COE-RES Discussion Paper Series
Center of Excellence Project
The Normative Evaluation and Social Choice of
Contemporary Economic Systems

Graduate School of Economics and Institute of Economic Research
Hitotsubashi University

COE/RES Discussion Paper Series, No.178
July 2006

Economics of Biotechnology, I:
Scientific Commons and University-Industry Collaborations

Hiroyuki Odagiri
(Hitotsubashi University)

Naka 2-1, Kunitachi, Tokyo 186-8603, Japan
Phone: +81-42-580-9076 Fax: +81-42-580-9102
URL: http://www.econ.hit-u.ac.jp/~coe-res/index.htm
E-mail: coe-res@econ.hit-u.ac.jp

Economics of Biotechnology, I:

Scientific Commons and University-Industry Collaborations

Hiroyuki Odagiri

Graduate School of Economics, Hitotsubashi University

Kunitachi, Tokyo 186-8601, Japan

E-mail: odagiri@econ.hit-u.ac.jp

July 2006

This study has been partly supported by the National Institute of Science and Technology Policy (NISTEP) of the Ministry of Education, Culture, Sports, Science and Technology, and the 21st Century Center-of-Excellence Project on "The Normative Evaluation and Social Choice of Contemporary Economic Systems" at Hitotsubashi University.

Abstract*

This paper aims to survey the discussions on the role of universities in supporting scientific commons and in their collaboration with industries, and to discuss the present situation, the changes, and the policies in Japan. The contribution of science on industrial innovation is particularly strong in biotechnology and pharmaceuticals. Thus, most discussion will be made in relation to life sciences and biotechnology.

We argue that Japan has been making progress in fostering university-industry collaborations but, still, at least compared to the US, there is a room for improvement and catch-up. At the same time, we argue that excessive promotion of universities' making exclusive collaboration with industry or patenting their inventions is against the *raison d'etre* of universities, which is to enrich scientific commons and thereby promote scientific progress. The balance between open science and exclusion has always been a big issue in the design of an academic system and a patent system, and is a particularly acute one in life sciences and biotechnology.

* This paper is an abbreviated and modified English translation of Chapters 3 and 4 of ."Baiotekunoroji no Keizaigaku" [Economics of Biotechnology] (Tokyo: Toyo Keizai, July 2006) that consists of the following ten chapters:

Chapter 1. Introduction – Economics of Science, Technology, and Industry
Chapter 2. The Breadth of Biotech-Related Industries
Chapter 3. Life Science as a Basic Science
Chapter 4. Biotechnology and University-Industry Collaborations
Chapter 5. Biotechnology and Intellectual Property Rights
Chapter 6. Biotechnology and Startups
Chapter 7. Biotechnology and the R&D Boundaries of the Firm
Chapter 8. Biotechnology and the Pharmaceutical Industry
Chapter 9. Biotechnology and the National Policy
Chapter 10. The Remaining Issues

List of Contents

1. Universities as a Supporter of Scientific Commons

Science, according to the *New Oxford Dictionary of English*, is "the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment." As this definition shows, science is an activity or a system of knowledge that is to be discovered, confirmed, and scrutinized by observations and experiments. As Popper (1959, p. 41) said, "it must be possible for an empirical scientific system to be refuted by experience."

Never does science progress unless repeated experiments are made to test if the proposed scientific proposition is true or false. Any scientists, whether currently active or only potentially so, have to be able to participate in such experiments and, for this purpose, any scientific knowledge, including the results of observations and experiments, has to be shared by scientists. That is, any outcome from scientific research must be kept in "scientific commons" (Nelson, 2004) and should not be privately monopolized.

This argument is reinforced by the three distinctive characteristics of knowledge -- externality, cumulativeness, and uncertainty. Externality results from non-rivalry, meaning that knowledge can be shared among people without any user suffering from the others' use. Cumulativeness implies that scientific knowledge can be and has to be accumulated based on findings from observations and experiments. And uncertainty implies that one scientific activity alone may not produce results or it may lead to false conclusions. Thus, to reduce this danger, experiments have to be repeated by the same or other scientists. All these strongly indicate that scientific results must be placed in scientific commons so that anyone can challenge received wisdom.

The basic means with which scientific commons is maintained are academic journals and conferences. Besides openness, the basic rule of scholastic journals and conferences is the priority system; that is, among the papers on the same discovery, the first to submit is to be accepted and receive the full credit. Under this rule, scientists are motivated to accelerate their research and submit the results ahead of others. This incentive mechanism is effective not only because the first discovery brings academic reputation but also because their lifetime income depends on the achievements. Just as market competition leads to efficient resource allocation with the help of Adam Smith's *Invisible Hands*, competition among scientists contributes to faster scientific progress.

However, the presence of uncertainty makes this competition risky from scientists' viewpoint. Even if they work hard, the experiments may not produce desired results or may do so just a few days later than their competitors', resulting in their losing opportunities for praise and, possibly, promotion. If this risk is too high, few will want to be scientists.

Dasgupta and David (1994) suggest that this fact gives a good reason why many scientists belong to universities. At universities, faculty members receive fixed salaries as compensation for their teaching, in addition to pays that can be linked to their research achievements. The fixed part will provide certainty in income and the variable part, an incentive to make discoveries and inventions ahead of others. This compensation scheme therefore makes teaching and research complementary, which explains why universities are the major undertakers of basic research in our society.

Of course, teaching and research are complementary for academic reasons as well. Both the existing knowledge scientists use as an input for their research and the new knowledge they create will be conveyed to the students through lectures. Also, by having the students participate in experiments, scientists can provide on-the-job training to the students. Thus, there is an advantage of joint supply or, in economist's term, economies of scope when universities provide both teaching and research services. An advantage is also there in terms of the usage of laboratory equipment and library, because the majority of them may be used both for research and teaching. It is for these reasons that scientists, particularly those for basic research, belong to universities.

Essentially, the responsibility of universities lies in producing knowledge so as to contribute to scientific commons and in teaching knowledge that has been accumulated in scientific commons. Publication of research outcomes by faculty members suits this purpose and contributes to the reputation of their universities. Universities, therefore, have to function as the principal supporter of scientific commons. Monopolizing the inventions of faculty members should never be the first objective of universities, unless there are *very* good reasons for it as will be discussed later.

To support scientists and their scientific activity, universities mainly finance with tuitions and contributions. However, with the costs of scientific research soaring, these incomes are insufficient in today's universities: in consequence, public funds have become more and more important. In other words, universities, together with public laboratories in some countries and in some research fields, are the central player in the public research sector.

2. Development of Life Sciences and University Organizations

Life science has been also developed primarily at universities. The two most significant discoveries, double helix and recombinant DNA, were both made in universities with the help of scientific commons. As vividly described by the memoirs of the participants (Watson, 1968; Crick, 1988; Watson and Berry, 2003; Wilkins, 2003), when J. Watson and F. Crick came up with the idea of DNA double helix at the University of Cambridge, they were aided by the research of R. Franklin and M. Wilkins, then at King's College, and many other scientists in various universities around the world whose discoveries had enriched the scientific commons. S. Cohen and J. Boyer invented the recombinant DNA method at universities (Stanford and the University of California, San Francisco, respectively), again aided by the accumulated knowledge in scientific commons. Also, the Human Genome Project was started in 1988 with J. Watson as its first leader and was carried out jointly by several universities around the world, together with US National Institutes of Health and a few other public laboratories.

Thus, universities played the critical role in the development of life sciences. In turn, this development of life sciences prompted universities to change. New research fields, such as molecular biology and bioinformatics, became important, fostering universities to start new faculties and laboratories to study and teach these fields. Both academic and industrial demands increased for graduates with the knowledge on such new sciences and technologies, prompting universities to start new departments and graduate schools to teach these subjects. Put differently, unless such reorganization of universities is smoothly made, neither the development of academic research nor the industrial application of scientific progress can be sufficiently and swiftly made.

2.1. The Case of MIT

Let us take the case of Massachusetts Institute of Technology (MIT) of the US. In the 1950s, molecular biology became an important part of the Department of Biology and, in the 1960s, a center for life sciences was established within the department. In 1977 Whitaker College of Health Sciences and Technology was established, and the Harvard-MIT Division of Health Sciences and Technology was started as a joint program between MIT's Whitaker College and Harvard Medical School. These are interdisciplinary programs and many of the faculties hold joint appointments with other departments, schools, programs, and laboratories. In addition to the usual degree of MD (medical doctor), a Ph. D. in Medical Engineering and Medical Physics (MEMP) is offered, the latter title clearly showing the interdisciplinary nature of the program. In 1982, MIT also founded the Whitehead Institute for Biomedical Research "to identify and support the finest young minds in science". "Each year, Whitehead provides advanced scientific training to more than two hundred students, postdoctoral fellows, physicians, and visiting scientists from around the world."[1] Its Whitehead/MIT Center for Genome Research played an important role in the Human Genome Project.

2.2. The Case of Three Japanese Universities

Compared to this reorganization at MIT, Japanese universities lagged behind. Table 1 lists the reorganization events of three major Japanese national universities, in relation to life sciences (including biology, agricultural sciences, and medical sciences) and biotechnology[2]. It indicates that, during the 1990s, all the three universities expanded or reorganized their schools and research centers to incorporate the evolving life sciences and biotechnology. The University of Tokyo had the longest history of teaching sciences (including biology) and medicines among the three universities. Separately from the School of Medicine, it used to have the Institute for Infectious Diseases, which, in 1967, was reorganized and renamed as the Institute of Medical Science. In 1991, Human Genome Center was established within this Institute. TIT

---

[1] All information came from the websites of MIT and Whitehead Institute (accessed March 2005).

[2] I chose these three universities because of their distinct characteristics. The University of Tokyo is the oldest and best-known comprehensive university, presumably with the largest research outputs and best graduates. Tokyo Institute of Technology (TIT) is the best engineering university in Japan, like MIT in the US. The University of Tsukuba is a 'new concept university'. Although it used to have a long history as Tokyo University of Education, it was renamed, relocated, and reorganized as a comprehensive university in 1973, adding engineering and medical colleges among others. It is called a 'new concept university' because, for instance, it separated educational units (colleges) and research units (institutes) on the assumption that, together with its more centralized decision-making structure, the separation should enable organizational flexibility and promote interdisciplinary education. All the three were established as national universities but, as will be discussed later, were incorporated into independent organizations in April 2004.

started an undergraduate course on bioscience within the School of Science, and another on biotechnology within the School of Engineering in 1886, but the School of Bioscience and Biotechnology was established only in 1990, which absorbed the courses on bioscience and biotechnology started four years earlier. University of Tsukuba was unique in that it had a College of Biological Sciences separately from the College of Natural Sciences almost from in foundation in 1973. Hence, there have been a few moves before 1990 to foster research and education in life sciences. They were exceptions, however, and major reorganizations took place only after 1990.

Two points are noteworthy. First, during the latter half of the 1990s, all the three universities (and also a few other national universities) reorganized themselves as 'graduate universities', making graduate schools as their central units and having the faculty members belong to graduate schools instead of undergraduate organizations (called departments, colleges, or faculties). With this reorganization, they increased faculty size and the size of student enrollment at graduate courses. Taking this opportunity, universities like Tsukuba were reorganized to start new graduate schools with more emphasis on new life sciences and new biotechnologies while other universities like Tokyo and TIT expanded the existing graduate schools to start new life/bio programs.

Second, as shown in the cases of Tokyo and Tsukuba, Schools of Agricultural Sciences were reorganized to more biotechnology-oriented schools. Such a move occurred because, with a decline in the population engaged in agriculture, such schools suffered from a declining number of applications. Hence, to attract more students, they renamed themselves and started to offer more life/bio-related courses.

2.3. Lagging Reorganization of Japanese Universities

Although we looked at the examples of only three universities, these three, we believe, are diverse enough and can be assumed to represent Japanese national universities reasonably well. They are also the most respected universities and, hence, likely to have responded to changing scientific environment ahead of others. That, even in these universities, the necessary reorganization for systematic education of new life sciences and biotechnology started only in the 1990s suggests a substantial lag in Japanese universities' adaptation to changing conditions. It was two decades later since the invention of recombinant DNA technique, and more than a decade later since

MIT's new programs.

Such a substantial lag in the adaptation of Japanese universities to changing scientific environment is, unfortunately, not unique with biotechnology. In a now classic study, Hayashi and Yamada (1975) found that, in response to the rise of high polymer chemistry, the first course to teach it within Japanese universities was established only in 1959, even though research papers on this subject started to be published in the latter half of the 1940s.

Probably two reasons explain this delay. The first is the government regulation. When universities intend to start new departments (or graduate schools), they had to be approved by the Ministry of Education[3] and this procedure took a few years. This regulation has been relaxed in the last few years and, with the incorporation of formerly national universities in 2004, national universities now have a freer hand in the organization of their universities.

The second is the decentralized nature of decision-making within Japanese universities. Usually, departments make decisions and it is rare that the university headquarters overrule them. It is thus extremely difficult to abolish outdated departments to create room for new ones, or to have two or more departments agree with each other to have them integrate and expand to accommodate new academic fields. Furthermore, in most departments, consensus is emphasized than majority voting or the chairpersons' leadership. It is with these reasons that Japanese universities were slow in reorganizing to adopt new courses.

This delay, not surprisingly, created both an obstacle to the development of new research and delay in supplying graduates with knowledge of new scientific achievements to academia and industry. With the globalization of biotech industry in the last decade or two, this delay quite likely created a handicap for Japan's biotech industry.

3. Linkage between Life Science and Biotechnology

As we have been emphasizing, the contribution of basic science on innovation has

[3] Formally, the Ministry of Education, Science and Culture (*Monbusho*) until 2000 and the Ministry of Education, Culture, Sports, Science and Technology (*Monbu-Kagakusho*, MEXT) since 2001. Hereafter, both will be referred to as the Ministry of Education.

been increasing and is most prominent in the field of life science and biotechnology,

Of course, scientific achievements always fostered innovation, from the application of chemical research findings 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.

3.1. Indices of Science Linkage

Narin and his group (e.g., Narin et al., 1997) have proposed to measure this science-to-innovation linkage by the frequency of citations of scientific papers per US patent. In the US, patent applicants are required to list any prior arts (mostly, papers and patents) that are related to the technologies to be patented[4]. 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 useful 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 the US patent applicants only, the index is 3.28 in 2003, several times higher than that among Japanese applicants, 0.51.

The difference may be overstated because, among the patent applications made in the US, American inventors are more likely to cite papers by American authors in American journals. Japanese inventors may have benefited from Japanese papers but they are probably less careful in citing them, because Japanese authors are less likely to notice the lack of citation and so will be the USPTO (US Patent and Trademark Office) examiners. By comparison, American inventors are more careful not to miss citing related papers in fear of being complained by the patent examiners or the authors/inventors of these prior arts. Still, the difference of 0.51 vs. 3.28 appears too large to be explained by this factor alone. Furthermore, the index is higher in the UK (2.71), France (1.71) and Germany (1.03) than in Japan, if still lower than in the US.

[4] In Japan, such citation became obligatory only after the 2002 revision of the patent law.

[5] NISTEP (2005a), with the original data coming from CHI Research, Inc.

Therefore, it appears that science linkage is in fact weaker among Japanese inventors than American or European inventors.

This weaker linkage in Japan is observed in any of the seven major fields shown in Table 2. Apparently, in either country, science linkage is strongest in biology/microbiology, followed by organic chemistry and medicine/veterinary medicine, which are all related to life science and biotechnology. We may thus conclude that in any country biotechnology is the most science-based technology and that Japan's comparatively weak science linkage in these fields may indicate that knowledge flow from academic research to industrial invention in Japan has not been as active as in the US.

The majority of the authors of cited scientific papers belong to universities, public laboratories, and public hospitals. According to MacMillan, Narin, and Deeds (2000), among the papers cited by 2334 patents of 119 US biotech firms, 71.6 percent originated solely at public science institutions (universities, medical schools, research institutes), with additional 11.9 percent being jointly published by public and private institutions.

In a case study of 62 patents issued in 1995 in the field of signal transduction and transcriptional regulation (STTR), Kroll, Ault, and Narin (1998) found that, among the papers cited by these patents, 73 percent acknowledged sources of funding for the research and, among these papers, 47 percent acknowledged NIH extramural funding. Together with the papers authored by NIH intramural scientists, the percentage reached 53.5 percent. This fact indicates a big role NIH has been playing in the promotion of biotechnology in the US. That is, the outcome of research by the members of universities and public laboratories (including NIH) with the financial support of NIH and other government agencies are published in academic journals, which enrich scientific commons and promote inventions.

Branstetter and Kwon (2004) studied the US patents of 335 Japanese firms that are active R&D performers (not confined to biotech or pharmaceuticals). They found that nearly a half of the authors of the papers cited by these patents belonged to universities, about a quarter of them to hospitals and institutions, and about a quarter to industries. They also found that more than a half of the authors were located in the US. Similarly to the finding from Table 2, the probability that a patent cites papers was highest among the patents issued to pharmaceutical firms.

Again, therefore, a strong contribution is confirmed of academic research to inventions through papers published in academic journals and, hence, placed in scientific commons. Such contribution, furthermore, is most prominent in the field of life science and biotechnology.

3.2. The Carnegie-Mellon Survey and the NISTEP Survey

This fact has been also confirmed by questionnaire studies. In the so-called Carnegie-Mellon Survey, Cohen, Nelson and Walsh (2000, 2002) asked 1229 US manufacturing firms to indicate on a four-point Likert scale the importance for a recently completed major R&D project of each of 10 possible sources of information on public R&D (i.e., R&D by universities or government R&D laboratories). The percentage of respondents replying that the source was moderately or very important was highest at 41.2 percent for publications and reports, followed by informal information exchange (35.6%) and public meetings or conferences (35.1%). These percentages were higher than those for such contract-based informational channels as contract research (20.9%), patents (17.5%) and licenses (9.5%), indicating clearly that the major channel of information flow from public research to industries is through scientific commons.

Moreover, all these percentages were higher among pharmaceutical firms, for instance, 73.5 percent for publications and reports; that is, three quarters of them thought that publications and reports were moderately or very important sources of information from public research for their R&D projects. Meetings and conferences also scored a high percentage at 64.7 percent. These percentages were highest than in other industries, implying that the pharmaceutical industry is the largest beneficiary of scientific commons maintained by public research.

The industry also showed the highest percentage among industries for contract-based sources, such as patents (50.0%), licenses (33.8%), and consulting (58.8%), and second highest for contract research (52.9%) and cooperative or joint ventures (41.2%)[6]. It is thus clear that the industry also benefited heavily from public research through contract-

---

[6] Rather curiously, the percentage for contract research was highest in the steel industry (54.6%) and that for cooperative or joint venture was highest in the glass industry (50.0%). Since the sample size for these industries is small at 6 to 11 (as compared to 68 in the drug industry), the high percentages are likely to have been caused by outliers.

based collaborations to be discussed later.

A similar but slightly different survey was conducted in Japan in 1994 by NISTEP (National Institute of Science and Technology Policy). The result again indicates a high contribution of public research in the pharmaceutical industry (Goto and Nagata, 1996). The survey asked the firms if they received information leading to new R&D project from each of 12 possible sources. 41.7 percent of the 593 respondents (all in the manufacturing sector) replied that they received such information from universities, 37.5 percent received from public research institutes, and 46.4 percent from academic or technical associations. These percentages were highest in the pharmaceutical industry at 89.7 percent (from universities) [7], 79.3 percent (from public research institutes) and 79.3 percent (from academic or technical associations).

Clearly, therefore, universities and public research institutes contribute to industrial R&D in both Japan and the US, and in both in an open manner through scientific commons and in a contract-based manner, such as patenting, licensing, and joint research. And, this contribution is conspicuously higher in the pharmaceutical industry. The contribution, presumably, is also high in non-pharmaceutical biotechnology-using industries, such as agri-bio, bio foods, and biotech-related instruments and informatics. However, since the conventional industrial classification does not show these industries separately, we cannot confirm this fact.

3.3. Contribution of University Research Need Not Be Immediate

The contribution of university research discussed so far may not be apparent immediately. The lag between scientific discovery and new product is particularly large for drugs, owing to the long process of pre-clinical and clinical tests. According to Fujino, the former chairman of Takeda, the biggest drug company in Japan, "for a drastic new drug to come out into the market, it takes 13 years after a ground-breaking discovery of the Nobel Prize class" (Kosai and Fujino, 1999).

Econometric studies confirm this speculation of Fujino *et al.* Toole (2000), for instance, found that the contribution of public-sector research stock on the number of new drugs was most evident when the 19-year lag was assumed. He calculated the

[7] With the exception of the medical equipment industry (100%), in which only four firms responded.

public-sector research stock as the accumulated amount of research funds supplied by NIH and other funding agencies using a 15 percent obsolescence rate. Hence, the lag includes both the lag between funding and discovery or invention (which must have been mostly published) and the lag between discovery/invention and the introduction of a new drug. Since the lag between funding and publication was estimated to be 5 years by Ward and Dranove (1995), the lag between publication and the introduction of a new drug is estimated to be 14 years, roughly agreeing with Fujino's speculation.

As discussed above, such a long lag is inevitable in pharmaceutical R&D because of required clinical tests. The lag is shorter in other industries but still significant. Using patent data, Branstetter (2004) estimated the lag between publication of a paper and patent application citing this paper to be 5 to 6 years.

Hence, it is unrealistic and even dangerous to anticipate that public investment on basic research should produce economic impact within just a few years. Furthermore, such a lag is likely longer the more basic the nature of the research is. Recall that the use of genomic information in drug R&D would not have occurred were it not for the discovery of the double helix structure almost a half century ago. Thus, a patient investment is essential for basic research, which is why the market mechanism can rarely support it. From this viewpoint, it is worrisome that, in Japan these days, public funding agencies tend to evaluate public R&D projects based on a short-term quantitative measures, such as the numbers of papers and patents.

4. University-Industry Collaborations -- Various Forms

So far, we have emphasized the importance of information flow from science to technology through scientific commons. Scientific commons is open to public and, usually, the originator of information and its user remain anonymous to each other. In addition, there are cases in which the originator and the user recognize each other and form a specific relationship. Most often, the originator belongs to a university (including a public research institute or a hospital) and the user, to a firm. Such relationship is called university-industry collaborations (UI collaborations hereafter).

Universities and industries may form specific relationship in various manners. It is convenient to classify them from two viewpoints. The first is whether the relationship is formal, based on an organizational contract between the university and the firm, or informal, based not on an organizational contract but only on a personal relationship between a faculty member and the firm (with or without a contract). The second is whether information is exchanged bi-directionally between the two parties or in one direction only, usually from the university to the firm. Literally speaking, only bi-directional ones deserve to be called 'collaborations' but, commonly, the word 'UI collaborations' refer to both cases.

Table 3 lists various types of UI collaborations along these two dimensions. We will now explain them in turn.

'UI joint research' requires that the two parties collaborate on equal terms. University faculty member(s) and company researcher(s) perform R&D jointly based on a contract signed by the university and the firm(s). Usually, the research is performed at the faculty's laboratory but, possibly, it may be performed at the company laboratory. Because it is performed under contract signed by participating organizations and information exchange must be made between the two parties, UI joint research sits at the lower left-hand cell of the table.

In most cases, joint research is made between a single university scientist and a single company. There are also cases in which a number of firms participate, forming a 'consortium'. The typical case is the Pharma SNP Consortium organized by a number of pharmaceutical firms, which collaborated with universities. Joint research may be also conceived as a means of national technological or industrial policy, with the major part of R&D funds coming from the government, in which case it is called a 'national project'. The Fifth Generation Computer Project is a good example, performed by a joint venture of a number of electronics firms (Odagiri, Nakamura, and Shibuya, 1997). The major part of R&D funds came from the then Ministry of International Trade and Industry (MITI, now METI). The MITI-sponsored Agency of Science and Industrial Technology (AIST) participated as well as a number of university researchers.

The distinction among joint research, consortium, and national projects need not be clear, because it is sometimes difficult to determine the exact number of participants as they participate in diverse fashions, and because a certain amount of government funds may be allocated in cases also of joint research and consortium. For instance, the above-mentioned Pharma SNP Consortium also received research funds from the Ministry of Labour, Health and Welfare; however, since the amount of this government fund accounted for less than ten percent of the Consortium's budget, it had better not be called a national project.

In 'commissioned research', a firm commissions research to the university. The firm pays the expenditure and the university member performs the research. The research outcome will be delivered to the firm, who may patent it. Thus, the information flow is basically uni-directional, which is why it is in the lower right-hand cell of the table.

Also in the lower right is the 'licensing' of university patents to the firm, because the right to use the information contained in the patent is uni-directionally granted to the firm from the university. Information also flows uni-directionally from the university to 'startups', when these are established by (or in collaboration with) the members of the university for the purpose of industrializing the knowledge they created. Thus, they are also included in the lower right-hand cell of the table. Later, we will discuss more about university licensing.

University faculty members may also collaborate with industries in an informal fashion. For instance, the firm may contribute research money to individual faculty members. Behind such 'contributions', there is often a tacit understanding that the firm will have the first access to research outcome; hence, it may resemble commissioned research. The difference is that research theme is specified in the contract in the case of commissioned research while it is not so in the case of contributions, and the firm will not have an exclusive right in the latter. In contributions, bi-directional interaction between the firm and the university scientist is not a rule; hence, it is put in the upper right-hand cell of the table.

Also in the upper right-hand side is the case of 'company researchers dispatched to university laboratories' to make research with the guidance of university members. Again, the information flow is considered basically uni-directional from the university to the firm.

Firms may also 'consult' with university members on technological or managerial issues. The consultation contract is usually made with individual faculty members and not the university as a whole. Consulting involves exchanges of information between the two parties; hence, it is in the upper left-hand cell of the table. The relationship becomes more official when university members 'participate' in the company on a part-time basis as, for instance, its director or technological supervisor. Again, the contract is signed not by the university but by individual faculties, which is why it is also in the upper left-hand cell.

These various forms of UI collaborations are now actively pursued in every science-based industry but particularly in the field of biotechnology.

5. University-Industry Collaborations Viewed Historically

By no means, UI collaborations are a recent phenomenon.

5.1. Pasteur's Quadrant

Stokes (1997) criticized the view that "quest for fundamental understanding" and "considerations of use" are the contrary motivations for scientific research and instead argued that they should be viewed as indicating two different aspects. He thus proposed to place different types of research in a two-dimensional plane as shown in Figure 1. In the upper left-hand quadrant is pure basic research, that is, the type of research "that is guided solely by the quest for understanding without thought of practical use" (*ibid*, 73). He called it "Bohr's quadrant", following Niels Bohr's quest of a model atomic structure. In the quadrant diagonally opposite to Bohr's quadrant is the type of research "that is guided solely by applied goals without seeking a more general understanding of the phenomena of a scientific field" (*ibid*, 74), which he called "Edison's quadrant" for the reason probably apparent to any reader. These two quadrants follow the conventional wisdom of separating R and D in the usual R&D statistics following the Frascati Manual (OECD, 2002).

Stokes, however, argued that "the annals of research are replete with examples of work by investigators who were directly influenced both by the quest of general understanding and by considerations of use. Pasteur wanted to understand *and to control* the microbiological processes he discovered. Keynes wanted to understand *and to improve* the workings of modern economies" (*ibid*, 79, emphasis by Stokes). For this reason, he named the first quadrant "Pasteur's quadrant".

It is noteworthy that Stokes had Louis Pasteur (1822-1895), a French biologist in the 19th century, represent this quadrant. Even though the European academic community tended to maintain the Greek tradition of placing superiority on pure science, the notion that science can improve technology and social welfare began to emerge in the 19th century. Pasteur's achievements proved the value of this notion more than anyone else's. No doubt, he contributed to the advancement of pure science, particularly microbiology and chemistry: yet he was strongly motivated to improve the livestock, food, milk, wine, silk and other industries, namely, today's biotechnology industries.

Since the quest for fundamental understanding and the consideration of use coexist in Pasteur's quadrant, and since the first is usually the mission of universities and the latter, that of industries, collaborations of universities and industries are frequent in this quadrant. Pasteur himself spent most of his active years in universities and public laboratories, but frequently collaborated with industries; hence, his was indeed an early example of UI collaborations. That this most famous example of early UI collaborations was in the field of life science and biotechnology, as we call it today, clearly illustrates the importance of UI collaborations in biotechnology.

Pasteur, however, was not the only example of UI collaborations in the 19th century. Murmann (2003) documents how, in Germany in the latter 19th century, alliances and network between universities and industry co-evolved together with the development of dye industry. In pharmaceuticals, Bayer built its own laboratory for academic-style research, hiring Ph. D. chemists. "Contacts with universities were maintained at a very high level and every potential products were immediately patented" (Liebenau, 1984, 333).

5.2. The Case of the United States

Orientation towards industrial uses was more apparent in relatively late-developing countries at the time, particularly the United States. According to Rosenberg and Nelson (1994, 325), "British visitors long sneered at what they perceived as the 'vocationalism' of the nineteenth and early twentieth-century American higher educational system. These educational institutions assumed responsibility for teaching and research in fields such as agriculture and mining, commercial subjects such as accounting, finance, marketing and management, and an ever-widening swath of engineering subjects, civil, mechanical, electrical, chemical, aeronautical, and so on, long before their British counterparts and, in most cases, long before their other European counterparts as well."

The first engineering school, the U. S. Military Academy at West Point, was founded in 1802 and the Massachusetts Institute of Technology (MIT), in 1865. A number of state universities were established after the passage of the Morrill Act in 1862, which allowed the federal government to grant federally-owned lands to states for the purpose of building universities. Many of these universities supplied graduates in response to the needs of the local industry and made research on subjects related to the industry.

The case of the University of Akron, making research in the processing of rubber to support the local rubber industry, is well-known and there are many other similar cases: see Rosenberg and Nelson (1994).

5.3. Japan in the Early Period

A similar move occurred in Japan, another late-developing country in the 19th century. In 1873, only six years after the Meiji Restoration that defeated the Tokugawa Shogunate government and started a modern government, the government founded a technical college called Kogakuryo to supply graduates with technological knowledge. This college would later reorganize and eventually become today's Engineering Department of the University of Tokyo. Hence, the start of this engineering department was only eight years behind that of MIT. Many of the graduates from Kogakuryo and then Tokyo's Engineering Department got leading jobs in industries, the government, and the academics. For instance, one of the first graduates named R. Shida played a pivotal role in establishing the Electric Laboratory, a national research institute which, later in the post-war period, would play important roles in the development of computers.

The faculty and the graduates also collaborated with industries actively. The best case is I. Fujioka who studied electrical engineering at Kogakuryo with a British professor and then became its assistant professor. While teaching at the college, he designed the first domestically-manufactured power generator. Later he quit the college and, after a visit to the US and Europe, established a company named Hakunetsusha in 1890 to produce and sell incandescent light bulbs. This company, later renamed to Tokyo Denki, merged to Shibaura Seisakusho in 1939 to become Toshiba. Hence, one half of today's Toshiba was started as a university startup, if we use the currently fashionable term[8].

Another example can be found in the pharmaceutical industry. When Dainippon Seiyaku (Dainippon Pharmaceutical) was established in 1885 as the first drug-making firm in Japan with government support, there was no one in Japan who had the necessary knowledge on drugs. However, two Japanese had been sent to Germany by

---

[8] For this and other cases for early Japan, see Odagiri and Goto (1996) and Odagiri (1999).

the government to study medicine. Thus, the firm entreated one of them, N. Nagai, to come back and lead the technological side of the business. He agreed and took up the position of the chief technological officer of the firm. At the same time, he became a professor of the just-established Pharmacy Department of the University of Tokyo. This fact indicates a surprising flexibility in the university administration at the time, which unfortunately would be lost in later years as discussed presently. Nagai thus not only contributed to the development of the Japanese pharmaceutical industry but also taught many students who later played important roles in the development of the pharmaceutical industry in Japan.

5.4. Increased Regulation on UI Collaborations

These two cases illustrate that the university system was flexible in the early industrialization period of Japan, namely, the late 19th century to the early 20th century, making it possible for UI collaborations to be actively pursued. Unfortunately, much of this flexibility was gradually lost because of, first, growing criticism that some faculty members spent more time in outside consulting jobs than in teaching; second, the postwar reform of the university system which put more emphasis on uniformity than diversity across universities and departments; third, the regulation placed on the behavior of faculty members of national universities as they came to be regarded as civil servants and thus subject to their code of conduct; and fourth, growing hostility against academic-industry-military complex during the Vietnam War and student movement during the 1960s.

In consequence, it became impossible during the post-war period for a faculty member of national universities to assume a position in private firms (as Nagai did during 1885-1893), and the contract-based UI joint research was infrequent. This fact, however, should not be taken as indicating that UI collaboration in general was inactive in Japan, because collaborations were often made on an informal basis, through consultation, contributions from companies, and so forth. Often, professors and companies maintained close relationship through graduates or through many opportunities in which professors met company managers and researchers. It is therefore inaccurate to conclude merely from quantitative evidences (e.g., the number of UI joint research projects or the number of university patent applications) that UI collaboration was inactive in Japan.

6. Recent Development in Japan

Since the 1990s, the science-based nature of innovation started to be emphasized and the 2001 Science and Technology (S&T) Basic Plan of the Japanese Government stated that "society can enjoy S&T benefit in terms of application to industrial technology, which are generated in publication, accumulation, application of new knowledge. Attaching importance to this process, it is needed to strengthen industrial technology through pursuing R&D systems to create excellent results and promoting closer industry-academia-government collaboration".[9]

6.1. Reforms since 1998

In accordance with the S&T Basic Plan, many policies have been adopted to promote UI collaboration. They are summarized in Table 4.

In my view, the most effective among the policies were those aiming at deregulation, that is, removing the obstacles for UI collaborations discussed above. Regulations on the way universities can expend the money funded by the government were relaxed, and so were the regulations on the conduct of faculty members of national universities. As a result, it became possible for faculty members to assume positions in private companies to provide advices or to help the companies commercialize the technologies they had invented.

Regulations on hiring at national universities were also relaxed, making it easier for them to hire company researchers on a short-term basis, for instance. Accounting rules were made more flexible and it became possible for national universities and laboratories to let their property to technology licensing offices (TLOs, later to be discussed in more detail), UI joint research, and university startups. The establishment and activity of TLOs were encouraged, with easier transfer of government patent rights to universities and increased incentives for faculty members to invent and patent.

Furthermore, in 2004, all the national universities were incorporated as independent institutions and, at around the same time, many of the national research institutes were also incorporated. Although these universities and institutions are still financially

---

[9] "Science and Technology Basic Plan (2001-2005)", 2001, pp. 14-15.
< http://www8.cao.go.jp/cstp/english/basic/2nd-BasicPlan_01-05.pdf >.

dependent on the government, they are now legally independent entities; hence, for instance, they can now apply for patents or sign contracts whereas previously it was the government who did. They now have their own assets, which they can let for the purposes of UI collaborations or startups. The faculty members are no longer regarded as civil servants and, now, university administrators have the authority to allow the members to engage in external activities or hire them on flexible conditions.

The newly incorporated universities not only have more freedom to pursue UI collaborations but also a bigger incentive to do so, because now they can keep basically all earnings within themselves and because, in the long-run, the government is expected to become more stringent in allocating funds from the national budget to these universities. As a result, they have become more eager to pursue UI collaborations, by encouraging the faculty members to seek such opportunities and by setting up offices to help them.

6.2. Increase in UI Collaborations

In fact, the number of UI collaborations has been increasing as shown in Table 5. During the 5-year period of 1999-2004, the number of joint research contracts between national universities and industries trebled from 3,129 to 9,378. The number increased even more rapidly in the field of life sciences. As a result, the proportion of life-science-related joint research among all joint research increased from 14 percent to 27 percent.

In the longer run, the increase is even more impressive. Table 6 shows the increase in the number of UI joint research contracts (not including those by private and municipal universities because only national universities et al. were required to report these contracts to the Ministry of Education). On a contract basis, the number of UI joint research was only 56 in 1983 but increased to 5,264 in less than two decades, with an annual growth rate of 29 percent. Both the number of participating universities and the number of contracts per such university increased. Also increased were both the number of participating companies and the number of contracts per such company. That is, not only did more universities and more firms start to perform UI joint research projects, but also many of them started to perform a larger number of them.

The bottom half of Table 6 shows that the rate of increase was most prominent in the pharmaceuticals and cosmetics industry among the five most active industries. The electrical equipment industry has been most active in UI joint research throughout the period, but the pharmaceuticals and cosmetics industry has shown a more rapid increase in the number of cases. Thus, both Tables 5 and 6 indicate that UI collaborations have been increasing and, moreover, the share of biotech-related UI collaborations has been increasing. With biotechnology being in Pasteur's quadrant, active UI collaborations are indispensable for its development and the two tables confirm that such activity has been in fact intensifying in Japan.

UI joint research in these statistics is defined as the cases in which "universities et al. and companies et al. jointly perform research and development, and the expenses are paid by the relevant companies et al. They exclude joint research for which no expense is to be paid, contributions from companies et al., and subsidies from the government."[10] In addition, universities collaborate with companies in various other ways as discussed earlier. The trend on some of these other forms of UI collaborations is also shown in Table 5.

"Commissioned research" is the case in which "with commission from the government or private companies et al., chiefly universities et al. perform research and development solely. It excludes contributions from companies et al. and subsidies from the government et al. It also excludes clinical research and pathological testing."[11] As shown in Table 5, the number of commissioned research contracts was larger than that of joint research contracts in 1999 but, with a faster increase in the latter, joint research contracts became more numerous after 2002. Yet, in terms of the funds received, commissioned research overwhelmed joint research by the factor of 3.5 even in 2004. It is thus suggested that, on average, commissioned research tends to involve a larger amount of research funds.

According to the *Report on the Survey of Research and Development* (Ministry of Internal Affairs and Communications), universities expended 3263 billion yen for R&D in 2003, of which approximately 163 billion yen was extramurally financed from private companies et al. as defined in the notes to Table 6. This figure roughly agrees with the figures in Table 6, because the sum of research funds for joint research and

---

[10] The author's translation from the Ministry of Education, "Heisei 16 Nendo Daigaku-tou ni Okeru Sangaku Renkei-tou Jisshi Joukyo Houkokusho".
[11] Same as in the previous footnote.

commissioned research for all universities et al. in 2003 together with the amount of contributions to national universities et al. in the same year amounts to 163 billion yen[12]. Although the increase of these research funds is impressive, the amount itself is modest. Compare, for instance, to 682 billion yen that just a single company, Toyota, expended for R&D in the same year.

Contributions to national universities have been made mostly by companies to support the research of faculty members. In return, these faculty members may provide scientific advices to the companies and have them patent the inventions. With national universities being basically financed by the government, they seldom received non-R&D-related contributions from the private sector[13]. Hence, most of the contributions shown in Table 5 are research funds contributed by industries. In 1999, it was larger than the funds for commissioned research or joint research; however, by 2003, research funds for commissioned research increased more rapidly and became larger than contributions. In fact, if we go back further to the early 1990s, the funds for joint research and commissioned research was less than 10 billion yen while the amount of contributions was around 50 billion yen[14]. Clearly, a shift occurred from contributions, an informal form of UI collaboration, to formal ones, that is, commissioned research and joint research. As we have argued, because of restrictions placed on national universities, a large part of UI collaborations in Japan used to be of informal forms. However, in response to reforms since around 2000 as shown in Table 4, companies started to collaborate with universities in a more formal fashion.

This shift from contributions to more formal forms of collaborations was also confirmed by R&D managers of several companies. In my interviews, they told that, even though faculty members tend to prefer contributions because of the ease and flexibility in the use of the money, their companies are now using more contract-based joint research and commissioned research arrangements in place of contributions because, with contributions, the obligation of the researcher and the ownership of the

---

[12] This figure does not include contributions to private universities. It appears reasonable to assume that the major part of these contributions are made for general university purposes and unrelated to UI research collaborations

[13] However, the situation has significantly changed since the incorporation of national universities in 2004. Now, they are increasing efforts to raise contributions for general purposes.

[14] NISTEP (2005b).

outcome tend to become ambiguous. Apparently, this strategic shift has also occurred because of growing recognition of the importance of intellectual property rights.

6.3. Universities as a Hub of Network

This rapid increase in contract-based UI collaborations by no means implies that informal UI collaborations and information exchanges through scientific commons have become unimportant. Consulting by faculty members to companies is frequent, though no statistics is available. Faculty members' assuming directorship in companies has been prohibited for a long time at national universities as discussed in the previous section. However, since its deregulation as shown in Table 4, many faculty members started to take such positions. In March 2004, 270 cases were reported to the Ministry of Education of the faculty members of national universities taking the positions of directorship in companies, mostly those established for the purpose of commercializing their inventions. Such report is no longer mandatory because of the now independent status of former national universities; hence, no recent figure is available.

The importance of informal UI collaboration has been also documented in two survey studies cited in Section 3 -- the Carnegie-Mellon Survey (Cohen, Nelson, and Walsh, 2002) and the NISTEP Survey (Goto and Nagata, 1996, 1997). The asked each of 593 (Japan) or 1229 (USA) manufacturing firms to evaluate on a four-point Likert scale the importance of each of ten possible sources of information on the R&D activities of universities or government R&D institutes. The percentage that the firms evaluated the source as "very important" or "modestly important" was highest with "publications and reports", reaching 76 percent in Japan and 41 percent in the US. It is followed in Japan by "meetings or conferences" (73%), "patents" (57%), and "informal interaction" (55%). Except for patents, they are all informal collaborations (including information exchanges through scientific commons) as defined in Table 3 and are considered to be more important than "contract research" (49%) and "R&D cooperation and joint ventures" (39%).

A similar tendency is also evident in the US: in addition to "publications and reports", "informal interaction" (36%) "meetings or conferences" (34%) and "consulting" (32%) were considered more important than "contract research" (21%), "R&D cooperation and joint research" (18%), and "patents" (18%). We may therefore conclude that, as a channel of information from public research, the most important is the access to scientific commons by means of publications and conferences, followed by informal interaction and consultation with members of universities and public laboratories. Comparatively, contract-based UI collaborations are less important.

Interestingly, Japanese companies evaluated these sources of public research as more important than US companies, except consultation. Of course, because survey results may be affected by linguistic and cultural differences across countries, such international comparison has to be made with caution. None the less, it still appears reasonable to assume that the results indicate that UI collaborations are in fact as important in Japan, if not more so, as in the US, particularly because the researchers of these surveys in Japan and the US collaborated to make sure that each question will have the same meaning to Japanese and American managers. The result also agrees with our earlier argument that traditionally Japanese firms have been active in pursuing collaborations with universities and public laboratories. What is rather surprising about the survey results is that Japanese managers gave higher evaluation even to contract-based collaborations, particularly because the survey was conducted in 1994, several years before Japan adopted most of the policies to promote UI collaborations.

Industry-wise, we have earlier shown that firms most highly value the contributions of both informal and formal collaborations in the pharmaceutical industry, the foremost user of biotechnology. Even in this most science-based industry, the surveys revealed that the open means of access to scientific commons, namely publications and conferences, is considered most important, followed by informal collaborations and then formal ones: see the survey results cited above.

The importance of informal UI collaborations has been also documented in several other studies. When Agrawal and Henderson (2002) asked 236 members of the Mechanical Engineering Department and the Electrical Engineering and Computer Science Department of MIT to "estimate the portion of the influence your research has had on industry activities, including research, development, and production that was transmitted through each of" eight channels similar to those raised in the Carnegie-Mellon Survey, the average percentage was highest with consulting (25.1%), followed by publications (18.5%), and recruiting/hiring (16.8%). These percentages were higher than those for research collaborations (12.1%) and patents and licenses (6.6%). That is, company managers (to whom the Carnegie-Mellon Survey asked) and university professors (to whom Agrawal and Henderson asked) agree that open knowledge diffusion and informal collaborations have been playing more important roles in UI collaborations than formal, contract-based ones.

As regards biotechnology, confining to the area of tissue engineering technology, Murray (2002) identified two researchers as "focal scientists" because jointly they invented one of the earliest and most important patents. Of the total 76 patents related to this technology, these focal scientists invented 12 (16%) and, of the total 158 papers, they wrote 50 (32%). These patents and papers also involved 11 other co-inventors (for patents) and 79 co-authors (for papers). The two focal scientists, in addition, played central roles through consulting, advisory board membership, and the placement of their graduates in academic and industrial positions. There were two distinctive "networks" -- one predominantly the community of science and the other more mixed between the institutions of science and technology. These were inter-mingled through the activities of the focal scientists. Thus, "we might think of co-publication and cross-citation as the tip of the iceberg" (Murray, 2002, 1401).

Liebeskind et al. (1996) studied the papers published by researchers of US biotech firms and found that, even though the majority of these papers were co-authored with outside researchers including university members, few of them were co-authored with the members of organizations with which their firms had contractual relationship, such as joint research contracts.

These results all indicate that universities and professors function as the hubs of networks in which informal information exchanges and consultation are made more frequently than contract-based collaborations. Focal scientists or star scientists, regarded as such because of their numerous and/or influential publications or intentions, are typical examples of such hubs. Darby, Zucker, and their collaborators found that, both in Japan and the US, biotech startup activities are more frequent in the areas in which star scientists are present, and the market value of biotech firm tends to be higher if the firm had been collaborating with star scientists (Zucker and Darby, 1995; Darby and Zucker, 1996; Darby, Qiao, and Zucker, 1999; Zucker and Darby, 2001; and Zucker, Darby, and Armstrong, 2002).

Several reasons explain why universities should function as the hubs of networks. First, as the major contributors to scientific commons, universities attract many individuals and firms seeking new knowledge and advices. Second, as an extension of the connections graduates maintain with professors, the firms recruiting these graduates are likely to establish relationships with the universities. Third, since universities seek long-term reputation than short-term profits, firms collaborating with universities need to worry less about being betrayed from the partners than when collaborating with other firms. Fourth, it is essential for professors to maintain reputation because, without such reputation, they will have difficulty in gaining information or research material from other researchers, in recruiting research collaborators, or in maintaining good relationship within the university and the society. Hence, opportunistic behavior is less likely and the relationship is expected to be long-lasting, fostering the formation of networks in which universities and professors, consciously or unconsciously, act as their hubs. As more people join the network seeking information, the opportunity increases for the members to gain valuable information from others or to find useful partners, raising the value of the network further. This fact explains why such networks are indispensable in science-based industries and why universities have to play important roles there.

7. University Patenting and Licensing

Table 5 also indicated a rapid increase in university patenting. The number of domestic patent applications by national universities increased by more than four times from 220 to 918 in the 5-year period of 1999-2003. It then jumped to 3756 in 2004, apparently because of the incorporations of national universities in April of the year, which made it possible for these universities to become the legal applicants and holders of patents. Licensing income has been also rising.

7.1. Why Universities Should or Should Not Patent

However, a question is: "should universities patent their inventions and earn royalty by licensing the patents?" As has been repeatedly argued, the knowledge created through scientific research at universities should in principle be placed in scientific commons and made available to everyone, which is why such research is financed through public funds. Then, why and when should universities patent their inventions to limit their usage?

The first argument in favor of university patenting emphasizes knowledge diffusion. Since in Japan all patent applications are made public after 18 months of application, patent application, it is argued, fosters the diffusion of invented knowledge, albeit with the lag of 18 months. This argument, however, does not explain why the university should choose patenting over publication to diffuse the invented knowledge, because knowledge should diffuse more widely and more swiftly through publication than patenting. Thus, unless the invented knowledge lacks the academic originality required by academic journals but is sufficiently non-obvious to be patentable, one cannot justify university patenting on the basis of better diffusion.

The second argument is defensive patenting, that is, the argument that the university should patent the invention to preempt private firms because, otherwise, these firms may patent the invention and prevent the university members or the public at large from utilizing the invention. Again, however, this argument does not explain why the university researcher should not publish the invention in journals because, once published, the invented knowledge is placed on public domain and hence cannot be patented by any of the later-comers.

The third and probably most persuasive argument is the incentive effect. Here, two incentive effects need be examined.

One is the incentive effect for the inventor, a common argument used to support the patent system. If the patented invention brings in royalty from licensing or profits from the firm established to commercialize the invention, at least some part of them will be allocated to the professor who invented it. Also, active patenting may be counted as research accomplishment, increasing the chance for pay raise or promotion of the faculty member. These possibilities are expected to provide an incentive for the faculty member to put more effort into research.

One may question, however, if such financial incentive is important for university researchers. According to the questionnaire study conducted by the Ministry of Education in 2003, the proportion of faculty members who replied that their universities use the number of patents as a criterion for research evaluation was 48 percent, far smaller than the similar proportion regarding the number of papers, which was 84 percent[15]. Hence, the incentive effect of patents appears less important than that of papers for university researchers. Also, most university researchers place the pursuit of scientific truth and the reputation from scientific discovery ahead of financial

---

[15] Ministry of Education, Culture, Sports, Science and Technology "Waga Kuni no Kenkyu Katsudo no Jittai ni Kansuru Chousa Houkoku, Heisei 15 Nendo."

rewards.

More important therefore is the incentive effect for a firm to develop a product out of the university invention and market it. When a joint research project with a university produces a patented invention, or when the firm licenses a patented invention from the university, the firm almost always needs to invest further in order to develop a commercially viable product out of the invented technology and to build production facilities and market the product. To recover the cost of this investment and make profits, the firm would require the technology to be protected by patent so that any competition would be preempted. That is, unless the university invention is patented, no firm will have an incentive to invest in its commercialization and hence the product will not reach consumers. This incentive effect of university patenting is particularly important in pharmaceuticals because the process of pharmaceutical development after the original invention involves clinical and other tests, which is vastly costly and takes a long time. Hence, for pharmaceutical firms to invest in the development, it is essential that the invented drug is protected by patent.

This incentive effect, in my opinion, gives the most prominent reason why universities should patent. However, the very fact that the patent guarantees monopoly profits to the developing firm implies that consumers have to pay a high monopoly price, in addition to taxes, which is used to support university research. Consumers, therefore, may ask why they have to pay both taxes and high prices. Is it reasonable that universities receive public research funds and also earn licensing income from inventions supported by these public funds?

For this reason, it has been considered for a long time that patents out of publicly financed research should belong to the state. But, then, universities and university researchers would not care to bear the burden of preparing patent applications. The consequence has been that university inventions were rarely patented, thereby lacking incentive for firms to commercialize the inventions.

7.2. Policies on University Patenting in Japan

In Japanese national universities, professors were required to report patentable inventions to the university's Invention Committee. If the research was financed publicly, the patent right belonged to the state. If, on the other hand, the research was financed by contributions from the private sector, the Committee usually decided that the inventor should have the patent right. In many of these cases, the inventing professor handed the patent right over to the contributing firms. Thus, among approximately 24,000 patent applications, for which about 17,000 members of 34 major Japanese universities are listed as inventors, 69 percent were applied by private firms alone and 18 percent, jointly by firms and professors. Only 2 percent were applied by universities and 3 percent, by Japan Science and Technology Agency (JST), a government agency that manages state-owned patents. The remaining 21 percent were applied by individuals, of which most were presumably the inventing professors (NISTEP, 2005b).

In 1999, the Industrial Revitalization Law passed the Diet. It is often dubbed the Japanese Bayh-Dole Act because, like the US Bayh-Dole Act, it allowed the state not to acquire patent rights from inventors making research with government funds. In the US, after the passage of the Bayh-Dole Act in 1980, patent applications by universities are known to have significantly increased (Mowery et al., 2004). Similarly, as already shown in Table 5, the number of university patent applications increased in Japan after 1999 and, together with the incorporation of national universities in April 2004, the number jumped to 3,756 by 2004. Again similarly to the US, about a third of these applications were made in the field of life sciences and biotechnology. It is likely that this increase in the number of university patents has been achieved at the sacrifice of the average quality of patents as found by Henderson et al. (1998) in the US, but we still do not have sufficient evidence to confirm this conjecture.

Licensing of university patents has been also encouraged with the Law for Promoting University-Industry Technology Transfer (usually called the TLO Act) in 1998. Following the passage of this law, a number of universities, including almost all the major ones, established technology licensing organizations (TLOs), which numbered 41 by 2005. Unlike similar offices in the US (called technology licensing offices, technology transfer offices, offices of technology transfer, and such), which are usually the divisions within universities, it is more common in Japan that TLOs are established as independent firms, with shares owned by faculty members and others. This is because they were established before the incorporation of national universities and hence, if established within universities, they were subject to various regulations on government offices. While the majority of them have a one-to-one relationship with specific universities, some TLOs handle patenting and licensing businesses of several universities in the local area.

Table 5 has shown that licensing income of national universities has been increasing rapidly since 1999. Many of these licensing contracts are now handled by TLOs. In 2005, these TLOs made 1,054 patent applications domestically and 681 abroad and their licensing income was 837 million yen (about 7.6 million US dollars).[16] It is still modest compared to the license income of 1,385 million dollars in the US.[17]

Even in the US, not all the TLOs are profitable and some survive only with the support of the university (Carlsson and Fridh, 2002). Japanese TLOs are having even more difficulties, because of the much smaller licensing income and because of its independent status. Thus, many TLOs are surviving with membership fees paid by member companies who, in return, are offered the privilege of priority access to university inventions. However, many companies expressed the opinion that, even though each membership fee may be modest, they need to join a number of TLO memberships to cover the universities of their interest and the membership fees add up to a significant amount. Compared to this cost, they seem to feel that the merit of priority access is insufficient.

As listed in Table 4, several policies have been already taken to help the activities of TLOs, such as subsidies and reduced patent fees. It seems that still more measures are needed to secure their financial positions.

8. Summary and Conclusion

This paper aimed to survey the discussions on the role of universities in supporting scientific commons and in their collaboration with industries, and to discuss the present situation, the changes, and the policies in Japan, with reference mostly to life sciences and biotechnology.

We started by arguing that scientific development can be achieved only when scientific discoveries are placed on 'scientific commons', so that every scientist can test them and use them to further their own scientific quests. The major contributor to scientific commons is (and should be) universities, because teaching and research are

---

[16] Ministry of Economy, Trade and Industry (http://www.meti.go.jp/policy/innovation_corp/top-page.htm).

[17] Association of University Technology Managers, "AUTM Licensing Survey: FY2004."

complementary in many respects. Universities certainly played critical roles in the development of life sciences and biotechnology, and this development, in turn, necessitated reorganization of universities to foster research and teaching in the new fields. Comparing the cases of MIT and three Japanese universities, we argued that Japanese universities were lagging in such reorganization.

Science generated by universities and others has always contributed to industrial innovation. Such contribution has been increasing lately and, among various fields, it is particularly strong in biotechnology and pharmaceuticals. This fact has been confirmed both in Japan and the US through many studies using patent data or surveys to firms.

Besides open access to science via scientific commons, firms often seek a closed relationship with the university. Such relationship is called university-industry (UI) collaborations and pursued in various forms. UI collaborations were historically active in Japan but, with increasing regulation particularly after the war, they became to be made more on informal basis. Since the latter half of the 1990s, however, Japan has adopted many policies to eliminate such regulation and promote UI collaborations, and the incorporation of former national universities in 2004 accelerated this trend. The results were increasing cases of contracts of UI joint research and commissioned research, as well as increasing cases of faculty members taking positions in companies, and university startups. Still, many evidences indicate that informal collaborations and information exchanges through scientific commons continue to be more frequent means of UI collaborations than contract-based collaborations. In other words, universities function as a hub of networks involving both academics and industries.

University patenting and licensing have also increased. In Japan, the patent right for university inventions made with government fund used to belong to the state whereas, if the research was made with contributions from the private sector, the faculty members were usually allowed to retain the patent right. Consequently, most of the inventions made by professors used to be patented by firms who contributed the fund to them. The passage of the Japanese Bayh-Dole Act in 1999 and the 2004 incorporation of national universities significantly changed the conditions and the number of patent applications by universities jumped in 2004. Many TLOs (technology licensing organizations) were established and the licensing income of the universities has also increased, even if it is still quite modest compared to US universities.

In principle, university patenting makes the use of scientific and technological knowledge exclusive and, hence, conflicts with the need to maintain scientific commons. One can nevertheless argue that such patenting can enhance social welfare if, without patent, firms lack incentive to invest in developing a product out of the university invention and commercializing it. This condition is most likely to hold in the case of pharmaceutical R&D because of the long and costly process of pre-clinical and clinical tests.

In conclusion, Japan has been making progress in fostering university-industry collaborations, so that the industry can benefit from university research, particularly in such science-based fields as biotechnology and pharmaceuticals. Still, at least compared to the US, there appears to be a room for improvement and catch-up. At the same time, one should be aware that excessive promotion of universities' making exclusive collaboration with industry or patenting their inventions is against the *raison d'etre* of universities, which is to enrich scientific commons and thereby promote scientific progress. Particularly because scientific discoveries are cumulative, that is, discoveries are made on the basis of scientific knowledge available at the time, a naïve belief in exclusive university-industry cooperation and university patenting can actually deter scientific and technological progress. The balance between open science and exclusion has always been a big issue in the design of an academic system and a patent system. It is, we believe, a particularly acute one in life sciences and biotechnology.

References

Agrawal, Ajay and Henderson, Rebecca (2002) "Putting Patents in Context: Exploring Knowledge Transfer from MIT," *Management Science*, 48, 44-60.

Branstetter, Lee (2004) "Is Academic Science Driving a Surge in Industrial Innovation?: Evidence from Patent Citations," Papers presented at the NISTEP Research Seminar, "R&D Strategy and Science and Technology Policy", Research Material No. 104, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

Branstetter, Lee and Kwon Hyeog Ug (2004) "The Restructuring of Japanese Research and Development; The Increasing Impact of Science on Japanese R&D," RIETI Discussion Paper, 04-E-021, Research Institute of Economy, Trade and Industry.

Carlsson, Bo and Fridh, Ann-Charlotte (2002) "Technology Transfer in United States Universities: A Survey and Statistical Analysis," 12, 199-232.

Cohen, Wesley. M.: Nelson, Richard. R.; and Walsh, John. P. (2000) "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," *NBER Working Paper,* No. 7552, National Bureau of Economic Research.

Cohen, Wesley M.; Nelson, Richard R.; and Walsh, John P. (2002) "Links and Impacts: The Influence of Public Research on Industrial R&D," *Management Science*, 48, 1-23.

Crick, Francis (1988) *What Mad Pursuit*. New York: Basic Books.

Darby, Michael R.: Liu, Qiao; and Zucker, Lynne G. (1999) "Stakes and Stars: The Effect of Intellectual Human Capital on the Level and Variability of High-Tech Firms' Market Values," *NBER Working Paper*, No. 7201, National Bureau of Economic Research.

Darby, Michael R. and Zucker, Lynne G. (1996) "Star Scientists, Institutions, and the Entry of Japanese Biotechnology Enterprises," *NBER Working Paper*, No. 5795, National Bureau of Economic Research.

Dasgupta, Partha and David, Paul A. (1994) "Towards a New Economics of Science," *Research Policy*, 23, 487-521.

Goto, Akira and Nagata, Akira (1996) 'Sabei Deta ni Yoru Inobeshon Purosesu no Kenkyu' [A Study of Innovation Process by Survey Data], unpublished report, National Institute of Science and Technology Policy, Ministry of Education, Science and Culture.

Goto, Akira and Nagata, Akira (1997) "Inobeshon no Senyu Kanousei to Gijutsu Kikai: Sabei Deta ni Yoru Nichibei Hikaku Kenkyu" [Technological Opportunities and Appropriating the Returns from Innovation: Comparison of Survey Results from Japan and the U.S.], NISTEP Report No. 48, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

Hayashi, Yujiro and Yamada, Keiichi [eds.] (1975) *Kagaku no Raifu Saikuru* [Life Cycle of Science]. Tokyo: Chuo Koron Sha.

Henderson, Rebecca; Jaffe, Adam B.; and Trajtenberg, Manuel (1998) "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988," *Review of Economics and Statistics*, 80, 119-127.

Kikumoto, Hitoshi and Shinya, Yukiko (2005) "Daigaku-to Hatsu Bencha ni Kansuru Chousa Kekka ni Tsuite: Dai 1 Ji Chosa no Happyo" [Reports on the Study on University Startups: The First-Stage Report], Tsukuba Industrial Liaison and Cooperative Research Center, University of Tsukuba.

Kosai, Yoshio and Fujino, Masahiko (1999) "Kakki-teki na Shin-yaku no Kenkyu Kaihatsu" [Research and Development on Drastic New Drugs], *Kenkyu Gijutsu Keikaku*, 14、229-234。

Kroll, Peter; Ault, Grace; and Narin, Francis (1998) "Tracing the Influence of Basic Scientific Research on Biotechnology Patents: A Case Study of Signal Transduction and Transcriptional Regulation," *Patent World*, 38-46.

Liebenau, Jonathan (1984) "Industrial R&D in Pharmaceutical Firms in the Early Twentieth Century," *Business History*, 26, 329-346.

Liebeskind, Julia Porter; Oliver, Amalya Lumerman; Zucker, Lynne; and Brewer, Marilynn (1996) "Social Networks, Learning, and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms," *Organization Science*, 7, 428-443.

McMillan, G. Steven; Narin, Francis; and Deeds, David L. (2000) "An Analysis of the Critical Role of Public Science in Innovation: The Case of Biotechnology," *Research Policy*, 29, 1-8.

Mowery, David; Nelson, Richard R.; Sampat, Bhaven N.; and Ziedonis, Arvids A. (2004) *Ivory Tower and Industrial Innovation*. Stanford: Stanford University Press.

Murmann, Johann Peter (2003) *Knowledge and Competitive Advantage*. Cambridge: Cambridge University Press.

Murray, Fiona (2002) "Innovation as Co-Evolution of Scientific and Technological Networks: Exploring Tissue Engineering," *Research Policy*, 31, 1389-1403.

Narin, Francis; Hamilton, Kimberly S.; and Olivastro, Dominic (1997) "The Increasing Linkage between U.S. Technology and Public Science," *Research Policy*, 26, 317-330.

Nelson, Richard R. (2004) "The Market Economy, and the Scientific Commons," *Research Policy*, 33, 455-471.

NISTEP (National Institute of Science and Technology Policy) (2005a) "Sangaku Renkei, 1983-2001" [University-Industry Research Cooperation: A Status Report, 1983-2001], Research Material-96, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

NISTEP (National Institute of Science and Technology Policy) (2005a) "Heisei 16 Nen-ban Kagaku Gijutsu Shihyo: Deta Shu, 2005 Nen Kaitei Ban" [Science and Technology Indicators: 2004, Data Updated in 2005], Research Material-117, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

NISTEP (National Institute of Science and Technology Policy) (2005b) "Kihon Keikaku no Tassei Koka no Hyouka no Tame no Chousa: Shuyo na Sangakuka Renkei, Chiiki Inobeshon Shinko no Tassei Koka oyobi Mondaiten" [Study for Evaluating the Achievements of the S&T Basic Plan in Japan: Achievements and Issues of Major Policies for Industry-Academia-Government Cooperation and Regional Innovation], NISTEP Report No. 87, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

Odagiri, Hiroyuki (1999) "University-Industry Collaborations in Japan: Facts and Interpretations," in Lewis M. Branscomb, Fumio Kodama, and Richard Florida [eds.] *Industrializing Knowledge: University Industry Linkages in Japan and the United States*. Cambridge. Mass: The MIT Press, 252-265.

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

Odagiri, Hiroyuki; Nakamura, Yoshiaki; and Shibuya, Minoru (1997) "Research Consortium as a Vehicle for Basic Research: The Case of a Fifth Generation Computer Project in Japan," *Research Policy*, 26, 191-207.

OECD (Organization for Economic Cooperation and Development) (2002) *Frascati Manual 2002*.

Karl R. Popper (1959) *The Logic of Scientific Discovery.* London: Hutchinson (Translated from *Ligik der Forschung*. 1934)

Rosenberg, Nathan and Nelson, Richard R. (1994) "American Universities and Technical Advance in Industry," *Research Policy*, 23, 323-348.

Stokes, Donald E. (1997) *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, D.C.: Brookings Institution Press.

Toole, Andrew A. (2000) "The Impact of Public Basic Research on Industrial Innovation: Evidence from the Pharmaceutical Industry," SIEPR Discussion Paper, No. 00-07, Stanford University.

Ward, Michael R. and Dranove, David (1995) "The Vertical Chain of Research and Development in the Pharmaceutical Industry," *Economic Inquiry*, 33, 70-87.

Watson, James D. (1968) *The Double Helix*. New York: Atheneum.

Watson, James D. and Berry, Andrew (2003) *DNA: The Secret of Love*. New York: Knopf.

Wilkins, Maurice (2003) *The Third Man of the Double Helix*. Oxford: Oxford University Press.

Zucker, Lynne G. and Darby, Michael R. (1995) "Virtuous Circles of Productivity: Star Bioscientists and the Institutional Transformation of Industry," *NBER Working Paper*, No. 5342, , National Bureau of Economic Research.

Zucker, Lynne G. and Darby, Michael R. (2001) "Capturing Technological Opportunity via Japan's Star Scientists: Evidence from Japanese Firms' Biotech Patents and Products," *Journal of Technology Transfer*, 26, 37-58.

Zucker, Lynne G.; Darby, Michael R.; and Armstrong, Jeff S. (2002) "Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology," *Management Science*, 48, 138-153.

Table 1. Changes in Teaching and Research Organizations of Three Japanese Universities in Relation to Life Sciences and Biotechnology

University	Year	Events
University of Tokyo		
	1967	Institute for Infectious Diseases renamed as the Institute of Medical Science
	1991	Human Genome Center established within the Institute of Medical Science
	1993	The School of Science reorganized to have 12 Departments: Information, Science, Physics, Astronomy, Earth and Planetary Physics, Chemistry, Biophysics and Biochemistry, Zoology, Plant Science, Anthropology, Geology, Mineralogy, and Geography
	1993	Institute of Applied Microbiology renamed as the Institute of Molecular and Cellular Bioscience
	1993	Biotechnology Research Center established
	1994	The School of Agricultural Sciences renamed as the School of Agricultural and Life Sciences, which, in 2000, was reorganized to have 12 Departments including those of Applied Biological Chemistry, Biological and Environmental Engineering, Biomaterial Sciences, and Biotechnology
	1995	Within the School of Science, the Departments of Zoology, Plant Sciences, and Anthropology were unified as the Department of Biological Sciences
	1997	Within the School of Medicine, three Departments (First Basic Medicine, Second Basic Medicine, and Second Clinical Medicine) were abolished and, instead, four were established: Molecular Cell Biology, Functional Biology, Radiology and Biomedical Engineering, and Neuroscience
	1997	The School of Pharmaceutical Sciences were reformed into three Departments: Pharmaceutical Chemistry, Pharmaceutical Biology, and Pharmaceutical Technology
Tokyo Institute of Technology		
	1989	Gene Research Center established
	1990	School of Bioscience and Biotechnology established with 4 Departments, absorbing 2 Departments established in 1986 and 1988 within the School of Science and 2 Departments established also in 1986 and 1988 within the School of Engineering
	1991	Graduate School of Bioscience and Biotechnology established with 2 Departments: Bioscience and Biotechnology
	1999	Graduate School of Bioscience and Biotechnology reorganized to add 3 Departments: Life Science, Biological Information, and Biomolecular
	1999	School of Bioscience and Biotechnology reorganized to 2 Departments: Bioscience and Biotechnology
	2000	Within the Graduate School of Bioscience and Biotechnology, the Departments of Bioscience and Biotechnology were reorganized to the Departments of Biological Sciences and Bioengineering
	2003	Gene Research Center, Researcch Center for Experimental Biology, and Radioisotope Research Center were integrated into the Center for Biological Resouces and Informatics
University of Tsukuba		
	1973	Founded.
	1975	College of Biological Sciences established
	1986	Gene Research Center started
	1993	Master's Program in Biosystem Studies established
	1994	College of Agricultural Sciences renamed as the College of Agrobiological Resources
	2001	Graduate School of Life and Environmental Sciences established by integrating 3 Graduate Schools of Biological Sciences, Agricultural Sciences, and Earth Sciences

Source: The author's compilation from respective homepages.

Table 2. Science Linkage in Japan and the USA, 2003

	All Fields	By Seven Major Fields						
		Biology/ Microbiology (1)	Organic	Inorganic	Medicine/ veterinary medicine (2)	Agriculture, forestry, fishery (3)	Computation/ counting	Basic electronic circuitry
Japan	0.51	7.61	3.73	0.86	1.64	2.11	0.63	0.71
USA	3.28	26.79	17.80	4.18	8.39	5.82	2.00	2.21

(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: CHI Research Inc., "National Technology Indicators Database"

Reproduced from NISTEP (2005a).

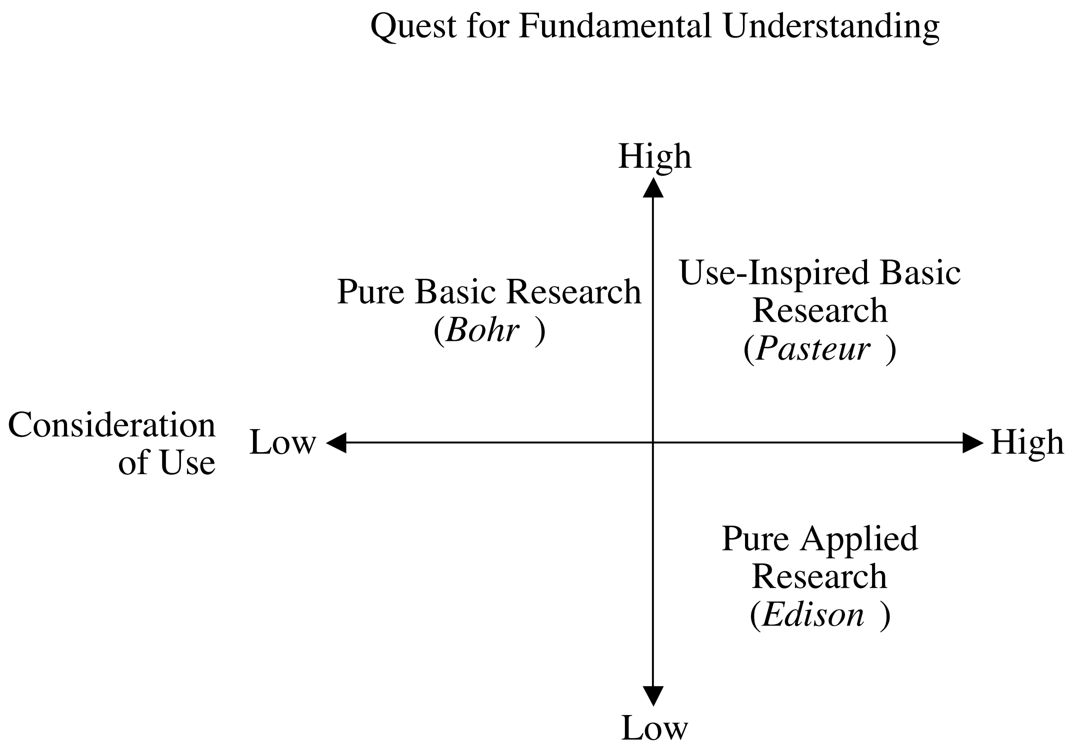
Table 3. Patterns of University-Industry Collaborations

Formality	Flow of information	
	Bi-directional (mutual)	Basically uni-directional
Informal	Consulting Participation (as directors, technological supervisors, etc.)	Contributions Company researchers joining university labs
Formal	Joint research Consortium National project	Commissioned research Licensing University startup

Note: "Formality" refers to the formality of the relationship between the organizations (i.e., universities and firms) and not necessality that of the relationship between the participating individuals.

Figure 1. Quadrant Model of Scientific Research

Research is inspire by:



Source: Modified from Stokes (1997), Figure 3-5.

Table 4. Policies to Promote Collaborations among Universities, Government Research Institutes (GRI), and Industries

Year	Policies
(1) Promotion of Joint Research and Commissioned Research	
1998-2000	Reduction of rents payable by the private sector when constructing R&D facilities on the premises of national universities and GRI
1998	Simplification of accounting rules for joint or commissioned research between national universities and industries
2000	Flexible rules to be adopted in the receipt of research funds from the private sector for joint or commissioned research with national universiteis
2000	Allocation of part of licensing income from government-owned patents to inventors' universities
2001	Liberalization on the salary of part-time researchers in universities engaged in joint or commissioned research
2002	Provision of sample contracts for joint or commissioned research
2002	Tax exemption on income from commissioned research by private universities
2003	Tax exemption on 12% of R&D expenditure of companies paid for joint or commissioned research with universities and GRI
(2) Promotion of Patent Acquisition and Utilization of Research Outcome	
1998-1999	Subsidies to TLOs and reduction of patent fees for applications by TLOs
2000	Abolition of rents for the use of facilities of national universities by TLOs
2000	Reduction of fees for patents applied by university researchers and private universities
2001	Increased delegation of the government's rights to patent to universities et al.
2001	Improved 'grace period' treatment in the patent law
2002	Promotion of TLO's activity to support university startups
2002	Liberalization of national universities' letting their facilities for university startups at their early stages
2002	Setting guidelines on the treatment of tangible research outputs
2003	Deregulation on the compensation to be paid to faculty members of national universities for their inventions
2003	Reduction of rents to be paid by private companies for the use of national university's property to develop or test research outcome of the universities
2003	Deregulation on the use of facility of national universities by private companies for the latter's testing, research, etc., to promote joint or commissioned research
2003	Simplified rules for the delegation to national universities of the nation's patent rights from research commissioned by the government
(3) Promotion of University-Industry Human Relations	
1997-2000	Relaxation of resriction on the faculty members of national universities and the researchers of GRI to assume R&D-related positions in private companies
2000	Relaxation of resriction on the faculty members of national universities and the researchers of GRI to assume positions in TLOs
2000	Relaxation of resriction on the faculty members of national universities and the researchers of GRI to assume directorship of private companies
2002	Clarification of the rules concerning equity acquisitions by faculty members of national universities and the researchers of GRI
2002	Relaxation of resriction on the faculty members of national universities and the researchers of GRI to become legal or management advisors of private companies
2002	Clarification and speeding-up of the process of approving the faculty members of national universities to assume positions in private companies
2002	Delegation of authority from the Minister to university presidents to approve the faculty members of national universities to assume positions in private companies
2003	Relaxation of resriction on the faculty members of national universities and the researchers of GRI to work in private companies in their normal working hours
1997	Liberalization on hiring faculty members of national universities and the researchers of GRI for short terms

(Source) Technology and Research Foundations Sector, Council for Science and Technology, "Shin Jidai no San-Gaku-Kan Renkei no Kouchiku ni Mukete" [Towards the Construction of Industry-University-Government Collaborations in the New Era], 28 April 2003. <http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu8/toushin/03042801.htm> (in Japanese only)

Table 5. University-Industry Collaborations of National Universities, 1999-2004

		National universities et al.[c]							All universities et al.	
		1999	2000	2001	2002	2003	2004	2004/1999 (倍)	2003	2004
Joint Research	No. of contracts (total)	3,129	4,029	5,264	6,767	8,023	9,378	3.00	9,255	10,728
	No. of contracts (life sciences)[a]	439	700	1,117	1,644	2,138	2,509	5.72	n.a.	n.a.
	(life sciences / total, %)	14.0	17.4	21.2	24.3	26.6	26.8			
	Research funds received (100 million ye	65	94	112	158	176	219	3.37	216	264
Commissioned Research[b]	No. of contracts (total)	5,898	6,368	5,701	6,584	6,986	7,827	1.33	13,786	15,236
	No. of contracts (life sciences)[a]	n.a.	n.a.	2,506	2,799	2,978	3,165		n.a.	n.a.
	(life sciences / total, %)			44.0	42.5	42.6	40.4			
	Research funds received (100 million ye	454	509	351	407	610	772	1.70	859	1,012
Contributions	(100 million yen)	460	497	552	579	556	631	1.37	n.a.	n.a.
Patents	No. of domestic applications (total)	220	321	345	496	918	3,756	17.07	1,881	5,085
	No. of domestic applications (life scienc	n.a.	n.a.	n.a.	n.a.	n.a.	1,226			
	(life sciences / total, %)						32.6			
	Licensing income (100 million yen)	191	261	206	252	428	416	2.18	543	543
		All universities et al.								
University startups	No. of firms established	66	135	153	164	194	195	2.95		

Note: (a) Biotechnology until 2000. (b) Commissioned research does not include clinical tests or commissioned tests. (c) "National universities et al." include national universities, graduate universities, junior colleges, technical colleges, and inter-university research institutes. "All universities et al.", in addition, include these universities and colleges established by local governments or the private sector.

Source: Ministry of Education, Culture, Sports, Science and Technology. For startups, Kikumoto and Shinya (2005). Data on "all universities et al." are based on questionnaire surveys and the response rates (%) are 100 (national), 77 (municipal) and 83 (private) for joint research, commissioned research, and patents; and 100 (national), 72 (municipal) and 68 (private) for startups.

Table 6. Trend in the Cases of Joint Research by National Universities et al.

	1983	1990	2001	Ratio 2001/1983	Ratio 2001/1990
No. of participating universities et al. (A)	21	81	139	6.6	1.7
Universities only	16	59	87	5.4	1.5
No. of participating private companies et al. (B)	52	542	2,508	48.2	4.6
Private companies only	50	488	2,151	43.0	4.4
No. of contracts (C)	56	869	5,264	94.0	6.1
No. of participants (D)	59	912	5,316	90.1	5.8
No. of contracts per participating universities et al. (C/A)	2.7	10.7	37.9	14.2	3.5
No. of participants per participating firms (D/B)	1.1	1.7	2.1	1.9	1.3
No. of participants by industry (Top six industries with the largest number of participants in 1983-2001)					
Electrical equipment	15	200	815	54.3	4.1
General machinery	5	74	260	52.0	3.5
Electric power generation	0	54	163		3.0
Construction	4	35	198	49.5	5.7
Pharmaceuticals and cosmetics	3	27	365	121.7	13.5
Other chemicals	4	55	219	54.8	4.0

(Notes) "Universities et al." include national universities, graduate universities, junior colleges, technical colleges, and inter-university research institutes. "Private companies et al." include domestic for-profit companies, special companies, independent administrative institutions, public companies, foundations, corporations, cooperatives, (non-national) public schools and public hospitals, and so forth. "No. of participants" refer to the number of participating private companies et al. A contract may involve more than two participating companies et al., and a company may participate in more than two contracts in which case this company is counted repeatedly. For these reasons, the number of parcipants is greater than the number of contracts.

(Source) NISTEP (2003).