Japan

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The socio-economic issues facing nations today are complex, difficult to define and unlike any that have gone before. No advanced country possesses the best solution. The world is entering the era of the knowledge-based society, in which knowledge is recognized as driving productivity and economic growth. The development of science and technology (S&T) is a *sine qua non* for the creation of new knowledge and international cooperation – both vital for coping with intensifying global competition in the new century. How should the global economy add to, and share, the world's intellectual reservoir? How can knowledge be put to efficient use in resolving pressing national issues? How may S&T be used to create new industries, increase productivity and maintain industrial competitiveness? These are all crucial questions for every nation's economic development.

Japan, like any other country, is striving to find its path in the new era. In the period following the Second World War, the country enjoyed a high-growth economy unparalleled in its history. The national standard of living improved dramatically, and Japanese life expectancy became the highest in the world, with 78.4 years for men and 85.3 years for women. During the last decade of the twentieth century, however, Japan's economy began to stagnate, and the country entered a prolonged structural recession. Now Japan is facing declining demand, and its economic recovery urgently depends on the creation of new industries and markets, as well as the development of systems capable of effectively generating sustainable innovation.

In order to overcome its recession, Japan has made S&T activity a top strategic priority. Its Basic Law on Science and Technology, formulated in November 1995, and its First and Second Basic Plans on Science and Technology, dating from 1996 and 2001 respectively, demonstrate the importance it places on this issue. Likewise, administrative reform launched by the government in 2001 has since been extended to include S&T, which will help build an appropriate innovation system for the new era.

The Science and Technology Agency's *White Paper on Science and Technology 2000: Towards the 21st Century* describes the objective of Japan's S&T policy as the construction of a new relationship between science, technology and society. Japan seeks to become a 'nation capable of long-lasting development' by creating intellectual vitality that will contribute to maintaining the vigour of Japan's economy and improving living standards.

In this chapter, we describe the overall performance of Japan in S&T, starting with a brief history of how the nation acquired modern S&T from the West and constructed its own infrastructure in the nineteenth century. The process of institutionalization and professionalization of S&T systems is depicted, and an overview of national S&T policy since 1950 shows the strategy behind the building of competence in S&T at the government level, as well as the measures taken to achieve this. The state of the art of S&T and its development are shown using S&T indicators and international comparison. We describe the current issues facing the nation's S&T development, the socio-economic problems hindering its expansion and the ongoing reforms to restructure the national system of innovation. We conclude with a view of the future.

A BRIEF HISTORY OF SCIENCE POLICY IN JAPAN

Institutionalization and professionalization of S&T (1868–1945)

In 1868, the Tokugawa Shogunate government collapsed and the new Meiji era began following the proclamation to 'restore imperial government'. This incident put an end not only to the dictatorship of the Tokugawa family and the feudal system, but also to a long isolation policy going back two and a half centuries. Meiji reforms were undertaken by the Emperor Mutsuhito, in the spirit of the Meiji era, Meiji meaning 'luminous reign' in Japanese.

Japan entered the world of modern S&T at this time, beginning an era of openness to Western influences. However, in order to resist attempts by Western countries to colonize Japan, the state gave high priority to building up national wealth and military strength. Administrative and social structures were radically reorganized; peasants acquired the right to own land; universities were set up; the samurai lost their ancient privileges; the government was Westernized and free trade with the outside world was established (1873). The imperial council was replaced by a cabinet based on the Western model (1885), and a constitution was created that provided for a two-chamber parliament, modern judicial system and armed forces. As part of the industrialization process, the first railway was built in 1870.

Entering the new world obliged Japan to become an autonomous state; as a means to this end, Japan made the accumulation of wealth and power a national goal. The country began by analysing the source of Western strength. Western military power was based on industrial power, which in turn had been born of the development of military technology and the Industrial Revolution. The West's underlying strength was its systematic use of S&T. In order to follow the same path, Japan faced the urgent task of constructing the infrastructure needed to acquire S&T knowledge from the West and introduce Western S&T into various sectors of Japanese society. With its strongly centralized administration, the Meiji government was able to play a crucial role in establishing S&T institutions and organizations.

The Ministry of Education was established in 1871 and a comprehensive education system was introduced a year later. Founded in 1877, Tokyo University was later to become (in 1886) the Tokyo Imperial University, the most prominent of the six imperial universities built successively over the half century that followed.

A significant characteristic of the imperial universities was that each one created a department of engineering, demonstrating the Meiji government's view that engineering was equal to science and medicine in importance. This high regard for engineering by a Japanese government stands in sharp contrast to the status accorded the field in Europe and the USA during the same period, where it was regarded as inferior to science, law and medicine. Science and engineering in the West developed in totally separate social and historical contexts. They were institutionalized in accordance with different outlooks and objectives, and developed different methods and approaches, all of which created a hierarchy between the two. The Meiji government reversed this hierarchy. The prestige conferred on engineers not only produced the large quantity of engineers capable of promoting the industrial development that ensued, but also created a tradition of superiority for engineers in the Japanese S&T infrastructure. Today, the country still produces more than five engineers for every scientist, compared with a ratio of 1:1 in other industrialized countries.

At the time it launched construction of its S&T infrastructure, Japan lagged 200 years behind the West in terms of scientific knowledge and the scientific revolution triggered by Galileo and Newton. Japanese industry lagged close to 100 years behind the UK's Industrial Revolution. However, in terms of the professionalization of science – namely, the recognition of science as part of the social system and the ability of scientists to live from their research activity – Japan was no more than 50 years behind France, Germany or the USA. In other words, there was a great time-lag between Japan and the Western world in terms of the institutionalization of S&T, but this was reduced as soon as science took on value in Japan and its benefits were pursued in a systematic way. The creation of engineering as a university department, in particular, facilitated the fusion of science and engineering.

The government followed a unique procedure to introduce S&T from the West. It first selected high-calibre scientists and engineers from around the world, using its embassies and consulates to recruit candidates. These foreign scientists and engineers of diverse specialities were offered posts as professors in the imperial universities. Their best Japanese students were then sent abroad to perfect the knowledge acquired under the tuition of the foreign professors. The returnees contributed to national development as university professors, gradually replacing government-employed foreigners in playing an important role as senior civil servants in their country. The best possible knowledge and expertise available at the time were in this way introduced into Japan from the world's leading scientific countries in the principal fields of industry and learning.

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Japan thus succeeded in nurturing its own industrial revolution with astonishingly little brain drain. The development of S&T continued to reflect the Meiji policy of putting S&T at the top of the nation's priorities. Besides strengthening its industrial base, the country produced scientists of international standing, including Hantaro Nagaoka, Kikunae Ikeda, Ryojin Tawara and Umetaro Suzuki.

The Second World War brought about the total collapse of the Japanese economy, which, after the country's defeat, dropped to pre-Meiji Restoration levels. To survive, Japan needed to reconstruct a nation based on technology. Economic growth once again became top priority and S&T an essential tool.

In pursuit of an independent state (1955–70)

The 1960s were marked by tensions between the USA and the USSR during the formation of Western and Eastern blocs. A decade that had begun with the construction of the Berlin Wall (1961) and the Cuban Missile Crisis (1962) would go on to see the beginning of the Viet Nam War and the Cultural Revolution in China. The era was marked by an ever-intensifying space race between the two superpowers following the USSR's successful launching of the world's first unmanned satellite, *Sputnik I*, in 1957.

In Japan, if the national productive capacity had depended heavily on imports of the latest foreign technology from 1945 to 1959, by the 1960s the archipelago was able to produce its own low-cost, high-quality, internationally competitive products. The pace of economic development in the 1960s took even the government by surprise. The target of its National Income Doubling Plan (1960–70) – to maintain an average annual economic growth rate of 9% in 1961–63 and to double the gross national product (GNP) within ten years – was soon surpassed. National GNP quadrupled, exceeding that of West Germany in 1968, and Japan rose to the rank of second-largest GNP in the 'free world'.

Technological innovation resulted in the rapid development of Japan's industries. The energy revolution, based on petro-thermals, and the materials revolution, based on synthetic resin and textiles, restructured the landscape of national industrial competencies. The first million-vehicle manufacturer appeared in the automotive industry. During the 1960s, domestic pollution issues started heating up. The decade also saw the first international trade frictions, which would only intensify in the decade to follow. As Japan's economy took off, there was a policy switch from 'catching up' with the Western level of S&T to the development of original technology by improving pilot and core technologies, and to enhancing competitiveness within a liberalized economic structure. The promotion of S&T was part and parcel of this plan.

Prior to the Second World War, there had been no policy devoted exclusively to S&T, science policy at the time being considered part of industrial or education policy and thus not formulated independently. In the mid-1950s, plans for constructing a social and economic structure were drawn up. The Science and Technology Agency (STA) was established in May 1956 as a core administrative organization headed by a minister. The advent of the STA symbolized the dawning perception of S&T policy as an important part of the national administration.

In 1959, the Council for Science and Technology (CST) followed. It was entrusted with the mission of fortifying S&T administration and, as the supreme deliberative S&T policy organization, promoting government S&T policies. It was to act as an advisory body to the prime minister, who today still chairs this body and consults the council for basic S&T policy making and when fixing long-term general research objectives. The prime minister first consulted the CST on what measures would be necessary to promote the development of national S&T. *Recommendation Report No. 1*, submitted to the prime minister in October 1960, was to form the basis for Japan's first integrated and systematic S&T strategy.

Japan's economic growth after the Second World War was driven by a large pool of researchers, engineers and technicians. By the late 1950s, however, industry was suffering from a shortage of skilled personnel. In its

Recommendation Report No. 1, the CST predicted a shortage of some 170 000 engineers and skilled workers between 1961 and 1970. The Ministry of Education consequently formulated a plan to increase the number of students to avoid compromising implementation of the aforementioned National Income Doubling Plan. These special enrolment policies channelled an additional 100 000 students into the science and engineering departments of higher-education institutions during the period when the plan was in force.

If competent personnel and adequate facilities and equipment are imperative for research, any development is heavily dependent on the level of investment a nation can make in research, which in turn is determined by the state of the economy. In the late 1950s, the ratio of research investment to national income for France, the UK, the USA and West Germany ranged from 2.7% to 1.5%, compared with a ratio of 0.94% in Japan. This spurred the archipelago to set a target ratio of 2% (near the UK level), a goal thought to be attainable by the turn of the decade.

The construction of the Tsukuba Science City was also planned during the 1960s. The CST recommended relocating national research institutes and laboratories outside overpopulated Tokyo to improve the research environment, accommodate modern facilities and equipment, encourage joint use of facilities and promote interaction and exchange among researchers. In short, the aim was to create an ambience conducive to joint research. A cabinet-level decision in 1963 led to the construction of a science city of international stature in the Tsukuba area, which is still expanding today.

In pursuit of harmonious S&T (1970–80)

Throughout the prosperous 1960s, Japanese society passed from a state of postwar devastation to one of economic expansion. Social demands shifted from a survival-level clamour for food to a thirst for wealth and learning. Technology that was oriented towards material comfort peaked around 1970, by which time 90% of Japanese households were equipped with washing machines and refrigerators. The country entered the 1970s yearning for education more than material satisfaction. Various technologies were developed in order to meet the diverse social demands: technologies in the areas of health and food production such as antibiotics, fertilizers and plant and animal breeding; household electrical appliances, cars and other new material-based technologies; printing and publishing; and telecommunications and broadcasting. This was the period when research and development (R&D) was guided by social needs, a time when consumer goods produced by research began to enter offices and households. Firms began investing in the development of end-products. R&D investment increased most rapidly in electrical and precision machinery, with R&D investment as a proportion of total sales climbing from 2.3% to 3.7%, and 1.6% to 3.0% respectively in these two areas between 1965 and 1980. By contrast, R&D investment in steel remained stable at around 1%, as did such investment in industrial machinery (around 1.7%). The 1970s thus saw a shift from the development of industrial products to that of consumer goods.

The technological gap between Japan and the USA narrowed, with Japan developing its own technology independently of military research. The success of the Japanese approach undermined the hypothesis that only large-scale military or space projects resulted in breakthrough high technologies. A new type of research organization and management based on the Japanese model emerged, whereby development was frequently carried out from the bottom up in the decision-making process, rather than under the leadership of a certain elite.

Thanks to its R&D efforts during the 1970s, Japan was earning 10% of world GNP by the end of the decade. But the country was then, and remains today, heavily dependent on oil. During the oil crises in 1973 and 1979, Japan, then the second-largest consumer of oil in the 'free world', was compelled to seek alternative energy sources. Nuclear energy emerged as one such source. Energy-saving technology was developed alongside this, as were antipollution and energy-saving measures. Meanwhile, social welfare had become a pressing issue, having been neglected during the nation's rush to expand productivity. The postwar

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generation sought intellectual stimulation and harmonious relations between science, technology and society. S&T, however, was primarily driven by material needs at the time, and R&D's emphasis was placed on technology rather than on basic science. Social pressure led to the development of 'comprehensive technology' that combined system technologies and social-science technologies. Under these circumstances, environmental science, behavioural science and the life sciences developed more rapidly than conventional physical technologies during the 1970s.

Recommendation Report No. 5, submitted by the CST in 1971, drew attention to the relationship between S&T and socio-economic, environmental and safety problems. The report encouraged the development of new areas in science, such as software and the life sciences.

In pursuit of greater creativity and internationalization (1980–90)

In the 1980s, Japan's trade surplus soared, its economic power was reinforced and its international influence consolidated. Japan's share of world GNP rose to 11.9% in 1986, and, with external net assets of US$ 18.04 billion, it became the largest creditor country in the world. Japan's consumer product technology and applications for pollution prevention and energy saving became world-class. International competition consequently intensified and relations with Europe and the USA entered a difficult phase.

Economic friction between Japan and the USA increased, and 'Japan bashing' reached new heights when the country was criticized for being 'a free-rider on the back of basic science'. Such criticism was based on the assumption that Japan owed its remarkable economic development to technology built on the scientific knowledge accumulated and made freely available by advanced countries. The message was clear: having profited from existing knowledge, Japan was expected, in turn, to take on the role of creator of knowledge. This 'linear model' was obviously exposed to counter-arguments, but industry itself then took up the model, insisting on the necessity of domestically developed technologies as a means of alleviating trade-based controversy. This proved to be a turning point for Japan's role in world development.

Acknowledging the need to contribute to the world's intellectual stock of basic research, Japan began strengthening its own, and debate intensified on how to foster national creativity. Internationalization – both of the Japanese economy and its S&T – emerged as an important issue. The adoption of the slogan 'internal internationalization' effectively broke with a form of internationalization that had, up until then, been mainly external, with the country sending material, personnel and money overseas. In the future, this would have to be reversed. The key to achieving such a reverse flow was to create a system that would metamorphose such structures as the domestic demand-driven economy, the pattern of scientific mobility that sent Japanese scientists to world centres of excellence but received few in return and the very limited participation of Japan in the creation and management of international programmes. In order for the country to become a centre of excellence itself and attract scientists from different parts of the world, it was essential to improve the conditions of basic R&D in Japan by reforming the research environment, including funds, human resources, facilities and support systems. The CST recommended three courses of action for national policy:

- promotion of creative S&T;
- development of S&T in harmony with society;
- fostering of capabilities to cope with growing internationalization.

The CST also identified three areas of utmost priority for the future development of S&T: new materials, microelectronics and biotechnology. Rather than focusing on socially oriented, problem-solving science as was encouraged by the pollution and energy problems of the previous decade, R&D in the 1980s would attempt to sow the seeds of frontier-breaking fields.

One of numerous measures to promote basic research, the Exploratory Research for Advanced Technology (ERATO) programme, was established in 1981. It presented a new way of organizing a national programme: generous funds were granted to competent and innovative research directors, who were entitled to use the funding as they saw fit and enjoyed a certain freedom in organizing the programme's team of Japanese and foreign researchers. ERATO contributed to the development of research competencies from different sectors, thereby stimulating mobility. In a similar vein, the Frontier Research programme implemented by the Institute of Physical and Chemical Research (RIKEN) in 1989 provided an opportunity for capable young researchers to conduct 'research of their own choosing' with great freedom. The Human Frontier Science Program (HFSP) – whose purpose is to foster basic research on the sophisticated and complex mechanisms of living organisms – was proposed by Japan at the Venice Economic Summit in 1987 as an international scientific cooperation programme, with the objective of increasing the international public assets of basic research and making the research results available to all humankind. HFSP was initiated and financed by Japan but has been organized internationally: its office – the International HFSP Organization – was established in Strasbourg, France, in 1989.

The 1980s also saw advanced research develop through deregulation. In 1986, the Facilitating Governmental Research Exchange Law was passed to remove obstacles to smooth interaction among fields and sectors. Closer cooperation between different scientific fields and among private, academic and government sectors was thus encouraged.

An assessment of the national education system concluded that it was no longer apt to cultivate creativity and individuality. Although it was recognized that early education had the potential to greatly develop creativity, identifying a workable way of achieving this proved more difficult, and the desire for reform was not translated into concrete action.

Expectations of S&T: a more fulfilling life (1990–2003)

The fall of the Berlin Wall and end of the Cold War in 1989 accelerated the construction of a new world order, although the Gulf War in 1990–91 and the terrorist attacks on symbolic US buildings on 11 September 2001 have demonstrated the difficulty of achieving world stability. North–South problems are worsening, aggravating disparities between developing and developed countries as the economic gap widens. Issues of environment, population, natural resources and energy have become global issues, and R&D has moved beyond the traditional framework of bilateral cooperation to complex, mutually dependent relationships between countries.

In only a few decades, Japan has succeeded in developing its economy to the point where the country now accounts for more than 14% of world GNP. The fact that S&T provides possibilities for solving many of the world's problems makes the Japanese feel their country should make a contribution in this area.

In the 1990s, however, Japan was faced with problems of its own, of an economic nature. Manufacturing industry, which had enjoyed a dominant position for decades, began encountering severe global competition. In pursuit of lower labour costs, industry moved its manufacturing offshore, leaving Japan 'hollowed out' – with an absence of industrial activity within the country. Total sales achieved by subsidiaries abroad surpassed total exports by Japan in 1996. Foreign investment in Japan reached a peak that same year, illustrating the development of 'borderless' entrepreneurial activities.

Japan's unemployment rate rose gradually, from 2.1% in 1990 to 5.1% in 2003, its highest level since 1953. The prolonged recession, restructuring of enterprises and overemployment over decades of economic expansion were behind the sharp rise in unemployment. Its worst effects are today being felt by the 15- to 24-year-old age group, 9.2% of whom were unemployed as of October 2003. A series of management fiascos at financial institutions has tainted their credibility in the minds of Japanese citizens. This erosion of confidence, coupled with an unstable employment situation, has had a negative effect on final demand in such areas as consumer spending and investment in production plants, equipment and housing.

The prolonged recession has led households and enterprises to tighten their purse strings. In 1998, the

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government formulated Comprehensive Economic Measures and Urgent Economic Measures in order to stimulate short-term demand. For the medium term, the Industrial Revival Plan was launched in 1999 in an attempt to increase supplier productivity.

In S&T, investment stagnated over two consecutive years (1993–94), with government investment in R&D (as a percentage of total GDP) in the early 1990s failing to rival that of Europe and the USA. In addition, the Japanese R&D system was revealed to be lacking in flexibility and competitiveness.

In recent years, numerous reforms have been implemented to remodel the national R&D system. These are described in the following section.

PRE- AND POST-BASIC LAW ON SCIENCE AND TECHNOLOGY (1995)

Reform I (1990–94)

Against the backdrop of recession brought about by an overvalued yen and 'technology friction' with Europe and the USA in the mid-1980s, Japan began internationalizing its S&T system. The establishment of R&D laboratories abroad by private firms and the increasing employment of foreign researchers in firms, universities and national institutions gave momentum to internationalization. Public policy reinforced this movement by creating fellowships for foreigners.

As for research activities, the goal was to shift from 'catching-up research' to 'original and innovative research'. In the late 1980s, policy documents stressed the promotion of creative research; in the 1990s, their stated objective became to reinforce basic research.

In *Recommendation Report No. 18*, which was entitled *Comprehensive Basic Science and Technology Policy for the New Century* (1992), the CST defined the objectives of S&T as being to:

- contribute to the international community and all of humankind;
- promote basic research.

The need to promote basic research was strongly expressed in the CST's ambitious proposal to double the government R&D budget and foster centres of excellence. The plan to create centres of excellence, which was put into practice in 1993, is expected to raise competence in basic research and improve research facilities and equipment, thereby ensuring that national research institutions merit recognition as centres of international activity. The new policy led the government to increase its R&D budget for 2000, but it also revealed the striking difference between the policy orientation of European and American research and that of Japan in the early 1990s.

In the 1980s, Japanese investment in industrial R&D greatly increased even as investment in universities substantially decreased owing to the financial difficulties encountered by the government, the stagnation of public investment and a reduced budget. By the end of the decade, the lack of research budget was being sorely felt, with the already obsolete and dilapidated state of research worsening and universities in a pitiful state. The universities thus welcomed the CST's 1992 policy recommendation to strengthen basic science, with its promise of a renewal of university facilities and equipment.

The collapse of the 'bubble economy' and the prolonged recession affected Japan's S&T policy. The government was obliged to increase investment, and, paradoxically, the renovation of universities was pushed forward as part of the investment in public utilities. In 1993, a large investment was made in R&D from a supplementary budget established as part of the measures to boost the economy.

Reform II (1995–present)

Under Reform I, a new research environment was constructed within the framework of measures taken to reverse the recession. At that stage, however, scientific research was not necessarily expected to contribute to economic development, as had been the case in some major Western countries. Rather, research facilities and equipment were renewed in Japan as part of public engineering works, in line with an overall orientation formulated by the CST.

The situation changed drastically in 1995. The supplementary budget voted that year included an 'economic frontier budget' to cope with a strong yen. This supplementary budget aimed to develop S&T and activities related to information technology (IT). In order to fully achieve the objective of restructuring economic systems and creating new industries, a policy was designed to support research activities in universities and public research institutes. What is important here is the policy objective to support research activity as a key to future industrial breakthrough technologies. Reform of universities and public institutions had evolved from representing a simple improvement in the research environment into being an important element of the nation's economic development.

The objective of S&T policy thus shifted from promotion of basic science to economic development, a substantial change in orientation. In some European countries and in the USA, S&T policy had been primarily oriented towards stimulating economic development as early as the late 1960s. Japanese S&T policy adopted this concept 30 years after the West.

In parallel, such funding organizations as the Japan Society for the Promotion of Science, the Japan Research and Development Corporation and the New Energy and Industrial Technology Development Organization established competitive R&D allocation systems. Any university or national research institution with the potential for yielding future industrial technologies may respond to the tender. The creation of an R&D allocation system based on tender has revolutionized the university funding system. A multi-funding system has in this way been introduced into the university infrastructure, where previously the only sources of funding were block grant and project funding from the Ministry of Education. Since the introduction of the new system, universities have been able to seek research funds from other ministries and agencies.

The supplementary budget drawn up in 1995 has thus modified conventional S&T policy. This new orientation was embodied in the Basic Law on Science and Technology (1995) and in the Basic Plan on Science and Technology (1996). Both of these are a reflection of the urgent needs of researchers at universities and public institutes for a better research environment. They also reflect the demands of industries in economic difficulty, which had turned to public research for impetus after the 'bubble economy' burst.

As stated in the Basic Law and Basic Plan, the country's expectations of S&T were that they would 'avoid the hollowing out of industry, prevent a decrease in social vitality and in the standard of living and create new industries'.

The government increased its R&D budget from 0.6% of GNP in 1995 to 1.0% five years later, corresponding to an investment of YEN 17 trillion between 1996 and 2000. Included in the budget was a provision for 10 000 postdoctoral students or assistants to researchers in their work, twice the number previously employed.

The Second Basic Plan on Science and Technology covering the period 2001–05 was drawn up in 2001 with less optimism for its success than its predecessor. Japan's deficit had more than doubled in the 1990s, climbing from 59.1% to 125.8% of GDP by 2000, so formulating a comprehensive, strategic S&T policy that ensured maximum efficiency had become an urgent concern of the state. The resultant budget was designed to focus on four determinant fields of science: life science, information technology, environment, nanotechnology and materials sciences. This was coupled with ongoing reforms of the existing S&T structure and an internationalization of Japanese S&T. The amount of 24 trillion yen was allocated to enhancing both basic research driven by scientific curiosity and applied research responsive to socio-economic needs.

The enactment of the Basic Law has proved to be a turning point in Japanese S&T policy. R&D has been reorganized and administrative reform has taken place in a climate of prolonged recession, modifying the S&T system as a result. Some of these changes will be described in the following section.

UNIVERSITY–INDUSTRY RELATIONSHIPS

Interaction between universities and industry was relatively unknown in Japan until 1990. In 1983 there were only 57 joint research projects being hosted by Japan's national universities, with a total of 50 participating firms. By the

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late 1980s, this number had risen sharply to 694 projects with 413 participating firms. This figure doubled to 1 442 projects involving 858 firms in 1995 and nearly tripled again over the following six years. In 2001, 4 190 projects were being conducted with 2151 participating firms. The government's 1987 decision to establish joint research centres in national universities in order to promote such collaboration was partly responsible for this exponential growth. The number of universities hosting these centres had risen to 61 in 2001, compared with only 18 in 1990.

The report entitled *Basic Guidelines for Activating Science and Technology Activities in the Regions*, formulated by the CST in 1995, evoked the importance of university–industry relationships at the regional level. A number of measures were taken to stimulate these relationships. Inspired by the Basic Law on Science and Technology, a law related to the employment of national researchers and university professors under contract was formulated in 1997. The flexibility this law adds to the system of employment is expected to stimulate the mobility of researchers among national institutions, universities and firms. Another law passed the same year relaxed the restriction on national university professors with regard to the holding of additional posts. A university professor is today entitled to supervise a private company's R&D department while maintaining his post at the university. The Law on Strengthening Industrial Technology Competence (2000) enables a public researcher or a national university professor to occupy a seat on the board of directors of a firm where the technology developed by the researcher will be put to practical use.

As for the transfer of technology, the Law on Promoting Technology Transfer from Universities (1998) encourages the transfer of research results from university laboratories to the private sector. As one means of attaining this objective, Technology Licensing Offices (TLOs) were established. By 2002, around 31 TLOs had been institutionalized. Between 2000 and 2002, these processed a total of 3 663 filed patents.

INNOVATION IN THE SMEs

R&D activities in small and medium-sized enterprises (SMEs) became intensive after the 1980s, by which time the SMEs established during the high-growth period of the Japanese economy had reached maturity. Stimulated by the emerging high-tech boom around 1980 and by the necessity to compete with the expanding newly industrialized economies (NIEs) in Asia, SMEs came under pressure to innovate and to produce high technologies. In the 1990s, SMEs became actively involved in innovation by collaborating with the research laboratories in Technopolises and universities. 'Incubators' were also created throughout the country in the 1990s, predominantly towards the end of the decade, and currently number 130.

The Law on Promotion of New Business Creation (1998) led to the setting up of a Japanese Small Business Innovation Research (SBIR) programme, modelled after the SBIR USA.

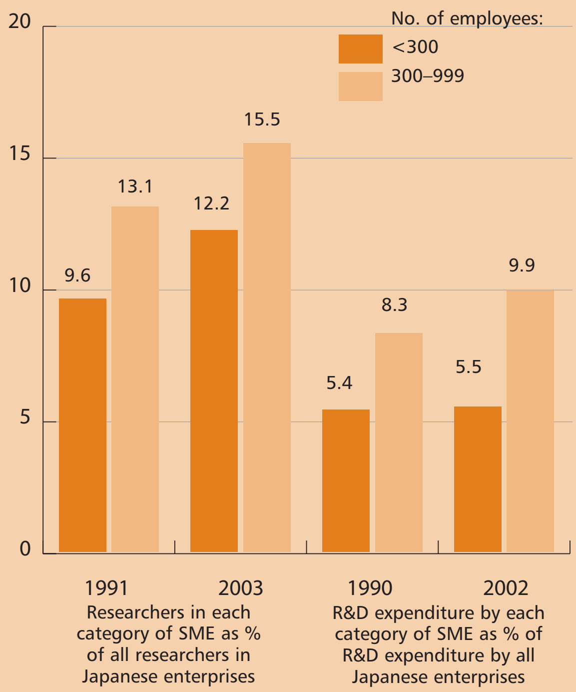
SBIR is a scheme to create new industry and employment, to which high-tech SMEs can greatly contribute. SMEs are now eligible for the contractual projects, subsidies and fiscal incentives the government previously made available mostly to large firms. In 2002, six ministries created 56 special grants-in-aid that will invest YEN 25 billion in SMEs. These are the Ministry of Education, Culture, Sports, Science and Technology (MEXT); the Ministry of the Economy, Trade and Industry (METI); the Ministry of Health, Welfare and Labour; the Ministry of Public Management, Home Affairs, Posts and Telecommunications; the Ministry of Agriculture, Forestry and Fisheries; and, lastly, the Ministry of the Environment. According to the *Report on the Survey of Research and Development*, R&D activities in the SMEs increased in scope during the 1990s (Figure 1).

REGIONALIZATION

The high-growth period of the Japanese economy also led to the development of the regions, since industry built new plants throughout the country. In the 1980s, against the background of the expanding high-tech economy, the spread of high-tech industries, universities and R&D facilities further fostered regionalization.

In the early 1980s, the construction of 'technopolises' was planned as a national strategy. A technopolis is an attempt to concentrate high-tech industry in regions where industries, universities and inhabitants will cooperate to develop l

Figure 1
RESEARCHERS AND R&D EXPENDITURE IN JAPANESE SMEs, 1990/91 AND 2002/03



Note: Researchers are head counts.

Source: Statistics Bureau (2000 and 2004) *Report on the Survey of Research and Development* 1999 and 2003.

leading-edge technologies. Since the mid-1980s, 26 regions have been designated as technopolises. R&D facilities have been constructed in these regions and various core industries established.

Initially, the principal objective of a technopolis was to attract R&D facilities of big enterprises or universities into a region, and a number of measures were taken to promote the technopolis programme. As the technological capabilities of local industries developed, regional R&D networks emerged. In 1998, the law mandating the construction of technopolises was repealed, and these high-tech hubs have now established themselves as the basis for regional development through innovation.

In 1995, in response to an inquiry by the prime minister, the CST submitted *Basic Guidelines for Activating Science and Technology Activities in the Regions*. As a result of the Basic Law that followed, local government is today able to formulate and execute policy to promote regional R&D. The regions are thus becoming important proponents of collaborative research projects involving university, industry and government, as well as of R&D conducted by SMEs.

The new policy formulated in the Second Basic Plan on Science and Technology encourages the creation of 'regional clusters' that would develop R&D resources and potential through the construction of networks and collaborative research between regional universities and industry. Regional clusters include 'knowledge clusters' promoted by MEXT. Whereas the core components of these knowledge clusters consist primarily of universities and public research institutions, the aim of 'industrial clusters' promoted by METI is to create a vast network of human resources in support of technological development, as well as an optimal environment for entrepreneurship. The system has been designed to foster interaction between the original technological 'seed' of the public research organization and the business needs of regional companies, leading eventually to technological innovation and new industries. In 2003, YEN 71.3 billion was allocated to these regional clusters. Currently, ten knowledge clusters in 12 regions and 19 industrial cluster projects are in progress. The 19 projects bring together some 3 800 SMEs and 200 universities.

ADMINISTRATIVE REFORM

In 1997, the Administrative Reform Council decided to restructure the Japanese public administration. The council's final report gave priority to reform of the public administrative bodies and structures related to S&T. Some of the major restructuring projects anticipated were:

- the founding of a Council for Science and Technology Policy (CSTP);
- the fusion of the Ministry of Education, Science, Sport and Culture (Monbusho) with the STA;
- a change in status for national research laboratories and universities.

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Founding of the CSTP

The CST was reorganized into the CSTP in January 2001. With this change, the CST, which had dealt only with the natural sciences, saw its sphere of activity extended to cover all the sciences, including social sciences and humanities. The objective of the reform was to enable the new CSTP to establish comprehensive and strategic S&T policy. The CSTP, which is independent of other ministries, examines the basic orientation of the S&T budget and the allocation of human resources, besides evaluating major national programmes. The CSTP acts as a control tower directing the multifold processes of S&T policy implementation. It is a powerful organization, responsible for deciding the country's overall S&T policy.

Fusion of the Ministry of Education with the STA

Monbusho and the STA merged to form MEXT in January 2001. The two main responsibilities of this ministry are to secure creative and talented human resources and to promote science, technology and culture in an integrated manner. MEXT is charged with drawing up a detailed plan for the execution of the strategic policy formulated by the CSTP for the areas under the Ministry's supervision. Institutionally, MEXT is to assume the role of reinforcing the administration of S&T policy. It was also to act as inter-ministerial coordinator, but this role is essentially now being transferred to the CSTP.

Other ministries were restructured at the same time as part of the government's plan to reduce the number of ministries by nearly half, from 22 to 12, in 2001.

National laboratory reform

In April 2001, national research institutes changed their status to independent administrative institutions (IAIs). Although control will be exercised by the appropriate government body, this reform should facilitate interaction between ministries and agencies and provides for flexibility in R&D, which was problematic under the former system. Pooling resources in a single organization makes for a greater concentration of funding, equipment and researchers.

National university reform

The country's 99 national universities were reorganized in April 2004. Their legal status changed to that of IAI. Three major reforms were implemented to improve their performance. First, decision-making power was transferred from the faculty to the rector of each university. Rectors will be held accountable for the way their institutions are run, obliging them to possess solid managerial skills. Second, an external evaluation system was introduced. Thirdly, the legal status of employees changed from that of civil servant to non-civil servant. With these reforms, universities have gained greater flexibility and autonomy in managing their R&D activities in terms of budget and human resources. They have become key players in industrial development. These are revolutionary reforms in the history of the Japanese university, reforms that are still under way and building momentum.

METI, in a 2001 document entitled *Targeted Plan for the Creation of New Markets and Employment*, fixed itself the ambitious target of creating 1 000 venture companies originating from universities within three years. As it is expected that university research and spin-offs from national research institutions will generate new industries and foster employment via creation of new concepts and breakthroughs, the government considers it vital to stimulate entrepreneurship among researchers and students by promoting venture start-up companies originating in universities. This will entail securing start-up capital and venture development systems, like campus incubators, to nurture an environment conducive to creativity. In parallel, human resources will need to be trained to devise business ventures responsive to social expectations and economic realities. The number of venture companies originating in Japanese universities has been increasing steadily. While these totalled 144 in 1998, the number climbed to 531 in 2002. Changing the status of national universities to IAIs will only deepen this trend.

Moreover, a new programme, Centre of Excellence for the 21st Century, was launched in 2002. Its objective is to concentrate large sums of research funding in a handful of universities. The sum of YEN 100–500 million will be granted for a five-year period. The funding is allocated to 'universities' rather than to 'projects'. This competitive programme compels universities to prepare a solid proposal, which in turn will contribute to an assessment of their activity and strategic R&D policy design.

All in all, institutions in higher education are currently facing both systemic change and a serious survival dilemma. With the population of 18-year-olds expected to plummet from the current 1.51 million to 1.20 million in 2009, there will be a surplus of national and private universities and junior colleges, which currently number 1 220. The ensuing severe competition for students will make it crucial for each institution to design a clear vision of the future that comprises its own unique policy and strategy. At the same time, the reform of the higher-education sector will impose management standards in the research community and make universities increasingly accountable.

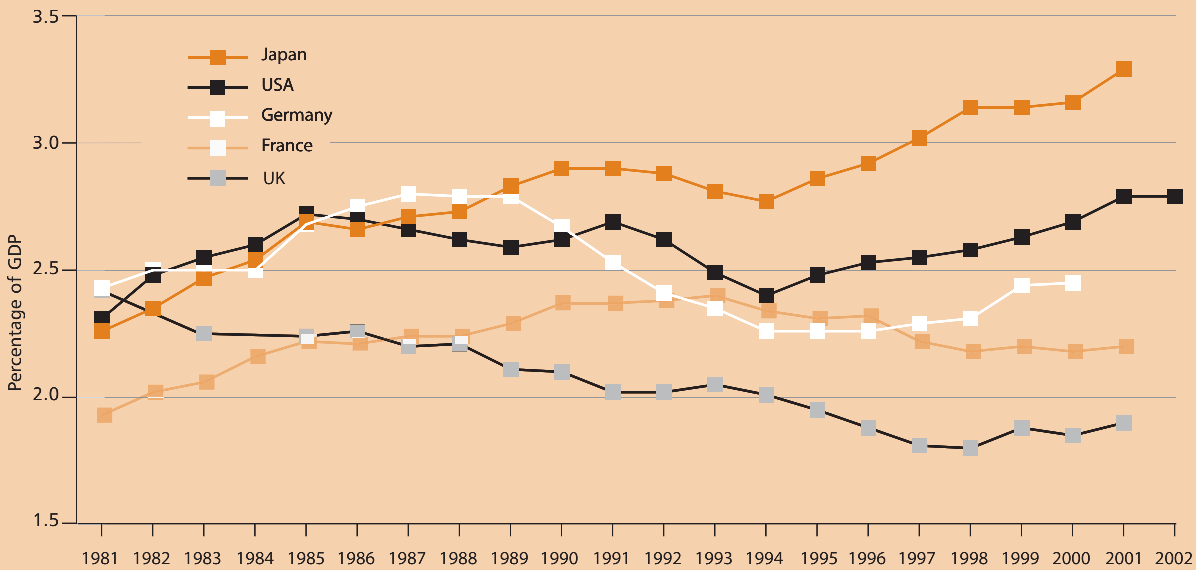
STATE OF THE ART OF JAPANESE S&T

R&D expenditure

Figure 2 indicates a considerable climb in Japan's R&D expenditure growth rate between 1981 and 2002. The CST report on long-term S&T policy, submitted to the prime minister in 1984, stated that both the government and private sector needed to make a greater effort to increase R&D investment to 3.0% of national income in the immediate future, and to 3.5% as a long-term goal, even though Japan's level of investment in R&D at the time was on a par with that of European and North American countries. By 1990, Japan had almost attained the goal of 3.0% and had overtaken its closest rivals in the process. Private-sector investment in R&D has contributed greatly to R&D activities and even tripled between 1981 and 2001.

Over the first half of the 1990s, all countries showed a decline in gross domestic expenditure on R&D (GERD) as a percentage of GDP, but Japan and the USA had recovered

Figure 2
GERD/GDP RATIO IN JAPAN, 1981–2002
Other countries are given for comparison



Source: NISTEP (2004) *Science and Technology Indicators.*

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by 1995. From 1989 on, Japan registered the highest ratio of any of the five countries shown in Figure 2.

In spite of stagnating Japanese GDP and a drop in R&D investment by industry, the R&D share of GDP continued to grow from 1995 onwards; by 2001 it had climbed to 3.29%, the best level Japan has ever achieved.

The share of R&D expenditure in terms of funding and performance by sector is shown in Table 1. The percentage share of R&D expenditure contributed by government may differ from country to country owing to differences in such elements as defence-related research, tax structure and private-sector activities. It can be seen from Table 1 that the government share of R&D funding in Japan is the lowest of the five countries studied, a mere 21.0%. Industrial participation in R&D funding is sizeable for all five countries, but with industry accounting for nearly 70% in Japan, the USA and Germany, these three stand out.

Both in terms of performance and funding, industry accounts for around two-thirds of the total R&D effort in all five selected countries, making industry the driving force behind R&D. The government sector performs the greatest share of R&D in France (18.1%), followed by Germany (13.4%) and the USA (11.0%). While in terms of funding and performance, government participation is lowest in Japan, the contribution of Japanese universities and colleges is the highest of the five in terms of funding, and the second highest (after the UK) in terms of performance.

Trends in the number of researchers

In 2002, Japan accounted for 756 336 researchers. This trend is part of a steady progression over the past 20 years that has seen numbers nearly double between 1981 and 2002 (Figure 3). During this period, numbers of female researchers increased at a faster rate than that of their male counterparts. Female researchers accounted for 11.2% (88 674) of all Japanese researchers in 2003, up from 7.1% (38 000) in 1989 (Figure 4). These numbers are mainly concentrated in the university sector and in social science and humanities.

Table 1
BREAKDOWN OF R&D IN JAPAN AND SELECTED COUNTRIES
By source of funds and sector of performance (%)

Source of funds

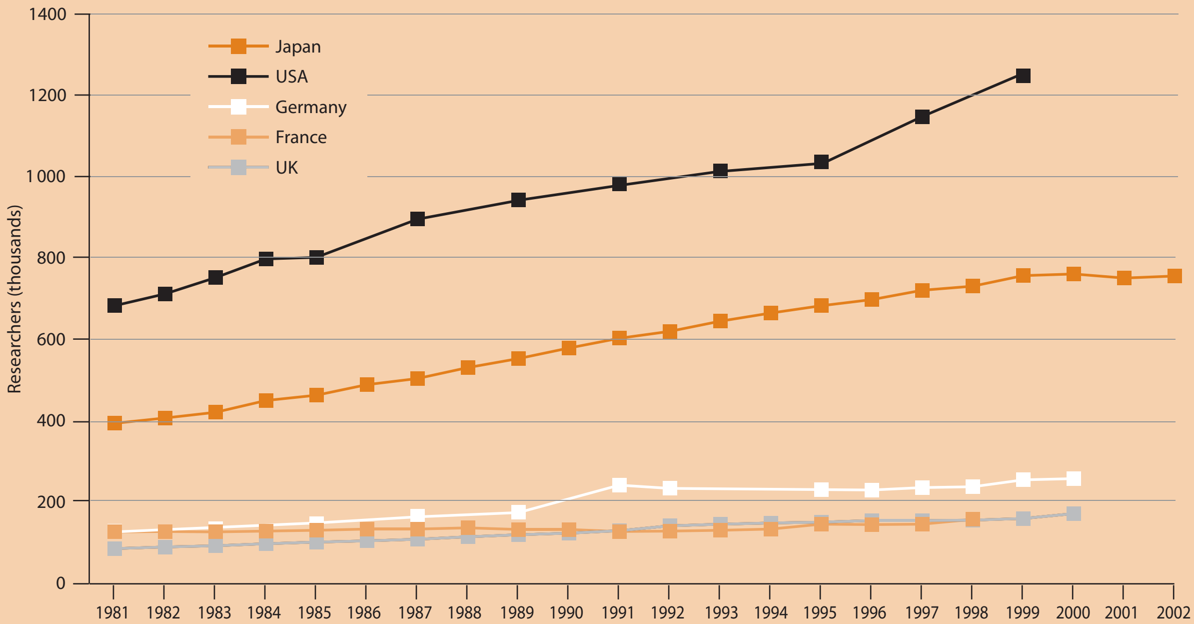
	Government	Universities and colleges	Industry	Private or non-profit research institutions	Abroad
Japan (2001)	**21.0**	**9.0**	**68.9**	**0.7**	**0.4**
USA (2002)	28.6	2.6	66.3	2.5	–
Germany (2000)	32.0	–	65.5	0.4	2.1
UK (2001)	30.2	0.9	46.2	4.7	18.0
France (1999)	36.9	1.0	54.1	0.9	7.0

Sector of performance

	Government	Universities and colleges	Industry	Private or non-profit research institutions	Abroad
Japan (2001)	**9.0**	**19.6**	**69.3**	**2.2**	–
USA (2002)	11.0	12.9	72.3	3.9	–
Germany (2000)	13.4	16.1	70.5	–	–
UK (2001)	9.7	21.4	67.4	1.4	–
France (1999)	18.1	17.2	63.2	1.5	–

Source: Statistics Bureau, *Report on the Survey of Research and Development*; MEXT (2003b) *White Paper on Science and Technology 2003*; NSF, *National Patterns of R&D Resources*; Faktenbericht Forschung; Bundesbericht Forschung; OECD, *Basic Science and Technology Statistics*; Office of National Statistics, *Gross Domestic Expenditure on Research and Development*.

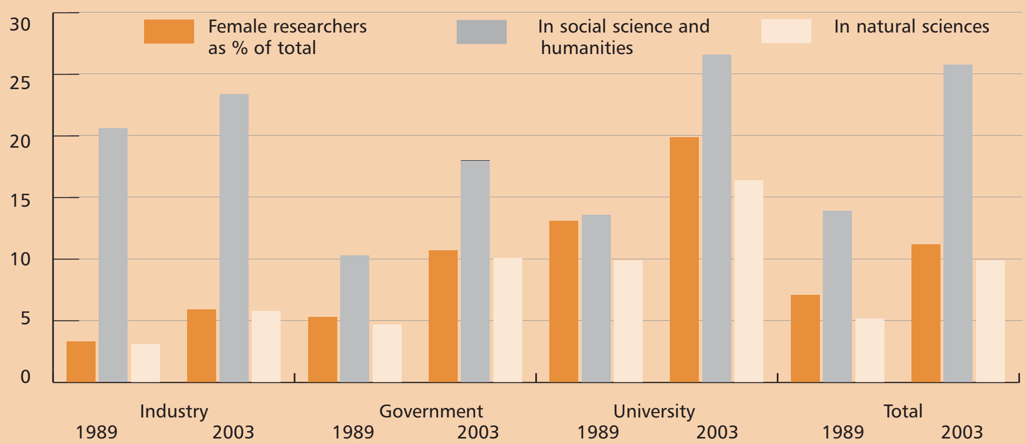
Figure 3
NUMBERS OF RESEARCHERS IN JAPAN, 1981–2002
Other countries are given for comparison



Note: Japanese researchers are head count figures; figures for the other countries are full-time equivalent.

Source: NISTEP (2004) *Science and Technology Indicators.*

Figure 4
FEMALE RESEARCHERS IN JAPAN, 1989 AND 2003
By sector



Source: Statistics Bureau (1989, 2003) *Report on the Survey of Research and Development*.

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Today, Japan has the largest number of researchers per 10 000 of both population and labour force among the five countries under comparison (Table 2). Some 56.9% work in industry, 37.1% in universities and colleges, 4.5% in public research institutes and 1.5% in private research institutes.

In spite of the growing number of researchers, Japan will at some point be facing a serious shortage. In order to improve basic research activities, it is essential to secure qualified researchers. However, since it is anticipated that the 18-year-old population will be smaller in future (estimates show that the number of young people is likely to decline more drastically in Japan than in the USA and Europe), numbers of high-school graduates going on to enrol in S&T courses in higher education are also sure to decrease.

To attract people to S&T fields, better working conditions and research environments are essential. To produce high-quality researchers, government measures include job flexibility in assignments, increased mobility among sectors and the cultivation of excellent research environments. Measures are also being taken to provide women, senior citizens and foreigners with job possibilities and better working conditions. It will also be important to improve the image of S&T to keep young people interested in S&T-related studies. The enthusiasm engendered by the pleasure of scientific discovery is difficult to convey from one generation to another. Designing a curriculum capable of stimulating such enthusiasm is one of the pressing challenges faced by the education system in Japan.

Scientific publication performance

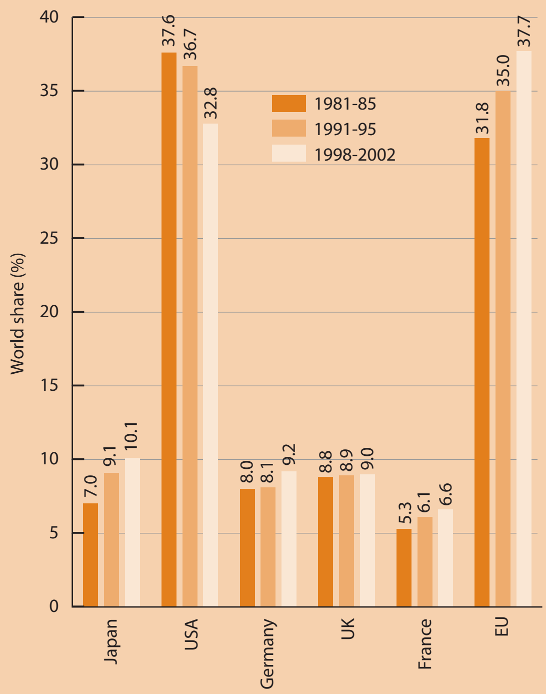
Publications provide a simple and approximate measurement of the quantity and impact of work produced by a nation. The number of world publications recorded in the major scientific journals and retrieved from the database known as the Science Citation Index increased by 160% in the period between 1981–85 and 1998–2002. The USA is today the single most prolific producer of scientific articles, contributing 32.8% of the world share, followed by Japan,

Table 2
JAPANESE RESEARCHERS RELATIVE TO POPULATION AND LABOUR FORCE, 1998–2002
Other countries are given for comparison

	Per 10 000 population	Per 10 000 labour force
Japan (2002)	**53.1**	**100.8**
USA (2000)	45.2	89.6
Germany (2000)	31.4	64.3
UK (2000)	26.6	54.6
France (1998)	28.4	64.8

Source: Statistics Bureau, *Report on the Survey of Research and Development* (annual publication); Statistics Bureau, *Population Estimated Source*; MEXT (2003b) *White Paper on Science and Technology 2003*; OECD, *Main Science and Technology Indicators*.

Figure 5
SCIENTIFIC PUBLICATIONS IN JAPAN AS A WORLD SHARE, 1981–2002
Other countries are given for comparison (%)



Source: NISTEP (2004) *Science and Technology Indicators*, based on the data in *National Science Indicators 1981–2002* (Deluxe version) compiled by the Institute for Scientific Information.

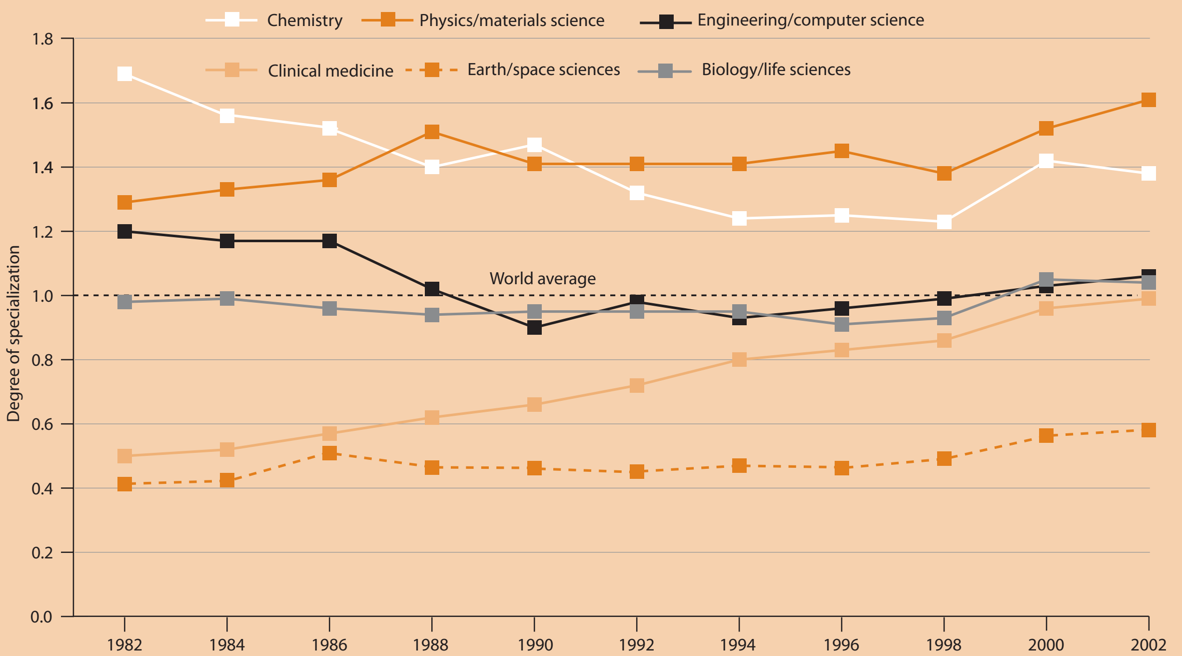
Germany, the UK and France (Figure 5). (Taken together, the countries of the European Union exceed the US share of world publications on the basis of articles in mainstream journals.) All of the countries listed in Figure 5, with the exception of the USA, increased their world share over the period under study.

Japan showed the fastest growth rate (61.1%), moving from fourth-biggest producer of scientific articles in 1981 to the second biggest in 1992. However, while the Japanese share did increase, the number of papers produced per researcher amounted to only 0.09 in 1998, the smallest figure among the five major countries. The other countries produced 0.39 (UK), 0.27 (France) and 0.22 (USA and Germany) papers per researcher, or 2.4 to 4.3 times Japan's rate.

A profile indicator is used to observe the specialization of Japanese science in comparison with the world pattern. A Japanese publication in a given field calculated as a percentage of total Japanese publications is divided by the number of world publications in that field as a percentage of total world publications. If the index score is 1, the country's propensity in that field is approximately the same as average world propensity in the same field. If the indicator value is more than 1, the country is oriented more towards that field than the world average. In this way, the core competencies of a nation and its orientation over time can be measured, thus bringing into view the scientific profile of the country (Figure 6).

Japan's science is strongly oriented towards chemistry and physics/materials science. However, the country's inclination towards chemistry has fluctuated somewhat in recent years, even if in 2002 it still conducted more research in chemistry than the world average (1.38). By contrast, in physics/materials science, Japan showed a sustained strong

Figure 6
PROFILE OF JAPANESE SCIENCE AND ENGINEERING, 1982–2002



Source: NISTEP (2004) *Science and Technology Indicators*, based on the data in *National Science Indicators 1981–2002* (Deluxe version) compiled by the Institute for Scientific Information.

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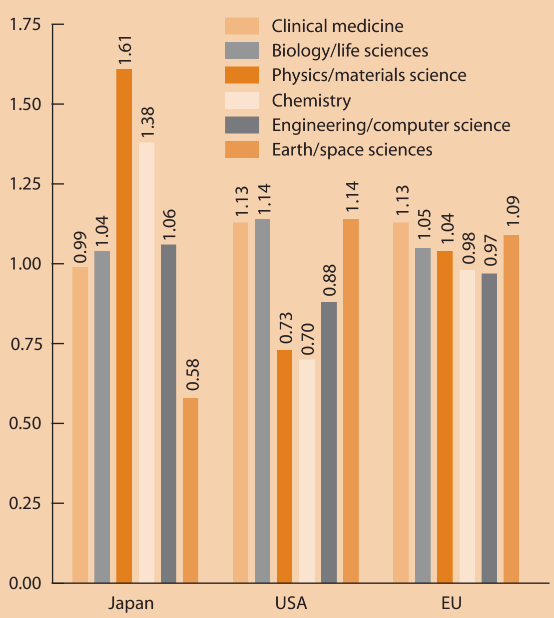
orientation, the profile index remaining around 1.4 to 1.5 throughout the period measured (1982–2002). Despite efforts to improve performance in clinical medicine, Japan had not yet reached the world average by 2002. Earth/space sciences have in the past been, and remain today, Japan's weakest field.

Figure 7 compares Japan's scientific profile with that of the USA and the EU. The USA is Japan's opposite in that it shows a strong leaning towards research in life sciences and Earth/space sciences, according a low priority to physics/ materials science and chemistry. For its part, the EU maintains a balance in all six scientific fields.

Citation performance

Citation provides a rough measure of the impact a country's published articles have on the worldwide scientific community. About half of world citations are of US publications (Figure 8). Even if that nation's share slipped slightly between 1981 and 2002, the impact of US science is unquestionable. The UK is cited most after the USA, followed by Germany, Japan and France. The citations share of Japanese articles increased from 6% during 1981–85 to 8.8% during 1998–2002 (Figure 8), and its publications share was rated highest, at 10.1%, over the latter period (Figure 5). The ratio between these two shares amounts to 0.87:1, indicating that the number of citations for Japan was low relative to the volume of publications produced. The impact of Japanese publications is less than might be expected, given Japan's productivity. Citations per paper can also be compared internationally by using the Relative Citation Index (RCI), which divides the number of citations per paper of a given country by the number of citations per paper in the world. During the period between 1998 and 2002, Japan's RCI indicated 0.88, compared with the USA's 1.48, the UK's 1.27, Germany's 1.14 and France's 1.07. Japan's RCI is lower than the world average (1.00) and is the lowest among the five countries studied. Its RCI figure has not changed much since 1981 (0.86), a trend that contrasts with the steady rise for the other four countries over the same period.

Figure 7
SCIENTIFIC PROFILES OF JAPAN, THE USA AND THE EU, 2002



Source: NISTEP (2004) *Science and Technology Indicators*, based on the data in *National Science Indicators 1981–2002* (Deluxe version) compiled by the Institute for Scientific Information.

Patents

Patents are a rough measure of the innovation and technological capacity of a nation. Inventors worldwide apply for patents at the US Patent and Trademark Office (USPTO). Japan accounted for 20.9% of all patents granted by the USPTO in 2002, ahead of Germany (6.8%), France (2.4%) and the UK (2.3%) (Figure 9). Whereas the national share remained relatively stable for other countries, Japan's share of US-granted patents nearly doubled between 1980 and 2002. According to the USPTO, of the top ten institutions granted US patents between 1969 and 1997, three were Japanese firms: Hitachi, Canon and Toshiba. In 1997, of the ten largest institutions to be granted US patents, seven were Japanese firms. Some 6 895 patents were granted to these seven firms that year. According to an analysis by the National Science Foundation (USA), the largest numbers of US patents were granted to

Japan in information-memory devices, copy, video and electronic components and optics.

The Federation of Economic Organizations of Japan conducted a survey on the competitiveness of the major technologies and products of a firm through auto-evaluation. According to this survey, household electrical appliances, non-ferrous metal, semiconductor devices and food technology are the more promising technologies or products, and firms active in these areas assume they will maintain or develop their competitiveness in the future. By contrast, in paper and pulp, software, engineering and medicines, competitiveness is weak and may continue to stagnate in the future. Based on these findings, the Federation issued a proposal entitled *Establishment of Strategic Industrial Technology Policy* in 1998, underlining the necessity of defining a strategic plan for new industrial technologies.

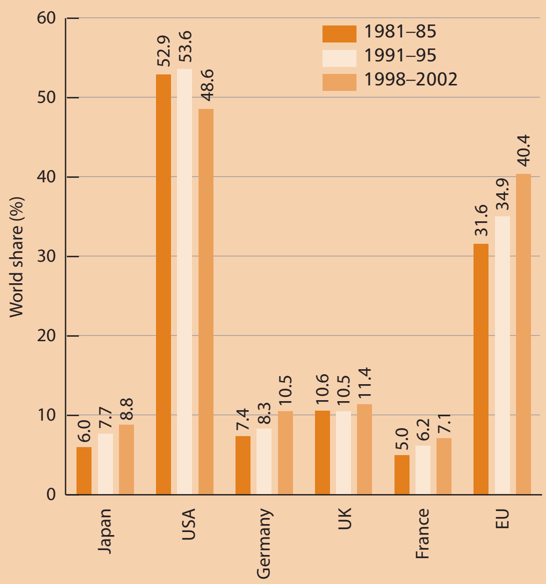
In order to promote R&D in private firms, tax incentives for R&D investment have been implemented, as well as various measures to support R&D in SMEs and new ventures.

OUTLOOK FOR THE FUTURE

As of 2000, Japanese life expectancy had increased to the point where the average Japanese citizen could expect to live a longer and healthier life than citizens of 191 other countries, according to the World Health Organization (WHO, 2000). The WHO has calculated that, by 2020, those over the age of 60 will represent 31% of the total Japanese population. This high percentage will qualify Japan as the most aged country in the world, ahead of Italy, Greece and Switzerland.

This problem of an ageing population is compounded by the fact that Japan also has the third-lowest fertility rate

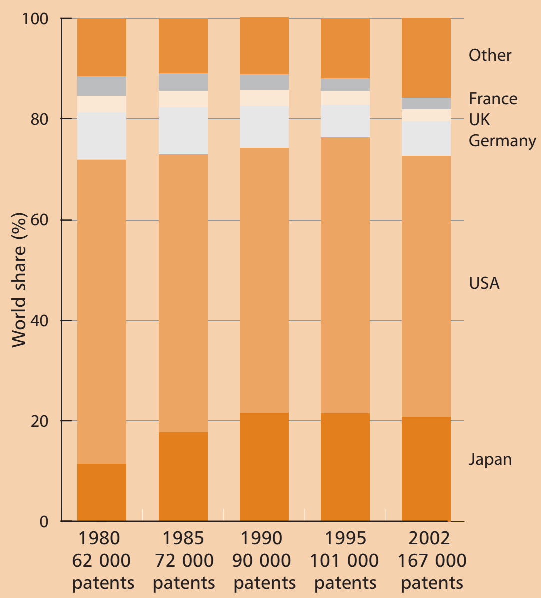
Figure 8
CITATIONS OF JAPANESE PAPERS AS A WORLD SHARE, 1981–2002
Other countries and groupings are given for comparison (%)



Note: Citations are based on five-year windows.

Source: NISTEP (2004) *Science and Technology Indicators*, based on the data in *National Science Indicators 1981–2002* (Deluxe version) compiled by the Institute for Scientific Information.

Figure 9
US-GRANTED PATENTS BY NATIONALITY OF INVENTOR, 1980–2002



Source: NISTEP (2004) *Science and Technology Indicators*, based on the data in *TP2-International Technology Indicators Database for Years 1980–2002* compiled by CHI Research Inc.

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in the world: 1.32 children per woman in 2002, the lowest since 1920. The decrease in population will seriously affect the labour force (those aged 15 to 65), which is expected to drop from 86 million in 2000 to only 55 million in 2050. With the rising number of elderly, not only will national social security payments increase, but so will the burden on the present generation, who will be called upon to assume a greater share of these payments. For the present generation, caring for their elders will be another constraint. Coping with the changing demographic pattern is a pressing national task, one that will involve constructing an S&T system capable of providing solutions for a new way of life. The shrinking labour force cannot be compensated for by an increase in capital investment, but only by a surge in productivity. In order to offset the 36% reduction in the labour force between now and 2050, productivity will need to be multiplied by 1.6, a goal that will only be attainable through technological innovation. Yielding a higher level of national productivity will require the development of revolutionary technologies bearing no resemblance to those produced by conventional concepts, methods or processes.

In order to secure the necessary labour force, its full potential must be exploited by creating a work environment attractive to women and adapted both to the disabled and to seniors. S&T will be needed to create such an environment. For example, information technologies currently under development will free workers from fixed working hours and workplaces, and will provide other forms of flexibility. S&T will be needed to reinforce the physical strength and judgement of the elderly, who will be called upon to work in production, construction or related industries. The aged and disabled will need to be able to go about freely and participate in social and economic activities. To make this possible, cities will need to be planned taking into account safety issues and eliminating obstacles such as stairs, steps and footbridges. Ticket dispensers, for example, will have to be user friendly. There is a growing demand for technologies that create a friendlier environment for those with physical disabilities – for example, a walking stick with an integrated sensor that would signal traffic lights to remain red until the person holding the cane has crossed.

Greater numbers of immigrants could also offset the effects of a declining population. The number of registered foreign residents in Japan has more than doubled in the past 30 years, from 710 000, or 0.58% of the total population, in 1970, to 1.85 million, or 1.45%, in 2002. That said, Japan still has one of the smallest foreign-born populations in the developed world. It is estimated that the mobility of foreigners will increasingly affect the total population of Japan in coming years, implying an important potential labour force. The number of foreigners coming to Japan for research purposes has been increasing at national universities and research institutions. In 2001, there were 30 067 individuals (including short stays) entering the country with this objective. This, however, contrasts starkly with the 103 204 individuals who left Japan that year with the declared objective of 'scientific research and survey'. International mobility may be developing steadily, but, in the case of Japan, it has started from a fairly low level.

Such a trend can also be seen in the level of participation in international collaborative projects. The number of papers co-authored by researchers from different countries has been increasing in Japan, but the ratio of international joint papers to total national publications is lower in Japan than in other developed countries. According to the National Institute for Science and Technology Policy, 20% of all scientific publications in Japan in 2001 were the result of international collaboration, a substantial increase on 1981, when it was only 5%. However, compared with the major Western countries, for which the average figure in 2001 was around 37%, Japan remains a relatively modest player in international scientific activities.

A survey of public attitudes towards S&T published in the *White Paper on Science and Technology* in 1993 and again in 2000 revealed that, while people acknowledge that S&T may foster a more fulfilling life, they strongly feel that it should be used to combat negative aspects of development, such as global environmental problems, the BSE (or 'mad cow') crisis in the 1990s and the ethical problems provoked by genome research. As S&T has permeated modern society, various questions have arisen. It is important that S&T form part of people's lives, but the insecurity and fear that they inspire will need to be eliminated if confidence is to be restored. Raising the social awareness and responsibility of scientists and engineers, establishing clear ethical guidelines, implementing risk and safety management, formulating adequate scientific advice and regulatory policy for risk reduction, and keeping the public informed about S&T activities are all steps in the right direction.

Current globalization and the revolution in information technologies will continue to broaden the activities of enterprises and inevitably lead to increasingly severe competition. The urgency of environmental and socio-economic problems calls for a new system of innovation involving all stakeholders in science. Japan is conscious of its responsibility in building a modern and responsible society capable of adapting to the changes on the horizon. It knows that the system, which dates from the Second World War, is dilapidated and needs to be disassembled so that some parts can be eliminated and others either reformed or recombined. It understands that innovation plays an important role in socio-economic development, and that the demands of society must be clearly articulated so that human, capital and other resources can be allocated efficiently. Japan has undertaken fundamental structural reform to create a more flexible, open and competitive S&T system that takes a strategic and proactive approach to S&T policy.

Since the late 1990s, Japan has implemented various administrative reforms and restructured its S&T system. Guided by the Second Basic Plan on Science and Technology, Japan has undergone a paradigm shift from 'science, technology and society' to 'science and technology for society'.

An S&T system for the new century is still under construction. S&T can offer solutions for revitalizing industry and stimulating competition, constructing a dynamic society that accommodates an ageing population, resolving global-scale issues, improving health and ensuring public safety. Japan's ongoing reforms are a challenge as well as an opportunity to reconfigure the nation's S&T system.

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