Intensity Modulated Radiation Therapy with Time Varying Delivery Plans and Fraction Constraints	Radiation therapy is prescribed for over half of cancer cases. Modern intensity modulated radiotherapy (IMRT) uses multiple non-homogeneous beams. This research extends modern (IMRT) planning methods that optimize combinations of multiple beams.	University of Arkansas
Business in General	Collaborative Research: Model Accuracy and Learning in Revenue Management and Dynamic Pricing	The impact of inaccurate models used by decision makers (buyers and sellers) in pricing processes will be analyzed.	University of Minnesota
	Scalable Analysis for Customer Contact Centers	This research aims to develop techniques that help analyze the performance of customer contact centers, such as general service time distribution and customer abandonment.	Georgia Institute of Technology
Transportation	Pareto-Improving Road Pricing Schemes for Sustainable Mobility	The objective of this research is to provide methodologies for developing road pricing schemes aimed at reducing both congestion and traffic emissions.	University of Florida
Logistics	Designing Distribution Centers for the Service Economy	This research investigates the design and operation of warehouses and distribution centers for maximum efficiency.	Auburn University
Large-scale disaster countermeasures	Contending with Materiel Convergence: Optimal Control, Coordination, and Delivery of Critical Supplies to the Site of Extreme Events	The goal of this project is to develop methodologies for supplies of critical resources to the site of an extreme event, based on concepts from the social sciences, control theory, and robust stochastic optimization.	Rensselaer Polytechnic Institute
	Collaborative Research: Patient Triage in the Aftermath of a Mass Casualty Event - A Dynamic Programming Approach	In the aftermath of mass casualty incidents, a significant number of injuries demand medical resources, such as operating rooms, ambulances, and X-ray machines. The effective use of these medical resources becomes extremely important. This project seeks to develop a better understanding of patient triage and prioritization decisions using stochastic dynamic programming.	University of North Carolina
Communications service	Positive Externalities and Complementarities in Networked Services	A positive externality: the value that consumers derive by being able to connect with other users of the service. In this research, models that help service providers evaluate the	Stanford University

		impact of positive externalities will be developed and analyzed.	

Source: Center for Research and Development Strategy, Japan Science and Technology

Figure 1-2-35 Curriculum Example of Service Science

Curriculum of the Operations Research & Management Sciences, College of Letters & Science, University of California at Berkeley

(1) Decision making in economic systems
Macroeconomic Theory, Advanced Microeconomic Theory, Economic Statistics and Econometrics, Engineering Stats/Quality Control/Forecasting

(2) Decision making in industrial and service systems
Production Systems Analysis, Service Operations Design and Analysis, Logistics and Supply Chain Management, Linear Programming, Engineering Stats/Quality Control/Forecasting

(3) Decision making in societal systems
Sociological Theory, Introduction to Sociological Methods, Intermediate Sociological Methods, Engineering Stats/Quality Control/Forecasting

(4) Algorithmic decision-making process
Data Structures, Intractable Problems and Efficient Algorithms (Algorithm Design Methods), Computability and Complexity, Combinatorics, and Discrete Probability

[4 credits each]

Source: National Institute of Science and Technology *Science and Technology Trends - Monthly Review* (December 2005)

(2) International competitiveness of science-based industries

"Science-based industries" refer to a "group of industries based on sciences, or a group of industries reliant heavily on basic sciences."[fn.22] In some fields, the gap between technology and science has been narrowing, as can be seen from the increasingly strong tendency in recent years to cite academic papers in patent documents. For example, as many of electronic component technologies are getting toward physical limits, fundamental scientific approaches to problem-solving play important roles in the electronics industry. Industries clearly showing such a tendency are called "science-based industries." Usually, pharmaceutical, IT, and semiconductor industries are referred to as such.

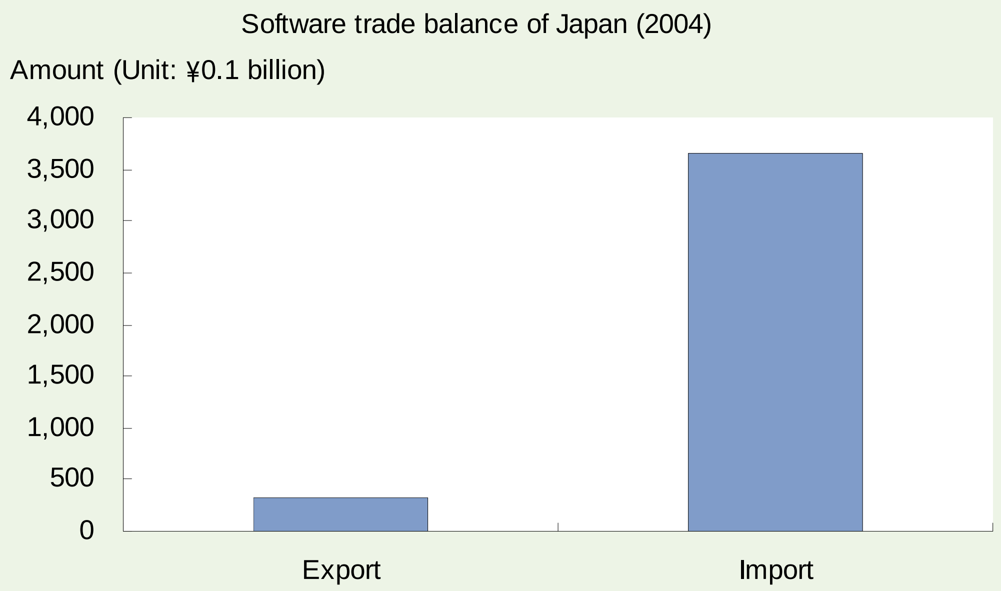
Japan does not necessarily have a very sharp international competitive edge in these industries, lagging far behind the USA, which, ever since the 1980s, has taken strong measures to encourage these industries. For instance, Japan has been running trade deficits in pharmaceutical and software products (Figure 1-2-36). When it comes to multi-purpose package software, the US has an unrivaled competitive edge (Figure 1-2-37). In addition, Japanese semiconductors have rapidly been losing their once-overwhelmingly large world market shares since the second half of the 1990s onward because of the loss of the comparative advantages of semiconductor manufacturing processes due to the so-called modularization and other factors. Now Japan has given up a huge lead to the Republic of Korea and the US (Figure 1-2-38).

fn. 22 *Science Based Industries*, Akira GOTO and Hiroyuki ODAGIRI (eds.) (2003), NTT Publishing Co., Ltd.

Figure 1-2-36 Import-Export Situation of Japanese Pharmaceutical (FY 2002)

Source: Ministry of Health, Labour and Welfare *Survey of Pharmaceutical Industry Productions*

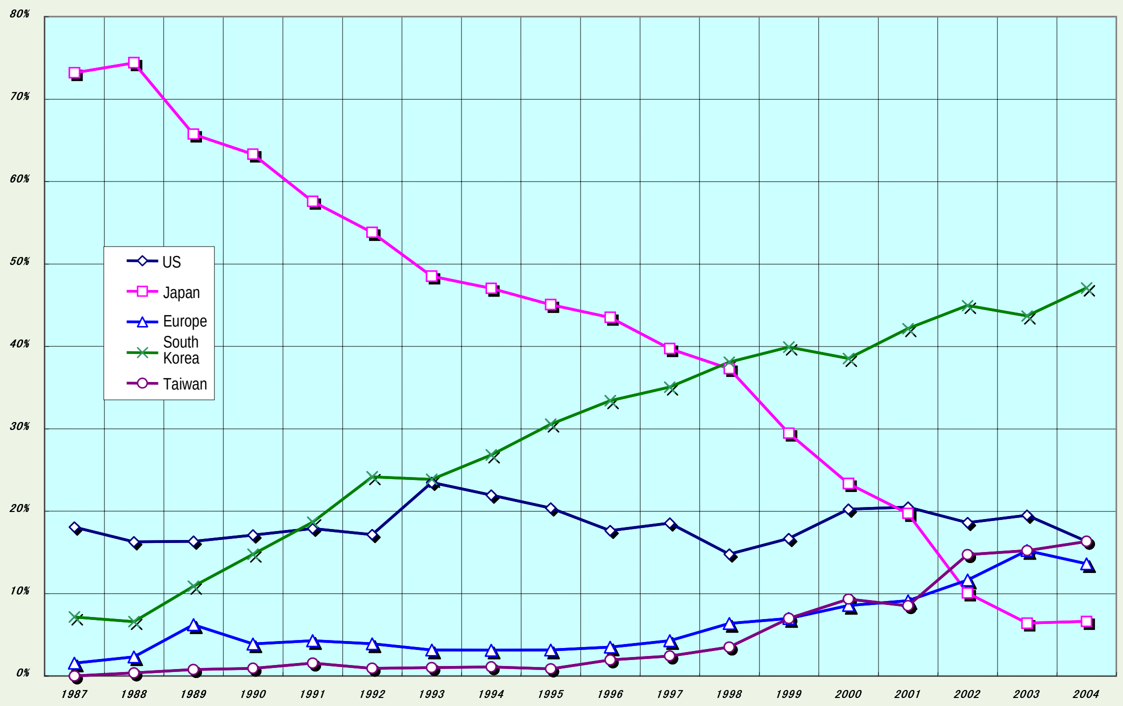
Figure 1-2-37 Import-Export Situation of Japanese Software (FY 2004)



Source: Japan Electronics and Information Technology Industries Association, Japan Personal Computer Software Association, and Japan Information Technology Services Industry Association *Survey on Overseas Transactions and Use of Foreign Labor in the Computer Software Industry*

Figure 1-2-38 Trends in the World Semiconductor Industry

Trends in share of DRAM shipment value (US$), by country



Source: National Institute of Science and Technology Report No. 103 *Preliminary Study on the Measurement of Innovation*

Japanese manufacturing industries have traditionally depended heavily on the improvement of shop-floor productivity to sharpen their international competitiveness. Unfortunately, such an approach alone cannot ensure maintenance of competitiveness in science-based industries. Hence, it is expected that fundamental scientific approaches to problem solving will increase their importance. Because of such a nature of science-based industries, in other countries, universities and R&D venture firms have been identified as playing leading roles in basic research and have achieved many successful product developments through industry-academia cooperation.

4 Weakening of Foundation of Human Resources

(1) Challenges concerning S&T human resources for the next generation

As can be seen from the results of the OECD Programme for International Student Assessment (PISA 2006 Survey) disclosed in December 2007, various problems concerning the human resources for the next generation's S&T have been noted including the tendency that Japanese high school students are less knowledgeable and interested in science and mathematics (Table 1-2-39). Such a situation poses a threat that may seriously undermine the foundation of research human resources expected to support the foundation of the next generation's S&T and play key roles in creating innovation.

Table 1-2-39 Students' Responses to the PISA 2006 Survey

Index of general interest in science

Percentage of students reporting high or medium interest in	Japan	OECD average
Human biology	65	68
Topics in astronomy	55	53
Topics in chemistry	48	50
Topics in physics	40	49
The biology of plants	58	47
Ways scientists design experiments	34	46
Topics in geology	33	41
What is required for scientific explanations	25	36

Index of enjoyment of science

Percentage of students agreeing or strongly agreeing with the following statements	Japan	OECD average
I enjoy acquiring new knowledge in science.	58	67
I generally have fun when I am learning science topics.	51	63
I am interested in learning about science.	50	63
I like reading about science.	36	50
I am happy doing science problems.	29	43

Source: National Institute for Educational Policy Research (ed.), *Knowledge and Skills for Life: Third Results from the OECD Programme for International Student Assessment (PISA 2006 Survey)*, December 2007, Gyosei Corporation

(2) Challenges concerning undergraduate and postgraduate education

In the context of global competition for researcher recruitment, it is of critical importance to enhance the international competitiveness of Japanese universities and graduate schools responsible for educating and training industrial researchers. Moreover, Japanese universities and graduate schools are left outside the international circulation of researchers, as can be seen from their disproportionately smaller numbers of foreign teaching staff and international students than the US and European counterparts, or from the fact that only small fractions of Japanese university graduates and graduate school graduates join overseas research institutions and enterprises. For Japan to win out in global competition, it is necessary to produce internationally active researchers from the country and develop research environments attractive to outstanding foreign researchers and international students.

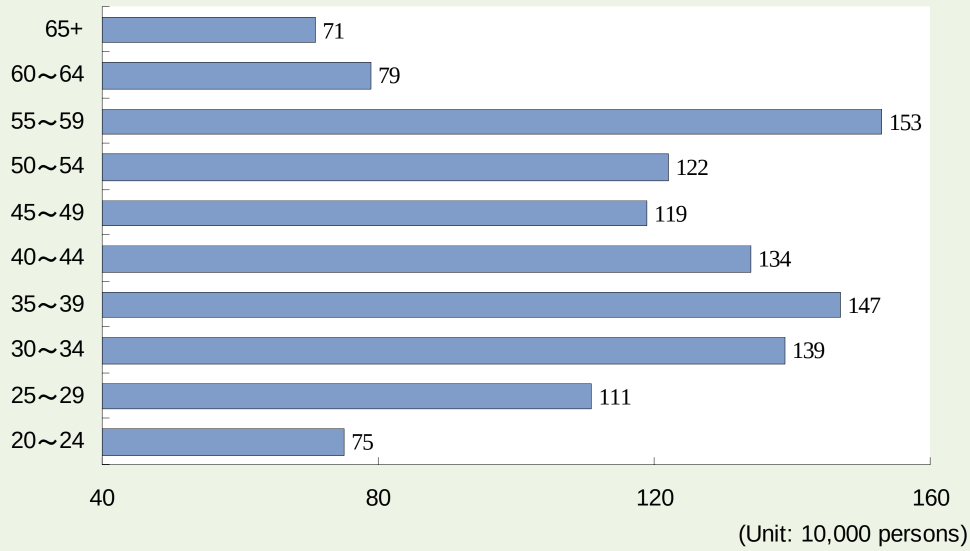
When considering such phenomena as the commoditization of technology, which is described in Chapter 1, and the increase and expansion of science-based industries explained above in this section (2.2), it will be more important on the part of industries to make better use of knowledge and expertise of universities and other public research institutions, rather than conduct all R&D activities internally. Accordingly, universities are expected to strengthen their ties with industries and provide more practical education that better matches the needs of society.

(3) Challenges concerning Monodzukuri (manufacturing) human resources

Concerns are rising that the mass retirement of the baby-boomer generation who turn 60 around 2007 and will turn 65 around 2012 may result in loss of sophisticated Monodzukuri techniques. Thus, preparedness for the so-called Year 2007 Problem has become a hot issue.

Now it has become a serious challenge how to hand down the existing Monodzukuri techniques from the retiring generation to the next generation in order to maintain the current level of techniques and skills that have been the forte of Japanese manufacturing industries.

Figure 1-2-40 Employed Population by Age (Manufacturing Industry)



Source: The Statistics Bureau, Ministry of Internal Affairs and Communications *Labor Force Survey (2007)*

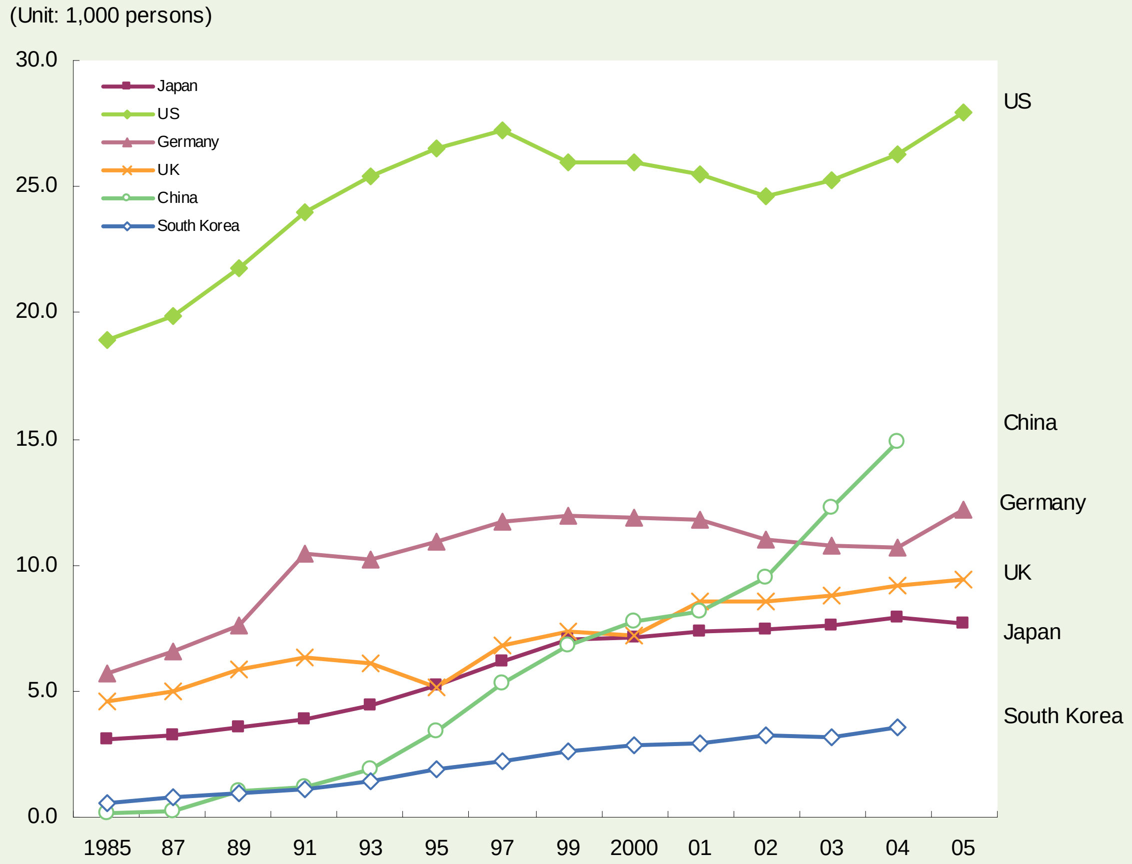
(4) Trends in numbers of young, female, and foreign researchers and research assistants

Facing with declining population and decreasing birth rate, coupled with advanced aging, Japan must make active appointment of young, female, and/or foreign researchers to maintain a secure pool of S&T human resources. To ensure efficient R&D promotion, it is essential to increase research assistants. The following paragraphs provide international comparisons in terms of S&T human resource issues.

1) Rapid Increase of science and engineering doctorate holders in China

It is said that, in the US, a high-quality postgraduate education system capable of producing large numbers of S&T researchers greatly helps to create innovation and sharpen its international competitiveness. While the US has the largest number of 27,974 S&E doctorate holders (2005) among the selected countries, China is in second place with its figure rapidly increasing in recent years to 14,858 (2004), nearly twice as many as Japan's figure of 7,912 (2005) (Figure 1-2-41).

Figure 1-2-41 Trends in Number of S&E Doctoral Degrees, by Selected County

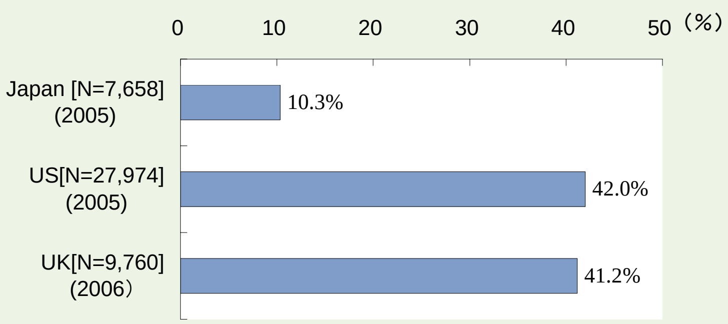


Source: Prepared by MEXT based on National Science Foundation *Science and Engineering Indicators 2008* Appendix tables 2-42 and 2-43

2) Composition of foreign researchers accepted in selected countries

In terms of the proportion of foreign researchers with S&E doctoral degrees, Japan remains at a low level of 10.3% (2005) in contrast to the US and UK figures of 41.2% (2005) and 42.0% (2006) (Figure 1-2-42).

Figure 1-2-42 Foreign Student Share of S&E Doctoral Degrees, by Selected Country



Note: The value "N" in each bar is the total number of S&E doctoral degree recipients.
Source: Prepared by MEXT based on National Science Foundation *Science and Engineering Indicators 2008* Appendix table 2-49

While foreign researchers account only for 1.3% of the total number of researchers in Japan (as of end of 2005),[fn.23] their counterparts in the US constitute 11.3% of the total number of scientists and engineers with doctoral degrees in the US[fn.24]. The proportion of foreign nationals in the total number of university teachers (full-timers) is 3.5% (2006) in Japan[fn.25], while 22.3% (2003) of the total number of US university teachers (full-timers with PhDs) are of foreign origin[fn.26]. Thus, there is a considerable gap between the two countries in terms of the acceptance and appointment of foreign researchers.

3) Appointment of female researchers

The number of female researchers, including those in humanities and social sciences, has been on the increase year after year, up to 109,000 in 2007 or 12.4% of the total number of researchers in Japan. Considering, however, that female accounted for 41.5% (26.59 million) of the annual-average total employed population (64.12 million) for 2007 according to the *Labor Force Survey* of the Ministry of Internal Affairs and Communications (MIC), the number of female employed in R&D fields is still disproportionately small. A percentile breakdown of female researchers by organizational type reveals that 6.8% belong to enterprises and other profit-making entities, 11.8% to non-profit organization, 13.2% to public organizations, and 22.1% to universities. Thus, in Japan, universities employ the largest share of female researchers. When compared in terms of the proportion of female researchers to the national total for 2005, they constitute an extremely smaller portion in Japan than in other countries (Figure 1-2-43).

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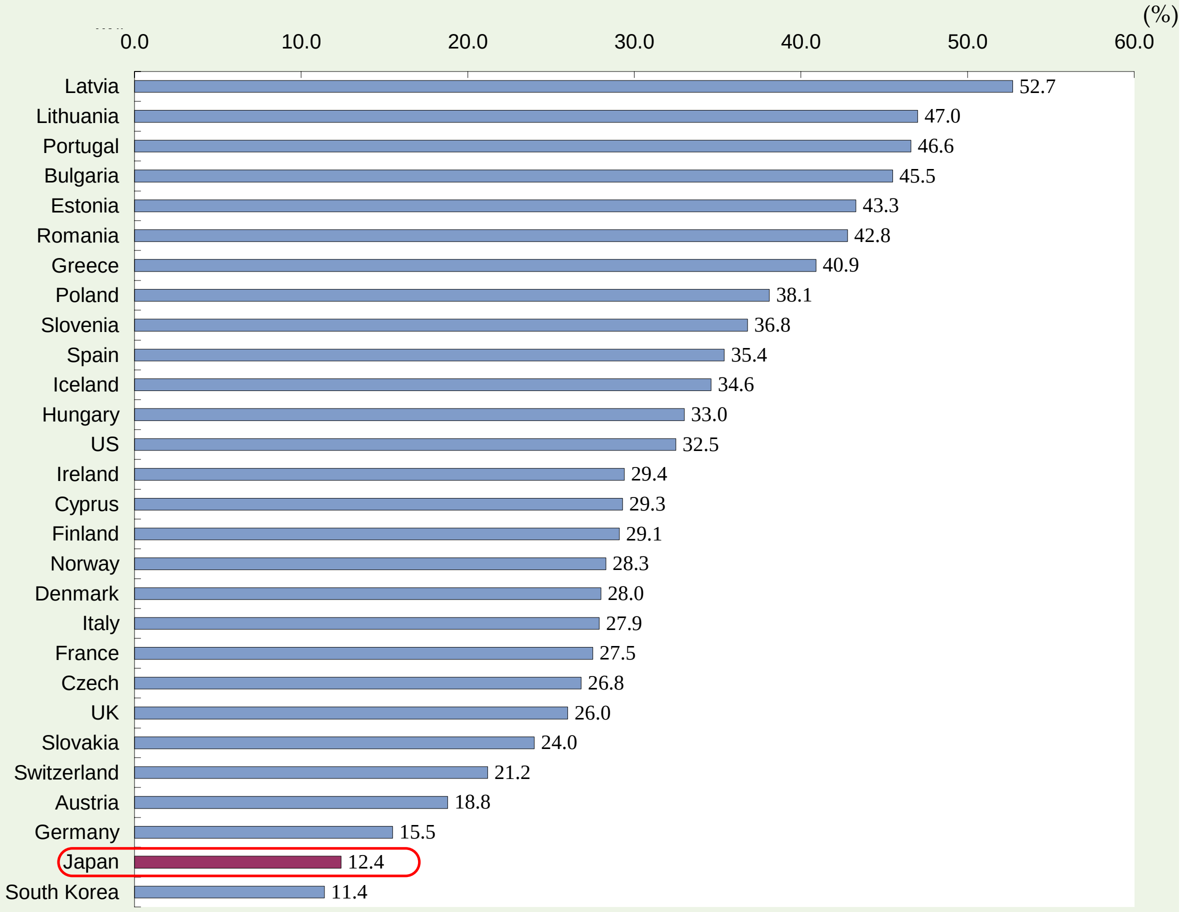
fn. 23 NISTEP *Science and Technology Indicators - Data updated in 2007 for 5th edition*

fn. 24 NISTEP & Mitsubishi Research Institute, Inc. *Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Achievements and Issues of Major Policies for S&T Human Resources Training Program (March 2005)*

fn. 25 MEXT *Fiscal 2006 School Basic Survey*

fn. 26 NSF *National Science Indicators 2006*, Appendix tables 5-30

Figure 1-2-43 Female Share of Total Researchers (International Comparison)



Sources:
1. Prepared based on *NISTEP REPORT No.86* (except Japan and the US)
   The figure for Iceland is for 2002. The figures for Germany, France, Ireland, Italy, Poland, Switzerland, and the UK are for 2000. The figures for Greece and Portugal are for 1999. The figure for Austria is for 1998. The figures for other countries are for 2001.
2. Japan's figure is based on *Report on the Survey of Research and Development (2007)* compiled by the Statistics Bureau, Ministry of Internal Affairs and Communications (as of March 2007).
3. The figure for the US is for 1999, and is the female share of total number of scientists (including some of humanities and social scientists) according to National Science Foundation *Science and Engineering Indicators 2004*.

4) Declining number of research assistants

Research assistants tend to be viewed as "fringe existences" in R&D despite their functional importance in R&D. In complicated and large-scale modern R&D activities, research assistants should be regarded as important support providers for researchers. The definition of the term "research assistant" varies from country to country similarly to the case of "researcher." In Japan, it is an umbrella term for assistant research workers, technicians, and clerical and other supporting personnel. The ratio of the number of research assistants to that of researchers, namely, the number of research assistants per researcher is used here for comparison. In Japan, the number of them per researcher has been on the decrease. In 2007, the figure went down to 0.27 persons per researcher, which is smaller than in European countries (Figure 1-2-44).

Figure 1-2-44 Trends in Number of Research Assistants per Researcher, by Selected Country

Note)

1. For the international comparison, the figures of all countries other than South Korea include those of humanities and social sciences.
2. Research assistants are those who assist researchers, provide technical services associated with research, or perform research-related clerical duties. In Japan, they are called "assistant research workers," "technicians," or "clerical and other supporting personnel" as appropriate for their functions.

Sources: Japan: Prepared by MEXT based on *Report on the Survey of Research and Development* compiled by the Statistics Bureau, Ministry of Internal Affairs and Communications
Others: Organization for Economic Co-operation and Development *Main Science and Technology Indicators*

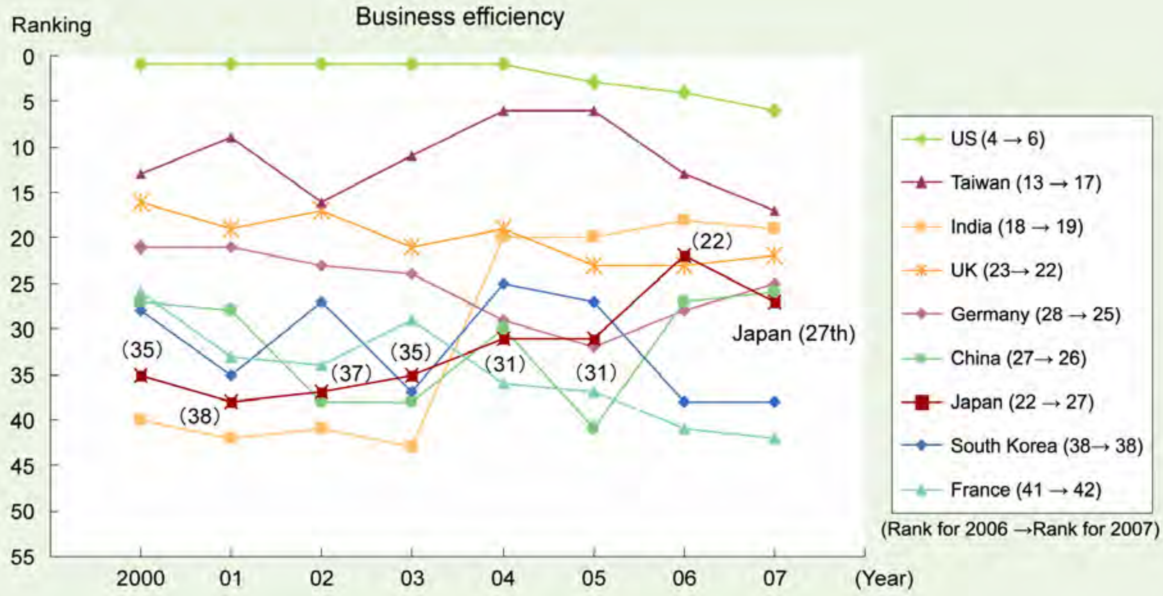
5 Challenges concerning Dissemination of Research Results to Society

What becomes important to ensure effective use of R&D in creation of innovation is the so-called exit strategies, according to which enterprises establish practical applications of R&D results without burying them. From such a perspective, this subsection overviews issues concerning the so-called management of technology (MOT) capabilities taken up as a typical example of exit strategies.

(1) Challenges concerning MOT

As explained in 2.1, Japan still invests a considerably large volume of resources in R&D and maintains a sizable volume of research outputs as compared with other countries, albeit the rapid catch-up by China and other competitors. According to the IMD ranking, however, Japan remains low at the 27th place in terms of management practices while ranking second in terms of scientific infrastructure (Figure 1-2-45). Therefore, it is concerned that Japan's resource input to R&D activities fails to lead to effective creation of innovation.

Figure 1-2-45 IMD World Competitiveness Rankings



Note) The ranking of each country is that for 2007.
Source: International Institute for Management Development *IMD WORLD COMPETITIVENESS YEARBOOK*

It is pointed out that the huge success of Japanese manufacturing industries has traditionally depended primarily on shop-floor productivity improvements or excellent "suriawase" (integration) techniques for complicated processes and intricate parts.[fn.27] In recent years, however, the general trends in R&D have shifted toward directions where such advantages of the Japanese way of manufacturing do not necessarily work effectively.

First, as explained in Chapter 1, commoditized technologies are in progress, which leads to increasingly short product life cycles and consequent side effects such as cost increases.

Second, the above-mentioned science-based industries, such as software and biotechnology, which usually involve fewer manufacturing processes and depend less on suriawase techniques, are increasing and expanding, coupled with the progress in service-industrialization of economy.

Moreover, the traditional manufacturing system of vertical integration using many internally procured components is becoming obsolete and outdated for some home electrical appliances and information equipment and is being replaced by the so-called manufacturing system of modularization, where many parts and components are procured from any suppliers around the world, as typically seen in PC and mobile phone assembly lines. In such a context, new forms of enterprises are emerging, including *fabless* R&D specialist companies that outsource non-R&D processes, such as manufacturing, and *foundry* companies specialized in manufacturing, as typically seen in the semiconductor industry. Furthermore, in recent years, there have been phenomena that pose threats to Japanese manufacturing industries. For example, automotives and other products with much lower price tags than before have been launched for markets in newly emerging countries.

To win in the international manufacturing competition under the rapid change in R&D practices, it no longer suffices to carry out excellent research and development. Now, it is also necessary to do so with an eye on how to use technologies and to have a far-reaching perspective of what kind of R&D activities should be pursued. Moreover, better use of external research resources, typically universities

fn. 27 See Column 6.

and other public organizations or technology-based venture firms, rather than entire dependence on individual entities for the whole R&D process, is the key for Japanese manufacturing industries to enhance their own R&D capabilities.

Therefore, to deal with such changing situations, it has never been more important than now that industries use external research resources effectively and, while understanding their capacities and surrounding situations, promote R&D activities in the right direction, create innovative technologies, and enhance their MOT capabilities for strategic application of R&D results.

COLUMN 11

Modularization in Manufacturing

It is often heard that the primary advantage of Japanese manufacturing industries lies in excellent *suriawase* manufacturing techniques using combinations of fine-tuned numerous processes and parts, each built in with one-of-a-kind technology. The complete opposite to such an approach is the so-called modularization, or manufacturing using combinations of off-the-shelf components. Similarly to the case of science-based industries, it is often pointed out that Japanese manufacturers are weak at this style of manufacturing.

A representative case of modularly manufactured product is personal computers. In 1981, IBM launched the IBM-PC, which later dominated the PC market as the de facto standard product. The IBM-PC was built using components consisting of combinations of off-the-shelf parts. Such a configuration enabled an assembling method that depended heavily on external suppliers. Consequently, various venture firms found their niche modules and made their ways into the PC market, contributing to development and production of innovative off-the-shelf modular parts and components.

Thus, global specialist companies emerged, including Microsoft Corporation (operating systems) and Intel Corporation (Central Processing Unit: CPU). Ironically, however, the modularization of PC manufacturing allowed the entry of many newcomers and eventually led IBM Corporation to sell its PC operations to China's Lenovo Group Limited and withdraw from PC manufacturing.

A typical example of modularized industries in an emerging country can be seen in an electrical appliance manufacturing industry in China. For instance, Chinese domestic mobile phone or PC manufacturers have introduced modularized production lines and won large shares in their respective product markets. Moreover, even in the automotive industry that traditionally has placed importance on *suriawase* techniques, modularization using outsourced components including engines has been introduced, and products are expanding their shares in China.