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A 'national innovation system' refers to the system of institutional and socioeconomic conditions that influence the innovation activity of a nation[1]. It has two important characteristics.

The first characteristic, say, a horizontal one, is its relationship with other 'systems'. In every country, the most active performer of innovation is private firms: inevitably, therefore, a nation's innovation system cannot be free from its business system, including the systems related to finance, corporate governance, the allocation and accumulation of human assets, and the boundary of the firm. Also, innovation is dependent on scientific research. Because such research is carried out within universities and government-sponsored research laboratories among others, a national innovation system is closely related to the country's university system and the national science system. Of course, the university system also affects the innovation system through supply of scientists and engineers. Another is the legal system because the country's law provides a basis upon which innovation is carried out. This is particularly applicable with intellectual property laws, such as the patent law, because they influence both inventors' incentives and the speed of knowledge diffusion. Also, the company law and the competition law affect private investment for innovation.

The second characteristic, say, a historical one, is path-dependence: the way the country's innovation system evolves cannot be free from the path it has taken before then. Because of uncertainty, bounded rationality, and inertia, one's search for better alternatives is bound to be local and, hence, dependent on the historical path. In consequence, the national innovation system can never jump to the 'optimal' equilibrium but only evolves towards it, as the evolutionary theory argues (Nelson and Winter, 1982; Nelson, 1995).

These two facts imply that a nation's innovation system co-evolves with its other systems. In this chapter, I intend to discuss how the innovation system and the business system are currently co-evolving in Japan, because I believe that the on-going change in scientific environment also calls for a change in the way businesses are performed.

In the next section I begin by arguing that Japan's post-WWII (World War II)

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[1] For an international comparative study of national innovation systems, see Nelson (1993).

development of innovation can be separated into three periods. The third period, that began in 1990, is characterized by science-based innovation, such as information technology and biotechnology, as will be discussed in detail in Section 2. In Section 3, I will discuss how Japan's business system and the labour system have been changing. In Section 4, I will argue that an important characteristic of science-based innovation is its broad applicability; that is, innovation is carried out and the outcome is applied beyond the traditional boundary of industries. In Section 5, I will discuss that, as a consequence of this changing industrial boundary, it has become imperative for firms to utilize outside capabilities and combine them with internal R&D through alliances and outsourcing. In other words, the R&D boundary of the firm also needs to change. Section 6 concludes the chapter.[2]

1. Japan's postwar innovation system

Even though it is hardly satisfactory to discuss only the postwar history of Japan's innovation system, because its development depended on the path it had taken in the pre-war period, the space limitation does not allow me to discuss the prewar experience: see Odagiri and Goto (1996) for a fuller discussion of development in both the prewar and postwar periods.

It is convenient to separate the sixty-year postwar history into three periods:

Period 1: 1945-1972 [catch-up with technology importation],

Period 2: 1972-1990 [emphasis on own innovation],

Period 3: 1991 to the present [increasing importance of science-based innovations].

Quoted years marking the beginning and ending of the periods cannot be accurate because, obviously, various conditions change only gradually and at different timing.

Period 1 started with the end of the war and covers the high-growth era of the 1950s and 1960s, ending with the oil crisis of 1972. Period 2 started when catch-up was mostly completed and many firms started emphasizing the need for own inventions. Period 3 corresponds to the so-called post-bubble depression period. As regards the innovation system, the prominent feature of this period is the increasing linkage between science and technology. We now discuss these periods in turn.

When the war ended, Japan was technologically behind the US and Europe owing,

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[2] Some of the discussion in the following overlaps with Odagiri (forthcoming, a and b).

for instance, to its isolation during the war from the scientific and technological discovery made in the West, such as petrochemicals and penicillin. Also, a large part of its production facility had been damaged by bombing. Still, the country had inherited industrial and technological bases, both tangible and intangible, from the pre-war period and, with these bases, the country resumed its efforts to catch up with the West, actively importing technologies. On a 1995-yen basis, technology import (i.e., the payment to technologies licensed from abroad) increased from 26 billion yen in 1952 to 512 billion yen in 1971 at an annual growth rate of 17.0 percent.

Domestic R&D expenditures also increased, at an annual rate of 16.9 percent during the same period. As a consequence, its ratio to GDP increased from 0.62 percent in 1956 to 1.85 percent in 1971. Technology importation is never a simple process. Imported technology may be immature or unsuitable to local natural and social conditions. Quite often, fierce domestic competition propelled Japanese firms to import new technologies at a still commercially untested stage. Thus, they had to expend heavily on R&D to develop the technologies further in order to make them applicable to manufacturing processes and to make them commercially viable. With this technology importation supported by R&D investment, Japan gradually caught up with the state-of-the-art technologies of the world.

In Period 2, the weight of R&D shifted from improvement of imported technologies to own inventions, as evidenced by the increased patenting activity. From 1971 to 1987, the number of patent applications by the Japanese to Japan Patent Office (JPO) increased at an annual rate of 9 percent[3]. Technology export also started rising, not only because of increasing inventions by Japanese firms but also because of increased licensing to Japanese subsidiaries abroad. Thus, the ratio of technology exports to technology imports improved and exceeded unity in 1993[4]. Since then it increased rapidly and, in 2002, the export was 2.6 times larger than the import. The ratio is particularly high in the automobile industry, reaching 75.0 in 2002, owing to the active globalization of Japanese carmakers, because 86.7 percent of technology export in the

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[3] Because JPO started to accept multi-claim patent applications in 1988, the number of patent applications after 1988 is not strictly comparable to that of the earlier period.

[4] The data on technology imports and exports, as well as R&D expenditures, are from *Report on the Survey of Research and Development*, various years, Soumusho (Ministry of Internal Affairs and Telecommunications).

industry is made between Japanese parents and their subsidiaries abroad.

In consequence of this increased R&D efforts, Japan now has its R&D/GDP ratio highest among all countries except Sweden and Finland. This high R&D investment is led by the industries. The proportion of R&D expended by industries is around 70 percent in Japan and in most major countries (except France where it is 62 percent). In 1991, the proportion funded by industries was 73 percent in Japan, slightly exceeding the proportion expended by them, implying that the industries paid more than they expended, that is, they subsidized the R&D of other sectors. This makes a contrast to the US where the proportion of industry funding was 57 percent, which is lower than the proportion of industry expenditure by 15 percent point, because the US industries received large government R&D subsidies. The same can be said with major European countries, in which the proportion of industry funding was 62 percent (Germany), 50 percent (UK), and 43 percent (France). Since then, the US and Europe decreased the proportion of government funds in contrast to Japan which increased it, resulting in the convergence of the proportion of industry funding among these countries, particularly among Japan, the US, and Germany.

The shift of innovation focus from catch-up with technology importation in Period 1 to own innovation in Period 2 was a response to two important changes in the global environment surrounding innovation.

The first, obviously, is Japan's completion of catch-up, as most clearly indicated by the fact that Japan's R&D/GDP ratio outweighed that of the US for the first time in 1987 and has been higher since then. In consequence, American and European firms became more and more reluctant to license technologies to Japanese firms who, they had observed, grew to be their formidable competitors in global markets. Many of them started to ask for technologies to cross-license rather than just monetary payments in return for the technologies. Furthermore, many of them started direct investment in Japan in order to gain the returns to their innovations fully.

Second, partly in response to Japan's catch-up, the US shifted its public policy stance towards a pro-industrial one in the 1980s. Mowery and Rosenberg (1993, p. 58) asserts that "the contrast between the position of the newly elected Reagan Administration in 1981, denying any role for the federal government in the development and commercialization of new civilian technologies, and the Reagan Administration of 1987-1988, is dramatic," raising, as an example, the launching of two military-funded research programs in civilian technology development. The US also strengthened patent protection "in three major ways: extending patent protection to new subject matter; giving greater power to patent holders in infringement lawsuits; and lengthening the term of patents" (Gallini, 2002, p. 133). During the 1980s, patents were extended, for instance, to genetically engineered bacteria, software, and business methods. Also, the creation of a special court for patent infringement cases (the Court of Appeals for the Federal Circuit, or CAFC) significantly increased the probability of patent-holders' winning in such cases (Gallini, 2002).

The impact of this change shook Japanese firms through, for instance, the lawsuit brought by Corning Glass Works (a US firm) against Sumitomo Electric Industries (SEI, a Japanese firm) on the alleged infringement by SEI of Corning's patent on optical fiber. SEI maintained that its technology is different from Corning's and hence did not infringe Corning's patent; however, CAFC interpreted the patent as covering a broad range of technologies, including SEI's, and concluded in 1989 that SEI infringed Corning's patent. In consequence, SEI was forced to pay 25 million dollars award to Corning. This incident gave a strong lesson to Japanese firms on the need to respect others' intellectual property rights (IPRs) and also to protect their own inventions with IPRs.

With these changes, Japanese firms started to realize that it was no longer possible or desirable to depend on technologies imported from abroad and that they had to pursue further growth with their own innovation of new products and new processes. They may still import technologies to complement and augment their own technologies. However, particularly in the case of electronics, cross-licensing has become common and, without technologies to offer, licensing bargaining became more and more difficult. It is with these changes that the emphasis on own innovation became the key aspect of Period 2.

2. Increasing importance of science-based innovations

A significant change that occurred during the last two decades of the 20th century as regards the nature of technological progress is the increased linkage of industrial innovation to science. Of course, scientific achievements always fostered innovations, from the application of chemical research in developing new dyes in the late 19th Century (Murmann, 2003) to the invention of computers and transistors. Yet, the last couple of decades have witnessed a dramatic increase in the use of scientific discoveries in industrial R&D. Narin and his group (e.g., Narin et al., 1997) have proposed to measure this linkage of industrial R&D to science by the number of citations to scientific papers per US patent. In the US, patent applicants are required to list any prior arts (basically, 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 commonly used as an index of 'science linkage'.

This index rose from 0.31 in 1985 to 2.24 in 2003, a seven-fold increase in less than twenty years, indicating a rapid increase in science linkage[5]. Among US patent applicants only, the index is 3.28 in 2003, higher than that among Japanese applicants, 0.51. Presumably, this US-Japan difference owes partly to more active university-industry collaboration in the US and partly to a higher tendency among US applicants to cite prior arts in fear of being complained by the patent-examiners or the authors/inventors of these prior arts.

Another important fact about science linkage is that, by patent code classification, several fields are known to have particularly high scores. Biology/microbiology has the highest score at 24.32 (among US applicants), followed by organic chemistry (15.83) and medicine/veterinary medicine (8.24), suggesting that biotechnology-related inventions benefited heavily from scientific discoveries.

That is, industrial innovation has become more science-based and this tendency is most evident in biotechnology. Information technology and nanotechnology are other fields in which innovation is science-based. Innovations, we note, are based on sciences 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 information discovered during R&D or production would be fed back to scientific research. Therefore, the flow of information is not uni-directional from science to development/commercialization as the so-called 'linear model' of innovation implies. Information also flows from development or production to science. This bi-directional

[5] NISTEP (2004). The original data is from CHI Research, Inc.

and 'chain-linked' interaction between scientific activities and industrial innovation is the essence of science-based innovation.[6]

Science-based innovation, we note, is not necessarily a discontinuous jump from more traditional engineering-based or manufacturing-based innovation. In fact, many of the industries characterized by science-based innovation are also engineering-based. The information and electronics industries probably give the best examples. The development of a next-generation mobile communication system requires both scientific knowledge and engineering knowhow, and so is the development of next-generation semiconductors. In biotechnology, the development and manufacture of DNA chips, for instance, also require the engineering knowledge on hydrodynamics.

Even though science-based innovation has become important on a global scale, the US may be said to be the forerunner on many fronts and Japan has been making efforts to catch up with it. This is particularly true with information technologies. While Japanese big firms were content with their DRAM semiconductor business dominating the world in the 1980s, Intel concentrated its development efforts on microprocessors and eventually dominated the world semiconductor market[7]. Other startup firms in the US, such as Hewlett-Packard, Apple, and Microsoft, gave rise to the PC revolution. Most of them were started by former university professors, university graduates, or university dropouts.

In biotechnology, the relationship of startups with universities is even more prominent, as exemplified by the case of Genentech of which one of the founders was J. Boyer, a professor of University of California, San Francisco, who is famous for his invention with S. Cohen of recombinant DNA method. Many other biotech startups were also established. Big pharmaceutical firms also introduced biotechnology in their R&D.

Being behind the US in such development of science-based innovation, Japan started big efforts to catch up with the US during the 1990s. Because the Japanese economy faced a post-bubble recession since 1990 and the firms were suffering from depressed

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[6] See Kline and Rosenberg (1986) for the comparison between the linear model and the chain-linked model.

[7] A little known fact is that a small Japanese company, in search of a better technology for hand-held calculators, played a key role in Intel's invention of microprocessor. See Odagiri and Goto (1996).

demand, the introduction of science-based innovation, such as biotechnology and IT, appeared to them to open up new opportunities for growth.

The new development in the US as discussed above suggest two prominent features of science-based innovations -- the need for closer university-industry relationship and the role of startup firms as a significant undertaker of innovations. These features are in part dependent on the US system of universities. For instance, unlike in Japan or Europe, many of the major American universities are private and financially depend on the contributions from individuals and industries. Many of the US state universities were established with the aim of supporting local industries[8]. With these traditions, collaboration with industries was not something to be despised by university people, even after the student movement of the 1960s. In addition, the US business system has been characterized by higher mobility of people among firms and between firms and universities, which also helped university-industry collaborations and startups.

Finding that these features of the US system suited the requirement of science-based industries, Japan also started to promote these activities in the 1990s. Thus began Period 3 as defined earlier. We therefore discuss university-industry collaboration (UI collaboration) and startups in turn.

University-industry collaboration

It probably goes without saying that, with the largest performer of scientific research being universities (and national laboratories), close UI collaboration is essential for science-based innovation. It should be emphasized, however, that, as the above-cited measurement of science linkage implies, the most common channel of information from academic research to industrial innovation is published papers. For instance, Branstetter's recent research (2003) confirms a great contribution of papers published by university faculties on industrial patenting. In other words, the greatest contribution of universities must be made through what Nelson (2004) called 'scientific commons'.

Yet, universities can also contribute to industrial innovation in other, less public ways, because, as discussed earlier, the unidirectional flow of science to innovation is insufficient. Industrial R&D teams may face technological difficulties and, to solve them, they may seek the advice of academic scientists or propose to start joint research

[8] See Rosenberg and Nelson (1994),

with such scientists. Invented technology may be transferred from universities to industries by means of licensing of university patents. However, the development of a commercially viable product out of patented invention is not always 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.

UI collaborations may be also called for at a pre-invention stage. That is, industries often commission research to universities or 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.

In Japan also, UI collaboration was by no means absent and, actually, universities did play an important role in Japan's early industrial and technological development (Odagiri, 1999). As was somewhat common with the US, another late-developing country at the time, Japan in the mid-nineteenth century was desperate to catch up with the then state-of-the-art technologies of advanced European nations. Thus, its higher education system emphasized the acquisition of practical technological knowledge and skills. Technologically knowledgeable people were scarce and mostly in universities; hence, industries actively sought information and advice from university faculties.

Unfortunately, particularly after World War II, a uniform and rigid regulation began to be imposed on university faculties. Such regulation was strictly enforced because most of the major universities in Japan were national and their professors were civil servants[9]. Hence, professors could receive industry funds only in a limited manner 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.

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[9] Actually, in terms of the number of universities or of students, private universities overwhelmed, accounting for 74.9 percent of universities and 73.5 percent of students in 2003. However, prestigious universities (e.g., Tokyo, Kyoto, Osaka, Hitotsubashi, and Tokyo Institute of Technology) were all national with only several exceptions (e.g., Keio and Waseda).

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. Policies to promote joint research with industries have been adopted. Technology licensing offices (TLOs) have been established for many universities. Furthermore, with the National University Corporation Law, every national university in Japan was incorporated into a semi-independent corporation in April 2004, giving universities more incentives to receive funds from industries and freeing the professors from the civil servant code. With these reforms, UI joint research projects have been increasing and so have the number of startups based on university-invented technologies and the number of patents by university researchers. 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.

Startups

The promotion of startups has been another major policy issue. The rate of entry (the number of new enterprises as a percentage of the initial number of enterprises) in Japan dropped from 5.9 percent of 1975-1978 to 3.1 percent in 1999-2001, which is lower than the rate of exit, 4.5 percent[10]. One may assume that the loss of market demand owing to the business stagnation of the 1990s caused this drop. Actually, however, the entry rate started to drop not after 1990 but in the early 1980s when the business condition was still favorable.

Thus, the government has adopted several policies to promote startups by, for instance, providing subsidies and debt guarantees to support the investment by small and medium enterprises (existing SMEs, new startups, or individuals) made to start new businesses and to develop and commercialize new technologies, providing tax advantages to individuals investing in startup companies, and reducing the minimum amount of capital required to found a stock company.

Helped by these policies, the number of high-tech startups has been increasing. For instance, the number of biotech startups in operation increased from 60 in 1998 to 387

[10] Source: Small and Medium Enterprise Agency, *White Paper on Small and Medium Enterprises in Japan*, 2003.

in 2003[11]. Three stock markets (HERCULES, JASDAQ, and MOTHERS) were newly opened or reorganized from existing ones to make it easier for startups to trade their shares and, as a result, many startups have succeeded in initial public offerings (IPOs).

Nonetheless, these startups have faced several difficulties because the Japanese business system has not been particularly favorable to startup activities. To understand these difficulties, let us now discuss the business system and its change.

3. Japan's business system and the change

By the 1980s, that is, during what I called Periods 1 and 2, Japan's business system came to be known for its several prominent characteristics, which may be summarized as follows. A substantial share of the firm is owned by friendly shareholders, such as banks and group firms. The management is almost always appointed through internal promotion and, hence, the top executive has the experience of working with the firm for a long time, usually identifying his (and rarely 'her') interest with that of fellow employees. The internal labour system is characterized by long-term (if not 'lifetime') company-employee relationship. In order to raise skill levels, internal training, both off-the-job and on-the-job, and rotation programs were organized in most companies.

Such a system had significant implications on the innovation system. First, with the managers having less need to worry about hostile takeovers and knowing that the employees are most concerned with the future promotion opportunities, they tended to pursue long-run growth by investing in both tangible assets (i.e., plants and equipment) and intangible assets (i.e., innovation and marketing). Second, owing to the long-term employment relationship with occasional intra-firm rotation, the linkage among R&D, production and sales departments was tight, fostering the manufacturing and marketing applications of innovations. Moreover, such linkage tended to extend to suppliers and other affiliated firms because the assembler-supplier relationship also tended to be long-term, which helped them to share information among them. Third, 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

[11] Source: Japan Biotechnology Association, *2003-Nen Baio-Bencha Toukei Houkokusho*.

nurtured through internal training and rotation. For more details, see Odagiri (1992).

Since 1990, gradual but significant changes have been taking place in this business system. Banks (excluding trust banks) reduced their share ownership of public companies from 15.7 percent in 1988 to 5.3 percent in 2004 while the percentage of pension funds increased from 1.0 percent to 4.0 percent and that of foreigners increased from 4.3 percent to 23.7 percent.[12] Since the latter two categories of shareholders are presumably more sensitive to returns, this change must have worked to have the management more concerned with the shareholder value. To reflect the shareholders' view better, many firms have reformed their boards of directors, in particular to invite outside directors.

The sharp decrease in banks' shareholding, together with the decreased cross shareholding among non-financial firms, also indicates that the so-called *kigyo shudan* or a business group (also called horizontal *keiretsu* by some westerners) has been losing its significance. I have discussed that the role of such a group used to be limited and it has not been more than a loose federation of independent firms (Odagiri, 1992). Now, this federation has become even more ineffectual. It is true that, for instance, Mitsui group and Sumitomo group still have their presidents' lunch meetings regularly. However, since the formation by merger of Sumitomo Mitsui Banking Corp. (SMBC) in 2001, it participates in both presidents' meetings. Given that the bank has been considered the leader of such a group, it is hardly realistic to assume that a business group can make collective decisions of any kind (except perhaps the use of trademarks and philanthropic activities) when its member bank is also a member of a rival group. That the Japanese Fair Trade Commission stopped conducting surveys of six largest business groups implicitly indicate their view that these groups can exert no influence on competition.

The labour system has been also changing, if gradually. One such change is the widespread adoption of a performance-based compensation scheme, in place of (or in

[12] The average of all the firms listed in five Stock Exchanges in Japan. Source: Tokyo Stock Exchange, *Kabushiki Bunpu Jokyo Chousa*. Note that some of the listed firms are subsidiaries of other firms; for instance, JVC is owned 52 percent by Matsushita Electric. Some are subsidiaries of foreign firms, for instance, Nissan is owned 44 percent by Renault, in which case Renault's ownership is included in the share ownership by foreigners cited in the text.

addition to) the traditional seniority-based compensation scheme. Even if performance is correlated with seniority and hence, on average, the performance-based compensation may resemble seniority-based compensation, it has now become common that workers of a same seniority receive divergent pay depending on their performance or ability. Another change is the increasing proportion of part-time, temporary, or dispatched workers. The proportion of these workers among employees increased from 18.8 percent of 1990 to 28.1 percent in 2003 and particularly high among wholesale, retail and restaurant industry (45.0 percent in 2002)[13].

Has the long-term employer-worker relationship collapsed? This is a difficult question to answer. During the recession of the 1990s, a number of companies took on a measure of voluntary retirement with extra severance pay, which, in many cases, might be regarded as *de facto* dismissal of workers. Bankruptcies also became more common. Hence, many workers now feel that their employment is not as secure and permanent as before. Still, according to a survey to 1066 Japanese firms in 2004, more than three quarters of them indicated that they intend to maintain long-term employment of their regular workers[14]. In this regard, the long-term employment relationship, we may say, still remains as the 'norm', if not necessarily reality, of the Japanese employment system.

I believe that this practice is still effective in maintaining and accumulating skills within the firm. Many firms consider this maintenance of skill levels to be an acute problem, particularly because the aging of working population together with the shift of plants to overseas, such as China and Southeast Asia, have been making such maintenance urgent.

4. The consequence of the business system on startup activities

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 listed probable obstacles to be a significant barrier in founding their firms, 54 percent of them answered yes to 'the difficulty in recruiting technological staff.' This

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[13] Ministry of Health, Labour and Welfare, *Rodo Keizai Hakusho* [White Paper on the Labour Economy].

[14] See the footnote immediately above.

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 financing.

Partly, this difficulty comes from the fewer number of specialists in Japan in comparison to the US, such as lawyers and certified accountants. More important in our view is the lower mobility of workers in general in Japan, caused by the long-term employer-worker attachment as discussed above. Even though Japan's labour system has been gradually moving towards a more mobile one, the mobility is still lower compared to other countries, particularly the US. The long-term attachment is most evident in big firms and these big firms tend to have 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 our survey to Japanese biotech startups.

Nevertheless, a gradual change is occurring towards more mobile labour markets and more recruitment of talented people by startups from established companies. For instance, AnGes MG, the first university-spinoff biotech company in Japan to have made an IPO, was established in 1999 with the first CEO being a person who had earlier led a startup in Silicon Valley in the US. However, its third CEO, who led the company to IPO in 2002, was a person who had quit one of the biggest chemical companies in Japan. There are a number of similar examples; for instance, another university-spinoff biotech company, established in 2002, is led by a former employee of one of the biggest securities firms. Thus, move of people from big companies to startups has been occurring and, we expect, is going to be more common in coming years.

Japan also faces the so-called 2007 problem. In the majority of Japanese firms, sixty is the age of compulsory retirement (which, incidentally, is why I do not use the word 'lifetime' employment but merely long-term employment). The peak of postwar baby boomers will reach 60 years of age in 2007, with two consequences. One, with a serious macroeconomic consequence, is the heavy burden to be placed on the national pension scheme. The other is the loss of experienced workers at many firms. On the one hand, this change makes the age composition of a typical Japanese firm healthier. This is particularly true with old firms that had been in existence before the high-growth era of the 1960s, because they hired a large number of baby boomers upon their graduation during the 1960s. Many of these firms have since then turned into the phase of maturity or even decline after the oil crisis of 1972, thus reducing their hiring significantly. The result has been a skewed age composition of their employees with a large bump around the baby boomers. Under the more or less seniority-related compensation scheme, this fact meant that the labour cost tended to increase as these baby boomers got older. Hence, the retirement of these workers is expected to reduce the firms' labour costs.

On the other hand, their retirement implies that the skills and experiences accumulated and embodied within them will be lost from the firm. Accordingly, as discussed earlier, many firms started special efforts in the maintenance of skills, for instance, by starting new programs in which young workers are paired with soon-to-retire workers to facilitate effective on-the-job training, or by starting to offer retiring workers opportunities to continue working with the firm on a part-time basis with lower pay.

Some of these retiring workers may also opt to establish their own startups or to work for other startups, utilizing their knowledge, experience and network, and not minding the lower and unstable pay since they are entitled to pensions and their children have grown up. Admittedly, these workers are unlikely to be suitable as researchers on frontier technology, because their scientific knowledge must be outdated. Yet, they may well have elaborate engineering skills with which they can help the development and manufacture of biotech devices, for instance. Also, their experience in planning and negotiating in legal or management matters can prove useful. An example is a startup company that specializes in consulting biotech and pharmaceutical companies and helping them in negotiating alliance deals, established by a former head of the licensing department of a big pharmaceutical company.

In conclusion, the Japanese business and labour system may not have been favorable to the creation of startups. Still, it has been evolving under the changing business environment in the last couple of decades, such as the 1990s recession and the globalization of business activities, coupled with the changing age composition of workers. At this moment one cannot make a precise prediction of exactly where this evolution will take us. Nevertheless, following the evolutionary theory of natural selection and path dependence, Japan, this author believes, would somehow come up with a new system in which the merits of, say, a Silicon-Valley type system characterized by close university-industry interaction, active startups, and high mobility of workforce coexist with the so-called Japanese system.

5. Science-based innovation and the changing boundary of industries: The case of biotechnology

An important feature of science-based innovation is that the innovation activity is carried out, and its outcome used, across the traditional boundary of industries. As is well known, computer, information, and communication technologies are used in virtually all industries. Here, let us take the case of biotechnology.

Table 1 shows the shipment of biotech-related products by industry. The food and beverage industry has the largest shipment, accounting for more than 60 percent of the total shipment, followed by pharmaceuticals. Still, these are not the only biotech-related industries and, as shown in the table, biotech is used in a wide range of industries from chemicals to machinery, electronics, information, and environmental remediation.

In addition, a wide variety of technology is used. In food and beverages, almost all the technologies are the so-called 'traditional' biotechnology, such as fermentation and cultivation. Although several firms in this industry also use 'new' biotechnology to diversify into pharmaceuticals, biotech services, and other biotech-related fields, food and beverages including beer and other alcoholic drinks overwhelm in terms of shipment value and, as a result, nearly 100 percent is shown to be based on traditional biotechnology.

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. Thus, with new biotechnology only, pharmaceuticals (including medical equipment) is the largest biotech user. In the US also, the health care industry is known to be the dominant user of biotechnology.[15]

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[15] Source: U.S. Department of Commerce, *A Survey of the Use of Biotechnology in U.S. Industry*, 2003.

<Table 1 about here>

That is, the range of biotech industry is not only broad but also dependent on the definition of 'biotechnology'. In consequence, a wide variety of firms, both old and new, have been making research, manufacturing products, and providing services using various biotech-related technologies. Let me give a few examples. In agriculture, even though the public disdain for genetically modified organism prevented Japanese firms from developing GMO foods, Suntory, the largest whisky distiller and a beer brewer, developed genetically modified flowers, such as blue roses, which do not exist in nature. In food, Ajinomoto has been developing many products applying its technology on amino acid. In environmental remediation, plant-makers and construction companies have been providing services to remedy polluted ground with microorganisms. Machinery-makers have been manufacturing equipment needed for biotech research, for instance, Hitachi developed sequencers in alliance with Applied Biosystems of the US, and Shimadzu developed mass spectrometers, for which its inventor, Koichi Tanaka, received a Nobel Prize in 2002. Several firms have been supplying DNA chips and almost all the big electronics and communication companies have entered into the bioinformatics business. Even general trading companies (*sogo shosha*) have entered into the business of supplying various biotech services, using its network of suppliers of such services. There are also many small and/or new firms providing specialized services.

Put differently, the presence of diverse industrial activity is essential in the development of biotech industry, both for the efficient innovation activity and for the smooth industrialization of inventions. The presence of established firms with knowledge in traditional biotechnology, such as Suntory and Ajinomoto, and in design and manufacture of machinery, such as Hitachi and Shimadzu, has proved indispensable, and so has the entrance of new firms specializing in, for instance, supplying custom-made DNA chips or providing outsourcing services, such as specific tests and informatics. Universities can also play an important role here because, as discussed earlier, many of the innovations are science-based and benefit from the collaboration with and licensing from universities.

From the business viewpoint, this fact implies that it is now essential for any firm to utilize resources and expertise of various outside players and combine them with its own R&D efforts. 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. That is, the question of *R&D boundaries of the firm* has become one of the determining factors of business success. To this topic, we now turn.

6. R&D boundary of the firm in biotechnology

Doubtlessly, inter-organizational collaboration has become increasingly crucial in any industry today. Still, it probably applies best for science-based innovation, such as the innovation activities in biotechnology and pharmaceuticals. Research alliances are frequently and increasingly formed between firms and between firms and universities or research institutes, in Japan or elsewhere. Hagedoorn's (2002) study of the 1960-1998 trend of inter-firm R&D partnerships in the world clearly indicates an increasing trend from just ten or so partnerships per year in the 1960s to more than 500 in the latter half of 1990s. It also shows that the share of high-tech industries (pharmaceuticals, information technology, and aerospace and defense) among these partnerships has been also increasing, exceeding eighty percent in 1998.

In Japan, the ten largest pharmaceutical firms together had 65 alliances in 1989 but this number increased three-fold in ten years to 189. Also, during the 32-months period of January 1999 to August 2001, 103 cases of alliances were formed by these firms (Odagiri, 2003). 43 of these103 were technology acquisitions (i.e., licensing-in), and 50 were joint or commissioned R&D, with the rest being the access to database and so forth. As a partner of these alliances, new biotech firms (NBFs), particularly those in the US, were as popular as established firms. Such 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 biotech-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 non-patented technological knowledge and capabilities' 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 internal 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 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 such resources and capabilities internally' as the main reasons for this decision. That is, firms are keenly aware of the need to accumulate their internal capabilities, not just for in-house R&D but also to perform more efficient R&D alliances. This fact coincides with the discussion earlier that Japanese firms are now deeply concerned with the maintenance of skills at manufacturing.

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.

As stated in the previous section, bio-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 the innovation (and also production and marketing) in science-based industries.

It this regard, a comparison with the supply system in, say, automobile production may be useful. A close and long-term assembler-supplier relationship in the Japanese automobile industry is well known, often dubbed the vertical *keiretsu* relationship. For standardized components, arm's-length transaction is common even in Japan. However, for assembler-specific or model-specific components, continuous close relationship is common between an assembler and the supplier. They often collaborate from the development stage to coordinate the design of a car model and the design of components necessary for the model. They also collaborate in production to achieve just-in-time delivery and to minimize inventory both at the stage of component production and at the stage of car assembly. This fact by no means implies that competition is absent. In fact, assemblers take multi-vendor policy if possible, in order to maintain competition among suppliers. They also perform detailed evaluation of the suppliers leading, if necessary, to some sort of punishment. For more discussion, see Odagiri (1992).

In comparison, the alliance relationship and the outsourcer-outsourcee relationship in biotechnology appear to be closer to an arm's-length relationship. Obviously, the main reason is that transaction-specific assets are less important here than in automobile production. Also, technologies change rapidly following the development of scientific discoveries, causing the search for new partners in constant need. As a result, entry and exit of biotech-related firms are much more frequent than those of automobile suppliers. Clearly, this fact coincides with the observation earlier that startups play a crucial role in science-based innovation. Thus, without an active startup activity, the availability of alliance partner or outsourcing opportunity would be limited, possibly hindering the development of biotechnology and other science-based industries. It is probably reasonable to say that, as discussed already, Japan still lags behind the US in this regard but has been making efforts to catch up. This and other needs coming from the changing economic and technological environment have been fostering the change in Japan's business and labour system towards the one more in harmony with the new science-based innovation system. This co-evolution of the business system and the innovation system, I believe, is the most important feature of post-bubble Japan.

7. Conclusion

I started this chapter by separating Japan's post-war innovation activity into three periods -- Period 1, which covers the 1950s and the 1960s and was the period when Japan actively imported technologies to catch up with the state of the art in the world; Period 2, which covered most of the 1970s and the 1980s and was the period when

Japanese firms shifted their innovation efforts towards own inventions; and Period 3, which started with the 1990 collapse of the bubble boom and was the period when science-based innovation has become important and once more an effort was started to catch up with the US, a nation leading in such innovation.

Taking mostly the example of biotechnology, I have argued that the salient features of science-based innovation is the need for university-industry collaboration, the prominent role played by startup firms, and the relevance of the technology across traditional industry boundaries. As a consequence, the boundary of the firm has been opened up to introduce more inter-organizational collaborations of various kinds. To accommodate such changes, the business system has been also changing, if gradually, to allow, for instance, more flexible inter-firm relationship and more mobile labour movement.

Looking at the history of Japan's economic development, one notices several turning points. The Meiji Restoration of 1867, the victory in the Russo-Japanese War in 1905, the boom during World War I in 1914-18, and the defeat in World War II in 1945 are the most prominent such turning points, which resulted not only economic fluctuation but also important changes in Japan's economic and business systems. The 1990s, I believe, will be viewed as another turning point by the observers of coming ages. To be emphasized is the fact that all the previous turning points were the consequences of wars (including the civil war at the time of the Meiji Restoration). By contrast, Japan since the 1990s has been trying to transform the system at (thankfully!) a peaceful time. It is hardly surprising, therefore, that inertia and what Olson (1982) called 'distributional coalitions' have been in action towards delaying the necessary changes. Yet, as the natural selection theory implies, only the fittest to the new environment must eventually survive in the long run. Under this force, the co-evolution of the Japanese innovation system and the business system is taking place and has to be promoted in order for Japan to accommodate herself to the new reality.

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Table 1. Shipment of Biotechnology-Related Products, 2003

Product Field	Domestic Shipment		Composition of Shipment by the Type of Technologies (%)				
	million 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	4,770,241	62.9	100.0	0.0	0.0	0.0	0.0
Misc. food	192,980	2.5	61.2	0.0	30.6	0.1	8.1
Agricultural	45,277	0.6	84.6	0.0	15.1	0.3	0.0
Livestock and fishing	33,517	0.4	48.9	14.6	22.5	8.5	5.5
Pharmaceuticals and medical equip.	1,574,072	20.7	48.1	0.0	46.2	5.4	0.3
Laboratory samples and reagents	17,870	0.2	8.3	0.0	65.9	3.8	22.0
Textile	2,711	0.0	62.5	0.0	37.5	0.0	0.0
Chemicals	445,323	5.9	40.6	0.0	59.4	0.0	0.0
Bio-electronics	32,221	0.4	0.0	0.1	0.3	99.5	0.1
Environment-related equip. & materia	196,959	2.6	1.9	87.5	0.4	10.2	0.0
Laboratory and plant equip.	44,247	0.6	27.3	0.2	13.0	41.0	18.5
Misc. manufacturing	62,102	0.8	79.4	5.2	0.0	15.4	0.0
Informatics	18,374	0.2	0.0	0.0	1.1	67.9	31.0
Services	141,103	1.9	1.5	1.2	11.7	58.8	26.8
Unclassifiable	8,964	0.1	32.4	38.6	0.2	0.1	28.7
Total	7,585,961	100.0	78.7	2.5	14.3	3.5	1.0

Source: Ministry of Education, Culture, Sports, Science and Technology, et al., *Heisei 15 Nendo Baio Sangyo Souzou Kiso Chosa Houkokusho* [Report on the Basic Survey of Biotechnology Industries, 2003].