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With the decline of demand to existing industries, intensifying technological competition on a global scale, and the rapid progress of scientific knowledge, Japan now aims at advancing *science-based industries*. In 2001, based on the recommendation of the Council of Science and Technology Policy, the Japanese Government has determined the 'Science and Technology Basic Plan,' in which four areas were given strategic priorities. They are life sciences, information and telecommunication, environmental sciences, and nanotechnology and materials. It is hoped that the promotion of these sciences will foster the development of industrial technologies, such as biotechnology, IT technology, and nanotechnology-based materials, thereby stimulating the development of related industries.

Accordingly, Japan's national innovation system is changing. In part, it is a spontaneous change that is occurring in response to changing market needs. Also, it is a consequence of conscious policy efforts because the advance of such industries made the existing institutional, legal, and policy framework obsolete. In this paper, I intend to describe such changes in Japan, occasionally taking biotechnology as a case, and show how technological changes, socio-economic changes, and institutional changes interact with each other, creating a new and yet path-dependent national innovation system.

In Section 1, I begin by describing Japan's national innovation system up to the 1980s and, in Section 2, discuss how the underlying conditions have changed since then. In Section 3, I will describe peculiar features of science-based industries. Especially I will focus on the four features of science-based industries: (i) the need for close university-industry collaborations; (ii) the impact of intellectual property rights system; (iii) the role played by new startup firms; and (iv) the changing and diversifying boundary of the firm. How Japan is making changes in these four aspects will be discussed in turn from Sections 4 to 7. Section 8 will conclude the paper.

1. Japan's National Innovation System up to the 1980s

Goto and I have earlier discussed the technological and industrial development of Japan from the Meiji Restoration of 1867 to the post-war high growth era by using the framework shown in Figure 1 (Odagiri and Goto, 1996).

Technologies imported from overseas played a critical role, particularly in the early period of Japan's development. They were brought to Japan through the movement of goods, people, information, and capital. Final products were imported and disassembled for the purpose of 'reverse engineering'. Capital equipment, such as plants, machines, and tools, was also imported, bringing advanced technologies with it. It is noted, however, that Japanese engineers often redesigned and modified imported equipment to make it suitable the Japanese geographic, climatic, economic, and social conditions. People moved in both directions. The Japanese government and industries not only invited many experts from abroad despite the heavy cost at the time to teach advanced technologies and management methods but also sent Japanese scientists, engineers, managers, and government officials abroad to learn the Western knowledge.

Information was also brought into Japan through licensing of patents and knowhow. In many occasions, alliances with foreign partners helped Japanese firms to acquire technologies from abroad. Capital inflow as a means of technology transfer was also common before World War II. A number of electrical and communications equipment producers, such as NEC and Fuji Electric (from which Fujitsu was later hived off), were established as joint ventures with American or European advanced firms. Several domestically established firms, such as Toshiba and Mitsubishi Electric, later invited foreign partners to become their major shareholders in return for technologies and management knowhow. The automobile industry was dominated by the Japanese subsidiaries of General Motors and Ford until 1935, and these firms played a major role in Japan's starting the car component industry.

However, this role of capital inflow as a means of technology transfer became relatively unimportant in the post-war period. In fact, inward foreign direct investment (FDI) was restricted after the war until the early 1970s, with only a few exceptions. Even after the capital liberalization of the 1970s (until, say, the early 1990s), the rate of inward FDI remained low. Accordingly, FDI was not a major route of technology transfer in post-war Japan (Goto and Odagiri, 2003).

Nevertheless, it had an important indirect effect through the potential threat of multinationals making investment in Japan. Japanese firms were aware that capital liberalization was inevitable. Also they were keenly aware from their own pre-war experience that American and European multinationals were far ahead of them not only technologically but also in terms of size, financial power, and marketing and management capabilities. Although such a fear may appear unwarranted today, it was certainly relevant in 1965 when General Motors was 26 times larger than Toyota in sales, and similarly for IBM versus NEC in computers and General Electric versus Toshiba in electrical equipment. With this threat of formidable competition expected after capital liberalization, Japanese firms made every effort to catch up technologically and raise productivity. Toyota, for instance, learned from American supermarkets to come up with their own 'just-in-time' system to supply components to assembly lines, thus improving their competitive position *vis-à-vis* American and European carmakers.

The threat of competition came not only from potential and existing foreign rivals but also from domestic rivals, which, in our view, was a central force in Japan's technological development as shown in Figure 1. Abundant entrepreneurship was there and resulted in a number of entries, despite the risk and financial burden of heavy investment in R&D and technology acquisitions and to sell the products. In the electrical equipment industry for instance, Toshiba entered by developing incandescent bulbs in the 1880s, Sony by developing transistor radios in the 1950s, and Sharp by developing calculators in the 1960s. Entry also occurred as a result of diversification efforts of existing firms; for example, Suzuki, originally a manufacturer of weaving machines, diversified into the production of motorcycles and then automobiles, and Toray, originally a manufacturer of rayon, expanded their product line to include nylon and other high-polymer synthetic fiber and then various fine chemicals. Challenges to market leaders were also made by smaller fringe firms with their innovations; in the steel industry for instance, Kawasaki Steel, hived off from Kawasaki Heavy Industries in 1950, increased their market share rapidly after building an innovative integrated steel mill, making itself a serious competitor against dominant Nippon Steel.[1]

The restriction of FDI, together with import restriction, had another effect. Since foreign firms could neither export products to Japan nor invest to manufacture within Japan, they could exploit their technological superiority only by licensing the technologies. This fact made technology importation easier for Japanese firms. Also, technology importation was regulated during the 1950s and 1960s because the firms had to apply to the Ministry of International Trade and Industry (MITI) to get the allocation of foreign exchanges needed for royalty payment. Often a large number of firms

[1] For more examples in these and other industries, see Odagiri and Goto (1996). Actually, all the discussion in this section heavily depends on this book.

applied to import a technology, even when the technology is still at a commercially untested stage. In such cases, MITI tended to permit just one firm to import it, thereby improving the Japanese firm's position *vis-à-vis* the foreign licensor in a licensing bargaining. As a result, as some authors argued (e.g., Peck and Tamura, 1976), Japanese firms may have paid a royalty rate lower than the international rate. This by no means implies that MITI had the ability to select a most appropriate licensee. Kiyota and Okazaki (2004) suggests that MITI tended to select big but low-productivity firms.

Technology importation increased rapidly. Domestic R&D also increased rapidly. As a percentage to GNP, domestic R&D expenditures increased from 0.84 in 1955 to 1.73 in 1961, 2.14 in 1980, and 3.26 in 1998, surpassing the US in 1987. We emphasize therefore that Japanese firms invested heavily not only for licensing but also for own R&D to assimilate and apply imported technology, although, gradually, the weight of R&D shifted from the improvement of imported technologies to the invention of original technologies.

Besides the control of technology importation, several government policies played important roles. Firstly and probably most importantly, the investment in the early period to establish both compulsory elementary education system and a higher education system laid the foundations for Japan's economic development. Second, the provision of infrastructure including both 'hard' infrastructure, such as transportation and communication networks, and 'soft' infrastructure, such as Commercial Code, Patent Law, and other legal systems, was essential. Third, the government secured demand to domestic firms through procurement, for instance, military procurement before the war and the procurement of communication equipment by Nippon Telephone and Telegrams, and through the protection of the domestic market by means of import restriction during the 1950s and 1960s. And, fourthly, there were also cases of the government financially supporting target industries by providing tax concessions, low-interest loans, and subsidies, such as the subsidies given by MITI through research associations in the 1960s and 1970s. In our view, however, these policies were not as successful or effective as the provision of infrastructure or the support of demand: see Odagiri and Goto (1996) for details.

In sum, as shown in Figure 1, three factors contributed to the technological and industrial development of Japan, which resulted in active entry and competition. They are (1) the accumulation of technological capabilities, which, particularly in the early period of industrialization, were acquired from abroad by the private sector through its willingness to learn and on the basis of its inherited indigenous technology, and by the public sector, which then diffused the information to the private sector through schools and public research institutions, (2) strong entrepreneurship of the private sector, and (3) the presence of sufficient domestic demand, which was supported not only from the large population but also from protection and procurement.

One may compare this experience of Japan to that of other countries that have achieved similarly rapid economic growth in the post-WWII period, most notably Korea and Taiwan[2]. There are several similarities; for instance, the promotion of supposedly infant 'target' industries by the government (whether or not such targeting was pursued consistently or effectively), the encouragement of technology importation, and yet limited reliance on FDI as a means of technology transfer. There are, however, marked differences. The first concerns the initial condition. When Japan started the post-war reconstruction effort in 1945, it already had some eighty years of experience in industrialization since the Meiji Restoration of 1867. Indeed, even during the Tokugawa Era that preceded the Restoration, commercial and industrial activities prospered despite the limited inflow of Western technologies caused by the seclusion policy of the Tokugawa Shogunate government. Hence, notwithstanding the devastating bombing and other damages during World War II, Japan had a set of accumulated physical and human capital. More than sixty percent of plants and equipment survived the war and a large labor force with knowledge, skills, and experience returned to industries. By contrast, because both Korea and Taiwan were under the Japanese rule before the war and Japan had little interest in raising the managerial and technological capability of occupied people, the lack of such capability was a serious handicap when these countries started their development effort after their independence.

The second is the different size of the economy. With the population of about 81 million in Japan, 20 million in Korea, and 8 million in Taiwan in 1949, Japan was more than four times larger than Korea and ten times larger than Taiwan. In terms of

[2] For Korea, see Kim (1993, 2003). For Taiwan, see Hou and Gee (1993) and Aw (2003).

economic size, the difference was even larger. Thus, with a domestic economy large enough for most industries to achieve economies of scale, Japanese firms could accumulate experience in domestic markets before entering into export markets. Moreover, this large domestic market provided opportunities for profitable introduction of new products and profitable entry by new firms; in consequence, several firms competed intensely against each other as discussed earlier. The automobile industry probably gives the best example. Although, in the beginning, the quality of Japanese cars was much lower than that of American and European cars, the Japanese carmakers improved both their products and production processes to survive the domestic competition, and then started exporting to the US. By contrast, Korean and Taiwanese firms had to target at export markets almost from the beginning because of the limited size of domestic markets. Their government, as a consequence, pursued an export-oriented policy. The Japanese government also promoted export until around 1970 but import substitution was as important as export. In this regard, China, with its huge population, may resemble Japan more than Korea and Taiwan. China's regulation of FDI may also resemble Japan during its high-growth era. Obviously, however, the global environment today is quite different from that of the 1950s and so is the concern for intellectual property rights. And, of course, Japan had a very different political system from China: in fact, there were many occasions in which Japanese firms did not obey the government's 'administrative guidance', which will not be tolerated under the Chinese political scheme. Therefore, actually, there may be more differences than similarities.

The third difference concerns the industrial structure. In Korea, several big company groups (*Chaebols*) were established and the government supported and utilized them to foster the development of heavy and chemical industries. In Taiwan, by contrast, big firms hardly existed and, to support small and medium enterprises (SMEs), the government played important roles by, for instance, expending for R&D at government research institutions and transferring the technology to SMEs. Between these two extremes, Japan was more balanced. Pre-war *zaibatsus* were disbanded after the war, with all the formerly *zaibatsu*-controlled firms becoming independent.[3] A

[3] It is true that former *zaibatsu* members later formed *kigyo shudan* (business groups) with cross shareholding, etc. However, *kigyo shudan* is merely a loose federation of

number of non-*zaibatsu* big firms, such as Hitachi and Toyota, survived and started to grow, and so did a vast number of SMEs. Some of these SMEs were independent while some were dependent on big firms as suppliers, subcontractors, or subsidiaries and tended to rely on the technologies provided by big firms. Yet several suppliers, such as Denso, started to invest in own R&D and grew to become multinationals themselves.

As a consequence of these differences, the role of the government was more limited in Japan. The proportion of public R&D expenditure in total R&D expenditure was 64 percent in Korea in 1980 (Kim, 2003) and 60 percent in Taiwan in 1986 (Aw, 2003), whereas it was only 27 percent in Japan in 1981.[4] We may therefore argue that Japan's development was essentially industry-led with the government providing necessary infrastructure and occasional (but not necessarily successful) intervention. This is why we put 'entry and competition' at the center of Figure 1. In comparison, the government played more active roles in the economic development of Korea and Taiwan.

It is out of the scope of this paper to discuss which of these three countries would give best lessons to current developing countries. However, in that these developing countries tend to have neither inherited industrial, managerial, and technological bases nor well-balanced size distribution of firms, the Japanese experience may not be as appropriate as that of Korea and Taiwan.

2. The Japanese Business System and the Change

In addition to the macro and industrial factors discusses above, several features of the business system also influenced Japan's national innovation system during its high-growth era. First, owing to the presence of friendly shareholders (e.g., banks and group firms) and the practice of appointing executives through internal promotion, the management could pursue long-run projects more easily. Second, the proportion of top management with science or engineering background was higher in Japanese firms in comparison to American big firms, which helped Japanese top management to have a

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independent firms and essentially differs from *zaibatsu* (Odagiri, 1992).

[4] The proportion has since decreased in both Korea and Taiwan. More recently, it is about the same between Japan and Korea, but still higher in Taiwan.

better understanding of the potential and limitation of R&D. Third, because of the Japanese internal labor system in which long-term company-employee relationship was common, coupled with internal training and rotation programs, the linkage among R&D, production, and sales departments used to be tight, fostering the manufacturing and marketing application of innovations. Moreover, such linkage tended to expand to suppliers and other affiliated firms, prompting the sharing of information among them. And fourthly, the introduction of new technologies to production lines was easier both because of the above-mentioned interaction between R&D and manufacturing departments and because of the flexibility in rearranging workshops and the broader skills of workers nurtured through internal training and rotation: see Odagiri (1992) for more details.

Since 1990, however, some of these advantages have weakened. Banks (excluding trust banks) reduced their share ownership of public companies from 15.7 percent in 1988 to 7.7 percent in 2002 while the percentage of trust funds, pension funds, and foreigners together increased from 8.4 to 27.5.[5] Even hostile M&As, which have been rare in the past except for those aiming at greenmailing, took place. Bankruptcy has become not uncommon and neither is *de facto* dismissal of workers. The establishment of basic, central research laboratories by a number of high-tech firms has often resulted in the disconnection of information flow between laboratories and business divisions. Several firms also experienced a loss of production skill bases that are needed to transform inventions to commercial products, owing to the shift of plants to overseas, such as China and Southeast Asia.

Changes also occurred as regards the mechanism shown in Figure 1. Even though, on the one hand, the inflow of technologies from abroad has increased because of globalized business activities and the use of advanced information technologies, the end of catch-up meant that Japan cannot rely on one-way technology acquisition from abroad. In addition, intellectual property rights (IPR) have become to be more strictly enforced by foreign firms, as exemplified by the IPR (or trade secret)-related lawsuits filed by IBM and Corning against Japanese firms during the 1980s.

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[5] The average of 2661 firms listed in five Stock Exchanges in Japan. Source: Tokyo Stock Exchange, "Kabushiki Bunpu Jokyo Chousa" (http://www.tse.or.jp/data/examination/distribute.html)

It is difficult to say if entrepreneurship of Japanese firms has been weakening. Still the fact is that the rate of new company establishment has declined. The rate of entry (the number of new enterprises as a percentage of the initial number of enterprises) dropped from 5.9 percent of 1975-1978 to 3.1 percent in 1999-2001 and is now lower than the rate of exit, which was 3.8 percent in 1975-1978 and 4.5 percent in 1999-2001[6]. Of course it is easy to imagine that the loss of market demand owing to the business stagnation of the 1990s caused this drop in business startups. Yet, it is noteworthy that the entry rate started to drop not after 1990 but in the early 1980s when the business condition was still favorable.

In addition to these changes in the business environment of Japanese industries, the emergence of a new scientific and technological environment calls for a significant change in Japan's national innovation system. Most importantly, the increasing importance of 'science-based industries' has been causing a profound impact on the R&D strategies of Japanese firms and Japan's science and technology policy. To this topic we now turn.

3. Salient Features of Science-Based Industries

Science-based industries (SBI) are the industries in which the development is pursued by means of innovations based on sciences. Scientific knowledge, we say, 'is used' in innovations in two senses. First, scientific research outcome would be applied and developed for industrialization. Second, sciences would be used to solve the bottlenecks that may arise in the course of R&D and production. Also, any discovery during R&D or production would be fed back to scientific research. Therefore, the flow of information is not only from science to development and commercialization as the so-called 'linear model' of innovation implies, but also from development/production to science (Kline and Rosenberg, 1986). This bi-directional interaction between scientific activities and industrialization is an important characteristic of SBI.

Four issues are relevant regarding SBIs. They are (1) science linkage, (2) intellectual property rights (IPRs), (3) the boundary of the firm, and (4) widespread use

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[6] Source: Small and Medium Enterprise Agency, *White Paper on Small and Medium Enterprises in Japan*, 2003.
(http://www.chusho.meti.go.jp/hakusyo/h15/download/2003haku_eng.pdf)

of the technology across industries. We will discuss these in turn.

Science Linkage

Science linkage is commonly measured by the number of citations to scientific papers per US patent (Narin and Olivastro, 1992). When applying for patents in the US (but not in Japan), applicants are required to list any prior papers and patents that are related to the technologies to be patented. It can be assumed that, if the application cites many scientific papers, then the invention benefited greatly from scientific discoveries. Thus, the per-patent number of citations to scientific papers is used as a measure of science linkage.

Table 1 shows the trend in science linkage in six major fields in the US and Japan. There are three major findings. First, there is an increasing trend in any field and in either country. Second, it is higher in the US than in Japan. This difference may be overstated because American inventors are more likely to cite papers by American authors in American journals, and they will be careful so as not to miss citing related papers in fear of being complained by the authors. Japanese inventors may have benefited from Japanese papers but they are probably less careful in citing them than American inventors, because Japanese authors are less likely to notice the lack of citation and so will be the USPTO (US Patent and Trademark Office) examiners.

Third, the six fields that are closely related to SBIs have higher scores of science linkage than that in all fields. This tendency is strongest with biology/microbiology, followed by organic chemistry, suggesting that biotechnology is the most science-based of all industries.

This high and increasing level of science linkage implies that, to foster innovations in SBIs, collaboration between universities -- the main players of scientific research -- and industries -- the main players of development and commercialization -- is essential. Moreover, as stated earlier, the relationship is not only uni-directional, that is, from scientific discovery to development, but also the feedback to the scientific sector of information gained in the process of development is also useful. Here rests an opportunity as well as a need for university-industry collaboration.

Intellectual Property Rights

Intellectual property rights (IPRs), such as patents and copyrights, have strategic importance in SBIs. This is primarily because huge R&D expenditures are required in SBIs and IPRs are considered to be the most effective means of appropriating the returns to R&D investment. Besides, IPRs are particularly effective in some of SBIs. In the US, the effectiveness of patents as an appropriability mechanism is highest in medical equipment and drugs among industries, followed by special purpose machinery, auto-parts, and computers (Cohen, Walsh, and Nelson, 2000). Also in Japan, the effectiveness is highest in drugs, followed by computers (Goto and Nagata, 1996).

This fact suggests that the design of IPR system and its implementation profoundly affects the development of SBIs. As just stated, IPR is considered to provide an incentive for innovation by protecting their rights to invented technologies. Particularly in small startup firms, technologies can be virtually the single source of income and, without IPR protection, they may not be viable. From this viewpoint, the so-called pro-patent policy of strengthening IPR may appear to be the right policy proposal for promoting SBIs.

Yet, stronger IPRs may actually hurt technological progress because IPRs restrict the usage of invented technologies (Merges and Nelson, 1990). Particularly, an increase in 'research tool patents' can hinder technological progress as the need to clear permission with the owners of these patents can make R&D more costly and time-consuming. Examples of research tool patents in biotechnology include those on the PCR (polimerase chain reaction) method, DNA chips, and transgenic mouse. If each patent-holder acts aggressively, then, many R&D projects would become economically infeasible, hindering technological progress as a result. This is what Heller and Eisenberg (1998) called the 'tragedy of anticommons'. In electronics, it is often the case that hundreds of patents have to be cleared before a product is to be commercialized. Pooling of patents and cross-licensing among patent-holders are common. Again, however, the cost of search for patents that have to be cleared and of making agreements with the patent-holders can be huge. For instance, large electronics firms employ hundreds of people to deal with IPR issues.

These two effects of IPR, that is, the positive incentive effect and the negative usage-restriction effect, have to be balanced in any design of an IPR system.

The Changing R&D Boundary of the Firm

The issue of the boundary of the firm has been discussed widely in relation to the make-or-buy decisions on parts and materials. For instance, the close and long-term relationship with suppliers has been considered to be the strength of the Japanese automobile producers, which contrasted with a higher proportion of in-house part production of American firms until the 1990s combined with arms-length transaction with independent suppliers (Odagiri, 1992). However, even in the US, more use of outside suppliers (including those spun off from the assemblers) and more collaboration with them have become common.

Similarly, in R&D, the use of outside suppliers and partners has become prevalent. It is now impracticable to perform all R&D works in-house and how to incorporate and utilize outside capabilities has become the key for successful innovation. Such utilization is made in several fashions. The firm may outsource routine R&D services, such as software development, supply of order-made samples, manufacture of prototypes, and animal tests (in the case of pharmaceuticals). They may form R&D alliances by commissioning research to other established firms, new startup firms, universities, or public laboratories, or starting joint research projects with them. They may also acquire technologies by licensing-in. In such diverse manner, firms today are extensively utilizing outside capabilities (Odagiri, 2003).

As a consequence, it is indispensable for the development of SBIs that the economy is equipped with a wide variety of potential partners and opportunities that the firms can use for outsourcing, R&D alliances, technology acquisitions, and such.

Widespread Use of the Technology across Industries.

Another feature common to SBIs is that a technology is used not in a single industry but in a variety of industries. Biotechnology is a good example. Table 2 shows the shipment of biotechnology-related products in Japan in 2000. The food and beverage industry has the largest shipment, accounting for nearly two thirds of the total shipment, followed by pharmaceuticals. Still, these are not the only biotechnology-related industries and, as shown in the table, biotechnology is used in a wide range of industries from chemicals to machinery, electronics, information, and environmental remediation. In addition, a wide variety of biotechnology is used. In food and beverages, almost all the technologies are the so-called 'traditional' biotechnology, such as fermentation and cultivation. By contrast, about a half of the technologies used in the production and R&D of pharmaceuticals is the 'new' biotechnology, such as cell fusion, recombinant

DNA, and bio-reactor, and if one only considers new biotechnology, pharmaceuticals (including medical equipment) is the largest user of biotechnology. In the US also, the health care industry is the dominant user of biotechnology.[7]

That is, the range of the biotechnology industry is not only wide but also dependent upon the definition of 'biotechnology'. The same can be said about information technology and nanotechnology as these technologies are used in a wide array of industries.

With declining demand to traditional products and in search of high value-added businesses, Japan is now in the process of building up science-based industries, both by starting new industries, such as the bio-informatics service industry, and by incorporating new scientific achievements into R&D and/or manufacturing of existing industries. However, in view of the above-mentioned four characteristics, the national innovation system discussed in Section 1 that proved to be useful in the past may no longer be appropriate for SBIs. As a consequence, the Japanese innovation system has been in the process of transforming itself and the government policy to foster this transformation is under way. Let us now discuss this change in detail.

4. Towards a Closer University-Industry Collaboration

The increasing importance of SBIs, with a strong science linkage as its main feature, implies the contribution of academic research on industrial innovation. Because a major part of scientific research is conducted by universities (and national laboratories), a stronger university-industry collaboration (UI collaboration) is called for. Of course, as the measurement of science linkage implies, the most common route of information flow from academic research to industrial innovation is through publication of papers. Branstetter's recent research (2003) indicates the great contribution of papers published by university faculties on industrial patenting.

Yet, there are also occasions in which universities are expected to contribute to industrial innovation in other, diverse ways. Most importantly, as discussed earlier, the unidirectional flow of science to innovation is not enough. Often industrial R&D

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[7] Source: U.S. Department of Commerce, *A Survey of the Use of Biotechnology in U.S. Industry*, 2003. (http://www.technology.gov/reports/Biotechnology/CD120a_0310.pdf)

teams would face technological difficulties and, in order to solve them, they would seek the advice of academic scientists and/or propose to start joint research with such scientists.

Also, technology may be transferred from universities to industries by means of licensing of university patents. University patenting is made not only to protect the right of university inventors but also to make exclusive licensing possible, thereby giving incentives for licensees to expend for further development. However, the development of a commercially viable product out of patented invention may not be easy or straightforward. The licensed patent may not cover all the necessary technology and knowhow, which may be smoothly transferred only when the university inventor is actively involved. Also, as the term 'absorptive capacity' implies, a sufficient capability is needed on the licensee's side and, even with such capability, unexpected bottlenecks may arise in the course of development. An advice by university inventors or other academics may help the industry to acquire a necessary capacity or to solve the bottlenecks.

There are also cases in which UI collaborations are called for at a pre-invention stage. Thus, industries often commission research to universities and propose joint research with them. Joint research is an attractive option because supposedly complementary capabilities of university scientists (who are good at, say, theorizing) and industry engineers (who are good at, say, experimenting and building prototypes) can be combined.

To promote SBIs, therefore, there must be an environment in which active UI collaboration, in the form of patent licensing, consultation, commissioned research, or joint research, is feasible and encouraged. Accordingly, Japan is now shifting its gear towards this direction.

It is not that UI collaboration was absent in Japan. In fact, universities did play an important role in Japan's industrial and technological development since the mid-19th century (Odagiri, 1999). As was somewhat common but probably more so than the US, another late-developing country at the time, Japan was desperate to catch up with the more advance European nations and its higher education system emphasized the acquisition of practical technological knowledge and skills[8]. Also, because

[8] For the US, see Rosenberg and Nelson (1994),

technologically knowledgeable people were scarce and tended to concentrate in universities, industries actively sought information and advice from university faculties.

Unfortunately, particularly after World War II, a uniform and rigid regulation began to be applied to the conduct of university faculties. Such regulation was strictly enforced because most of the major universities in Japan were national universities and their professors were civil servants[9]. Hence, professors could receive funds from industries only in a limited manner and with tedious paperwork, and so was their spending time for industries. They were not encouraged to apply for patents and could not become a director of a private company.

In the past few years, however, there has been a drastic shift towards deregulation and encouragement of UI collaborations. Professors can now join boards of directors of private companies. Besides, to promote joint research with industries, several policies have been adopted. First, red tapes regarding the acceptance of research funds and of researchers from companies to university laboratories were relaxed. Second, many universities built special facilities for UI joint research. Third, universities can now offer their space to startups at a low rent, if these startups were established for the purpose of commercializing technologies of the university's origin. Fourth, many universities have founded technology licensing offices (TLOs), which help faculties in applying for patents and licensing them and help companies in finding suitable university patents to be licensed and suitable faculties to start joint research with. Fifth, patent fees have been reduced for applications by university researchers or TLOs. Sixth, special tax concessions are now given to company R&D expenditures used for UI collaborations.

Furthermore, with the 'National University Corporation Law', every national university in Japan was incorporated into a semi-independent corporation in April 2004. Although the majority of its budget will continue to be supported by the government, this reform is expected to promote UI collaborations further for several reasons. First, incorporated universities can now hold patents, whereas in the past patents belonged to

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[9] Actually, in terms of the number of universities or of students, private universities overwhelmed, accounting for 75 percent of universities and 74 percent of students. However, prestigious universities (e.g., Tokyo, Kyoto, Osaka, Hitotsubashi, and Tokyo Institute of Technology) are all national with only several exceptions (e.g., Keio and Waseda).

the nation. Second, as the faculties are no longer civil servants, more flexible employment arrangement is now possible, making it easier for the faculties to work for companies part-time and receive industry funds. Also, the recruitment of specialists to support patenting, licensing, spinning off, and other activities should become easier. Third, naturally, each university will have more incentive to increase its revenue not only by offering more up-to-date courses but also by attracting industry funds for UI collaborations and promoting patenting and licensing of university inventions.

With these reforms, UI collaborations have been increasing rapidly[10]. The number of UI joint research by national universities increased from 1139 in 1990 to 4029 in 2000 and 6767 in 2002. The number of startups based on university-invented technologies increased from 11 in 1995 to 135 in 2002 and, as a result, the number of such companies in operation at this moment is estimated to be more than 600, which is much fewer than in the US[11]; still, the increase is impressive. 36 TLOs have been set up and several cases of licensing have been already reported, even if they are still few and the TLOs are all suffering from loss. Also, as of September 2003, 280 cases were reported in which the professors of national universities were acting as directors or auditors of companies.

This rise in UI collaborations and, more in general, the change in the expected role of universities has been significantly transforming the national innovation system of Japan.

5. Intellectual Property Reform

In 2002, Japan enacted the 'Basic Law on Intellectual Property'. With this law the government established the 'Intellectual Property Policy Headquarters' within the Cabinet, for the purpose of "providing stipulations on the development of a promotion program on the creation, protection and exploitation of intellectual property." There is a strong pro-patent feeling among the policy-makers as well as the industries, particularly in response to the pro-patent shift (at least at some point of time) of the US,

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[10] The following statistics are available at the website of the Ministry of Education, Culture, Sports, Science and Technology (http://www.mext.go.jp/), although few of them are given in English.

[11] In the US, 450 startups were formed in 2002 and the accumulated number during 1980-2002 was 4,320 of which 2,741 were still in operation. Source: The Association of University Technology Management, *AUTM Licensing Survey: FY2002*. (http://www.autm.net/index_n4.html)

as indicated by its wider acceptance of EST (expressed sequence tags) patents and business model patents. However, because stronger patent rights may hinder diffusion as discussed earlier, the Japanese Patent Office (JPO) has not explicitly shifted its stance towards an extension of patentable inventions. Still, such a shift seems to have gradually occurred in reality.

The new IP policy emphasizes, first, a wider utilization of patented technologies and, second, a stronger enforcement of patent rights.

According to JPO's survey, among the patents held by companies, only 27 percent were actually used by the patent owners[12]. Although no comparable US statistics is available, this proportion is considered to be much lower than in the US. This difference partly comes from the larger number of applications in Japan. Owing to the first-to-file rule adopted in Japan (as opposed to the first-to-invent rule in the US), firms tend to apply whatever invention they made, even if many of them would be later found to be commercially useless.

The effectiveness of patent protection depends on the enforceability of patents. Patent litigation is a notoriously costly and time-consuming process in Japan, mainly because there is no court specialized in patent-related litigations and, hence, there is no judge (and only a few lawyers) with technological knowledge. To remedy this situation, a discussion is currently going on to establish a special court within Tokyo High Court to deal with patent litigation.

Also, to supply more personnel with knowledge on patent law and patent management to industries as well as the courts and the government, the government encouraged universities to establish necessary courses and JPO has been making efforts to hold public lectures on related issues. Since small and medium enterprises in particular suffer from the lack of necessary personnel, the government has been also establishing a scheme to introduce to SMEs those people having retired from big companies after years of experience in patent management.

Another policy emphasis has been on the production and utilization of patents by universities and national institutes. As already discussed in the previous section, the

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[12] The 'use' here includes both own use and licensing. See the website of Japan Patent Office (http://www.jpo.go.jp/indexj.htm) for this and most of the following statistics and facts. Most of them are in Japanese only.

government has been promoting more active involvement of universities in industrial innovation. As regards patents, an important policy change was made in 1999 with a law dubbed the 'Japanese Bayh-Dole Act' after the 1980 Bayh-Dole Act of the US. With this law, researchers who made inventions out of the R&D projects commissioned and funded by the government can now claim the ownership of the inventions. This new policy aimed to give more incentive for researchers to patent and also to promote commercial application of the patents by the researchers themselves or by licensing. As discussed already, patent fees were reduced for academic inventions and TLOs have been set up in many universities.

Consequently, although the rise in university patenting and licensing may not be spectacular yet, a gradual change has been occurring and, together with the incorporation of national universities as discussed in the previous section, a big impact on Japan's national innovation system is anticipated in coming years.

6. Promotion of Startups

The promotion of startups has been another major policy issue, primarily because, as discussed in Section 2, the rate of entry of new enterprises has been declining and is lower than in the US, and because the advance in the US of biotechnology and IT industries is considered to owe significantly to the activity of high-tech startups, such as those in Silicon Valley.

Thus, several policy measures have been taken to promote startups. Policies regarding university-based startups have been already discussed. In more general, under the 'Law for Facilitating the Creation of New Business' (dubbed the Japanese SBIR program after the US Small Business Innovation Research Program) of 1999, the government started to provide subsidies and debt guarantees to support the investment by SMEs (existing SMEs, new startups, or individuals) to start new businesses and to develop and commercialize new technologies. In addition, the government started in 2002 to give tax advantages to individuals investing in startup companies (called the Angel Tax System), and reduced the minimum amount of capital required to found a stock company from 10 million yen to a mere 1 yen, provided the company is established to start a new business, on the condition that the capital should be increased to a minimum of 10 million yen within five years of the establishment. Startup firms were also allowed to use stock options as a compensation scheme to its directors and employees, because these firms often face cash-flow shortages as they have to expend for R&D and other investment in the early stage when their revenue remains still low.

With these and other policies to promote startups, the number of high-tech startups has been actually increasing. For instance, the per-annum number of newly established biotech startups increased from less than 20 in the latter half of 1990s to more than 40 after 2000. As a result, the number of existing biotech startup companies increased from 60 in 1998 to 387 in 2003[13].

Financing for these startups has been made easier. Three stock markets, such as JASDAQ and MOTHERS, were opened or reorganized to make it easier for startups to trade their shares. The number of new initial public offerings (IPOs) has accordingly increased: in 2003, for instance, about 100 firms made IPOs in these markets. Many venture capitals have been also established.

Yet, there remain a number of problems. In 2001-2002, Odagiri and Nakamura (2002) made interviews and a questionnaire survey to 65 Japanese biotech startups. When we asked the firms if they felt each of thirteen probable obstacles in the list to be a significant barrier in founding their firms, 54 percent of them answered yes to 'the difficulty in recruiting technological staff.' This was followed by 'difficulty in financing' (49%), 'difficulty in recruiting non-technological staff (e.g., finance, accounting, and legal)' (23%), and 'difficulty in securing wet laboratories' (23%). Evidently, recruitment of technological and non-technological staff is a big hurdle for Japanese startups, together with (if not more than) financing.

A part of this difficulty comes from the fewer number of specialists, such as lawyers and certified accountants, in Japan in comparison to the US. More important in our view is the lower mobility of workers in general in Japan. As discussed in Section 2, long-term attachment between workers and their companies has been the norm in Japan. Although *de fact* dismissal did occur even in Japan and the so-called 'lifetime employment' may have been adopted only in the public sector and big firms, most managers took it as a norm toward which they should make efforts (Odagiri, 1992). Likewise, most workers tended to assume that they can and will stay with the same company until retirement. True, with the collapse in the past decade of a number of

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[13] Source: Japan Biotechnology Association, *2003-Nen Baio-Bencha Toukei Houkokusho* (http://www.jba.or.jp/bv/bv-tokei2003.pdf, in Japanese).

firms that were once considered infallible, many people started to regard the concept of lifetime employment suspicious. And, in fact, there now appear to be more cases of workers changing jobs and firms hiring mid-career workers, part-timers, and temporary workers. Still, according to the government survey, 40 percent of the firms with 1000 employees or more replied that they intend to maintain the lifetime employment system[14]. The same survey, however, also reveals that those firms replying that they no longer have a lifetime employment system accounted for less than 10 percent in 2003 but had increased compared to four years earlier.

That is, Japan's labor system has been gradually moving towards a more mobile one and yet, at least at this moment, the mobility is much lower than compared to other countries, particularly the US. This tendency is most evident in big firms and these big firms tend to have more talented people both because they can recruit better workers and because their workers tend to receive more in-company training and wider experience. This situation makes it difficult for startups to recruit good scientists and engineers as well as management staff including those in accounting, finance, legal affairs, intellectual property management, and administration, as shown in the above-mentioned result of our survey to Japanese biotech startups.

Nevertheless, a gradual change is occurring towards more mobile labor markets and more recruitment of talented people by startups from established companies. For instance, the first university-spinoff biotech company to have made an IPO, called Anges MG, first had a CEO who had had an experience of leading a startup in Silicon Valley in the US but was succeeded by a person who had quit one of the biggest chemical companies in Japan. Another university-spinoff biotech company is led by a former employee of one of the biggest securities firms. Thus, the move of people from big companies to startups has been occurring and, we expect, is going to be more common in coming years.

7. R&D Boundaries of the Firm

It is now not only inefficient but also impractical for firms to perform all R&D-related works in-house. Through R&D alliances, licensing, outsourcing, and such,

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[14] Source: Ministry of Health, Labour and Welfare, *White Paper on Labour, 2003* (http://www.mhlw.go.jp/wp/hakusyo/index.html, in Japanese).

they have to incorporate and utilize outside capabilities to achieve innovations efficiently and swiftly. As a consequence, how to set a boundary between in-house R&D and external R&D has become a key factor for successful innovation. From a national viewpoint, the presence of opportunities for R&D outsourcing and alliance is a key factor for a successful national innovation system.

I trust that this increasing importance of inter-organizational collaboration applies to any industry today. Still, it probably applies best in SBIs, such as biotechnology and pharmaceuticals. The number of research alliances (including those with firms and universities, in Japan or elsewhere) by the ten largest pharmaceutical firms in Japan increased three-fold in ten years, from 65 in 1989 to 189 in 1999, and, during January 1999 to August 2001, 103 cases of alliances by these firms were reported by the press (Odagiri, 2003). 43 of them were technology acquisitions (i.e., licensing-in), and 50 were joint or commissioned R&D, with the rest being the access to database (e.g., that of Celera) and so forth. As a partner of these alliances, new biotech firms (NBFs), particularly those in the US, were as popular as established firms. These tendencies, that is, an increase in the cases of R&D alliances with many of them being those with NBFs, is found among all major pharmaceutical firms across the world (see, for instance, Henderson, Orsenigo, and Pisano, 1999).

In a survey conducted by Japan's National Institute of Science and Technology Policy (NISTEP), among the 146 firms who replied that they have conducted biotechnology-related businesses in 2000, 97 performed R&D alliances and/or technology acquisitions (Odagiri, Koga, and Nakamura, 2002). Asked about the reasons why they perform R&D alliances, they gave the highest score to the 'utilization of the partner's technological knowledge and capabilities (rather non-patented ones)" and the next highest to "speed", "utilization of capital equipment", and "cost reduction" that can be gained through alliances. This result illustrates the importance of utilizing outside assets (tangible or intangible) and capabilities, and of combining them with internal ones.

Of course, firms cannot relegate all R&D works to outside because they have to maintain capabilities that are indispensable not only for own development and commercialization but also to evaluate potential alliance partners, monitor them, and understand and absorb the results supplied by them. In the NISTEP survey, many firms reported that they have had cases in which they could find reasonable alliance partners but nevertheless decided to perform the R&D by themselves. Besides the fear for ambiguity in the ownership of the outcome, these firms raised 'utilization of internal human and other resources and capabilities' and the 'need to nurture them internally' as the main reasons for this decision. That is, the firms are keenly aware of the need to maintain and hopefully heighten their internal capabilities, not just for in-house R&D but also to perform more efficient R&D alliances.

Utilization of outside resources and capabilities also occurs in the form of outsourcing of more routine R&D-related services. In such outsourcing, the contract specifies the details of the work to be outsourced and all the output from the work is to be handed over to the outsourcer. Examples are, in the case of biotechnology and pharmaceuticals, animal tests, supply of specific samples (such as knock-out mice), production of test products, software development, genome analyses, and clinical tests. The amount spent for outsourcing reached 25 percent of R&D expenditures among pharmaceutical firms, according to the NISTEP survey.

I have earlier discussed about the wide application of biotechnology across industries. Bio-related informatics and services, as well as the provision of laboratory equipment, bio-electronics, and samples and reagents, constitute an important part of biotech-related industries. Many firms in these fields are active outsourcees whether they are large or small and established or new. The presence of such firms is a prerequisite for an SBI-oriented innovation system.

That is, an increasing importance of the issue of the R&D boundaries of the firm in SBIs is closely connected with the important role played by universities and by startups and with the widespread use of the technology across industries. Together, they constitute a background without which SBIs cannot grow.

8. Conclusion

After explaining the innovation system behind the industrial and technological development of Japan since the Meiji Restoration of 1867 until the 1980s, I have discussed that the end of catch-up, together with the depressed market demand and the weakened financial power of the banking sector, necessitated a significant change in Japan's national innovation system.

Scientific advance has been playing a central role in the emergence of new science-based industries (SBIs), as exemplified by those based on biotechnology, nanotechnology, and information technology (IT). The advance of life science promoted its industrial application in the form of biotechnology, which transformed pharmaceuticals and other industries and gave rise to new industries, such as bio-informatics and other bio-related services. Nanotechnology has been changing the material-related industries and IT has been changing the electronics and communications industry. Also, technologies are interrelated as exemplified by the application of nanotechnology in biotech devices and the application of IT in bio-informatics.

The Japanese government, therefore, has designated four key areas (life sciences, information and telecommunication, environmental sciences, and nanotechnology and materials) and increased the science and technology budget allocated to these key areas. In addition, the government has been making efforts to promote industries based on these sciences by, for instance, promoting university-industry collaborations and the startup of new high-tech firms.

Changing a national innovation system is by no means an easy task because the factors constituting a national innovation system are complementary. The financial system of Japan, characterized by close bank-firm relationship and the presence of stable shareholders, was complementary to the labor system characterized by long-term worker-employer relationship. And this system was conducive, for instance, to the accumulation of firm-specific human skills and the close intra-firm (and intra-group) information sharing, which made cumulative technological innovation easier. Such advantage should not be disposed of easily. Many of such advantages have been actually exploited even in science-based fields; for instance, a big brewer applied the fermentation process technologies to the production of biotech drugs. Still, to promote new industries and new firms, the economy needs to foster reallocation of talented people through external markets (as opposed to internal labor markets) and the supply of more venturous funds (for which banks lack comparative advantages). Probably, these needs do not conflict with the traditional Japanese system because, for instance, many established firms today have redundant middle-aged workers and hence their reallocation must be mutually beneficial, and venturous funds and risk-averse banking sector should be able to coexist. The search for a right balance between the traditional system and the, say, more Silicon Valley-type system is in process, from which a new national innovation system is hopefully to emerge.

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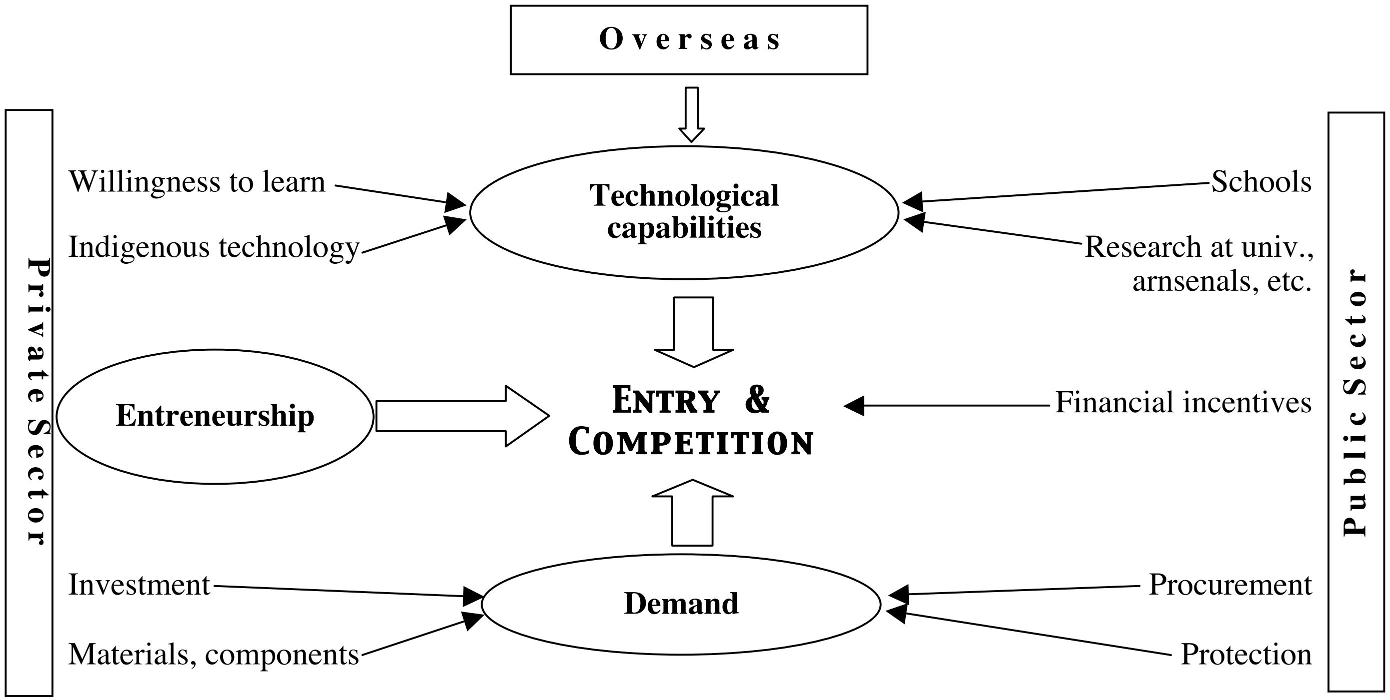
Figure 1. Technology and Industrial Development in Japan: The Basic View



Source: Hiroyuki Odagiri and Akira Goto, *Technology and Industrial Development in Japan* , Oxford University Press, 1996.

Table 1. Trends in Science Linkage in Japan and the USA

	All Fields	By Six Major Fields						
		Biology/ microbiology (1)	Organic	Inorganic	Medicine/ veterinary medicine (2)	Agriculture, forestry, fishery (3)	Computation/ counting	Basic electronic circuitry
Japan								
1985	0.17	1.48	0.85	0.32	0.45	0.16	0.19	0.35
1990	0.27	2.42	1.04	0.93	0.53	0.40	0.31	0.62
1995	0.56	5.15	1.95	0.85	1.27	0.89	0.83	0.91
2000	0.51	5.84	2.99	0.55	2.31	1.41	0.69	0.69
2002	0.49	6.80	2.99	1.19	1.83	1.16	0.63	0.61
USA								
1985	0.39	5.13	1.38	0.72	1.08	0.27	0.50	0.55
1990	0.72	8.07	2.54	1.86	1.74	0.59	1.08	0.99
1995	1.61	15.53	6.54	2.72	3.58	1.33	1.91	1.47
2000	2.82	23.20	14.20	3.08	7.15	5.63	2.01	1.44
2002	3.23	24.32	15.83	3.53	8.24	6.03	1.97	1.62

(1) Biology, Beer, Alcohol Sprit, Wine, Vinegar, Microbiology, Enzyme, Mutation or Genetic
(2) Medicine and Veterinary Medicine, Hygienic
(3) Agriculture, Forestry, Stockbreeding, Hunter, Capture, Fishery

Source: National Institute of Science and Technology Policy, "Kagaku Gijutsu Shihyo" [Science and Technology Indicators 2004], *NISTEP Report* No. 73. The original data is from CHI Research Inc.

Table 2. Shipment of Biotechnology-Related Products, 2000

Product Field	Domestic Shipment		Composition of Shipment by the Type of Technologies (%)				
	billion yen	%	Traditional fermentation, cultivation, modification, etc.	Traditional environmental remediation with organisms	Cell fusion, recombinant DNA, bioreactor, etc.	and electronic and other equip. and software making use of biological knowledge	Non-response
Food and beverages	4474	66.0	100.0	0.0	0.0	0.0	0.0
Misc. food	155	2.3	90.0	1.2	6.3	0.0	2.5
Agricultural	24	0.4	24.8	0.0	15.2	0.0	60.1
Livestock and fishing	32	0.5	24.0	8.4	9.9	5.3	52.4
Pharmaceuticals and medical equip.	1098	16.2	38.4	2.8	48.3	3.1	7.6
Laboratory samples and reagents	23	0.3	32.9	0.0	60.3	6.4	0.4
Textile	2	0.0	60.6	3.4	11.1	10.7	14.2
Chemicals	439	6.5	47.0	0.0	52.4	0.0	0.6
Bio-electronics	33	0.5	0.0	0.0	0.2	73.0	26.7
Environment-related equip. & materia	212	3.1	0.3	92.8	1.0	1.8	4.1
Laboratory and plant equip.	159	2.4	8.8	0.0	5.6	84.7	0.8
Misc. manufacturing	61	0.9	88.7	1.6	1.2	8.5	0.0
Informatics	12	0.2	0.0	0.0	0.0	91.8	8.2
Services	54	0.8	9.4	20.6	26.1	43.1	0.7
Total	6779	100.0	75.9	3.6	14.5	3.2	2.9

Source: Ministry of Education, Culture, Sports, Science and Technology, et al., *Heisei 13 Nendo Baio Sangyo Souzou Kiso Chosa Houkokusho* [Report on the Basic Survey of Biotechnology Industries, 2001], 2003.