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Characterizing Receiver-Active National System of Innovation

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ABSTRACT

The rise in biomedical research predates the passage of Bayh-Dole Act in the United States. Our measurements of science linkage based on the Japanese patents also show that biotechnology is extremely high in science linkage. We will describe an in-depth case study about how a Japanese sanitary ware company could commercialize a totally new toilet system, by use of scientific findings discovered by university professors. The firm played a more *proactive* role in technology transfer than the role implied by the term of "absorptive capacity." The Japanese national system of innovation has been built to stimulate absorptive capacity functions proactively.

1. INTORDUCTION

Everywhere in the world, governments are seeking to increase the rate of transfer of academic research advances to industry and to facilitate the application of these research advances by domestic firms, with the hope to improve national economic performance in an era of higher unemployment and slower growth in productivity and incomes. Most of these "technology-transfer" initiatives, however, focus on the codification of property rights to individual inventions, rather than the broader matrix of industry-university relationships that span a broad range of activities and outputs.

Mowery and Nelson (Mowery, Nelson, Sampat and Ziedonis, 1999, pp. 269-306), however, suggests that the direct effects of Bayh-Dole on the content of academic research have been modest. The most significant change in the content of research at the three universities (Columbia University, the University of California， and Stanford University)， has been the rise of biomedical research and inventive activity， but Bayh-Dole had nothing to do with this development. Although their evidence suggests little if any change in the content of academic research， the effects of Bayh-Dole on the *marketing* efforts of U.S. universities appear to have been considerable.

In this paper, first of all, we are interested in finding out how the biomedical research is different from other fields of sciences, in terms of university-industry linkages (UIL). We will describe our measurement results of science linkage based on the Japanese patent data base, and show that biotechnology is extremely high in science linkage (number of scientific papers cited in patent), compared to other fields of science. This indicates that the formal UIL might become important if the Japanese industrial structure shifts toward the science-based industry.

Nevertheless，Bayh-Dole was an important catalyst，and among other things，the Act represents the following two views of national innovation system. One view is an application of the "linear model" to science and technology policy, assuming that if basic research results can be purchased by would-be developers, thereby establishing a clear "prospect" for the commercial development of these results, commercial innovation will be accelerated. The other view is that universities support innovation in industry primarily through the production by universities of "deliverables" for commercialization (e.g., patented discoveries). Moreover, the most important channels through which university-industry interaction advances industrial innovation and economic growth, in this view, are the formal channels of patent licensing and in some cases, the formation of university "spin-off" firms. But for most industries, university research aids innovation through its informational outputs, which in turn often reach industrial scientists and engineers through the channels of "open science," such as publications, conference presentations, or the movement of personnel between universities and industry (including the hiring by industry of university graduates).

In their seminal article, Cohen and Levinthal (Cohen and Levinthal, 1990, pp. 128-152) introduced the term "Absorptive Capacity" of a firm, which they defined as "an ability to recognize the value of new information, assimilate it, and apply it to commercial ends." In order to test the importance of this absorptive capacity in the Japanese university-industry linkages, we will describe an in-depth case study about how TOTO Ltd., a Japanese sanitary ware company, could commercialize a toilet system in which the organic compounds are decomposed bio-chemically, therefore, instantly, by use of the unique photo-catalytic properties of titanium dioxide discovered by professors at the University of Tokyo. This development involved as many as three scientific findings published in Nature magazine. More interestingly, the last paper had been co-authored by TOTO researchers, because they discovered that the titanium dioxide has another unique character, i.e., super-hydrophilic property.

Based on this case study, we will find that a firm plays a more *proactive* role in technology transfer than the role implied by the term of "absorptive capacity." Therefore, we will propose the "receiver-active paradigm" of university-industry linkage, the model that successful technology transfer is largely dependent on the active receiving firm rather than the active marketing by the university. When it comes to a national innovation system, our analysis on the receiver-active characteristics of technology transfer suggests that the Japanese national system of innovation has been built to stimulate absorptive capacity functions proactively. Instead of counting the number of TLOs (Technology Licensing Organizations), which is normally the measurement of the system characterized by the sender-active paradigm and by the active marketing of research by universities, our measurements include those of co-authorship of scientific papers and co-application of patents between universities and companies. We will also show how co-publications and co-applications are overlapped and complimented, by analyzing the University of Tokyo compared with the MIT of United States.

Finally, we will try to demonstrate that there exists two distinct types of national innovation system, i.e., receiver-active versus sender-active system. We will conclude that the effectiveness of these two systems are dependent on their several socio-economic factors.

2. MEASURING SCIENCE LINKAGE: SCIENCE-BASED INDUSTRIES

Using the Japanese Patent Date Base, we have measured the science linkages (number of scientific papers cited per patent) for different fields of technologies (Tamada, 2002). Based on these measurements, we can argue that the importance of science and/or universities differs in different industrial sectors, and conclude that we have to be cautious about generalizing the growing importance of university science into every sector of industrial development.

In recent years, there have been a number of analyses that treat patents as an indicator of technological innovation by calculating the number of non-patent references such as academic papers as an indicator of the degree of "science" in such patents -- in other words, the number of papers cited per patent. This indicator is called "science linkage," and although there are limitations to this method, it helps to clarify the influence of science on technology.

Indeed, several studies on the relationship between technological change and science have been conducted using the academic papers cited in the *front* page of US and European patents. By contrast, there is virtually no research on science linkage in patents filed in Japan despite the fact that it is crucial to analyze Japanese patents in order to study the national innovation system in Japan, a country whose per-capita gross domestic product rivals that of the U.S. or Europe. Patents are applied for overseas only when they are related to tradable goods or needed for overseas production, and the benefit exceeds the cost of overseas patent application, which is double or more that of patent application in Japan[1].

In our study, academic papers cited not only on the front page and but also in the main text of Japanese patents were analyzed, which have been virtually overlooked up to now. The study aims to shed light on such matters as the degree of influence science has on patentable technologies, and whether that influence differs according to technological category.

We began by creating a database of Japanese patents using Patent Gazette CD-ROMs. From this data we analyzed gazettes (which list patent applications that the Patent Office screened and found no reason to reject) issued from 1995 to 1999. The data analyzed was restricted to this period because the International Patent Classification (IPC) used to classify the technological categories of the patent gazettes is revised every five years, and the patents issued between 1995 and 1999 are all based on the sixth edition of the IPC.

Next, we created *filtering* programs to find patents in the four technology categories designated as priority areas in the government's "Second Science and Technology Basic Plan" -- biotechnology, information technology, nanotechnology and environmental technology -- and extracted patents in these categories from the database[2]. From the patent sets for the categories of biotechnology, IT, nanotechnology and environmental technology, we extracted 300 patents from each category and 300 patents from the entire patent set (regardless of sector) for comparison purposes via random sampling using pseudo-random numbers. In other words, a total of 300 x 5 (the four priority categories + all categories) = 1,500 patents were included in the sample. Finally, we visually extracted all the other patents and papers cited in the full text of these 1,500 patent samples and analyzed trends within them. Specifically, we read the text files of each of the 1,500 patents, found citations, extracted the cited literature, created a separate file, and classified them into patents and academic papers.

Both in terms of the percentage of sample patents that cited academic papers (the ratio of science-based patents) and the average number of papers cited per patent (science linkage), we discovered a clear trend. From highest to lowest, the patent categories with the greatest science linkage were: biotechnology, nanotechnology, IT and environmental technology (Tamada, 2004, 2005). This trend was unchanged regardless of whether the patents were applied for according to the provisions of the Patent Cooperation Treaty.

We examined the entire text of the sample patents (300 patents in each of the four areas) and counted the number of academic papers cited, all by *visual* observation. We found that biotechnology patents have the largest number of citations (science linkage), followed by those in the nanotechnology, IT and environmental areas, in that order. In the area of biotechnology, a maximum of 111 citations were found per patent, while the average and median number of citations were 11.5 and 6 respectively, with a standard deviation of 14.6. With respect to patents in the nanotechnology area, the largest number of citations per patent was 73; 2.0 on average, 0 at the median, with a standard deviation of 5.8. As to IT patents, the maximum number of citation per patent was 8; 0.32 on average, 0 at the median, with a standard deviation of 0.92. In the environmental area, the number of citations was 9 at the maximum; 0. 26 on average, 0 at the median, with a standard deviation of 1.1., as shown in **Figure 1** for the distribution and in **Table 1** for the average statistics.

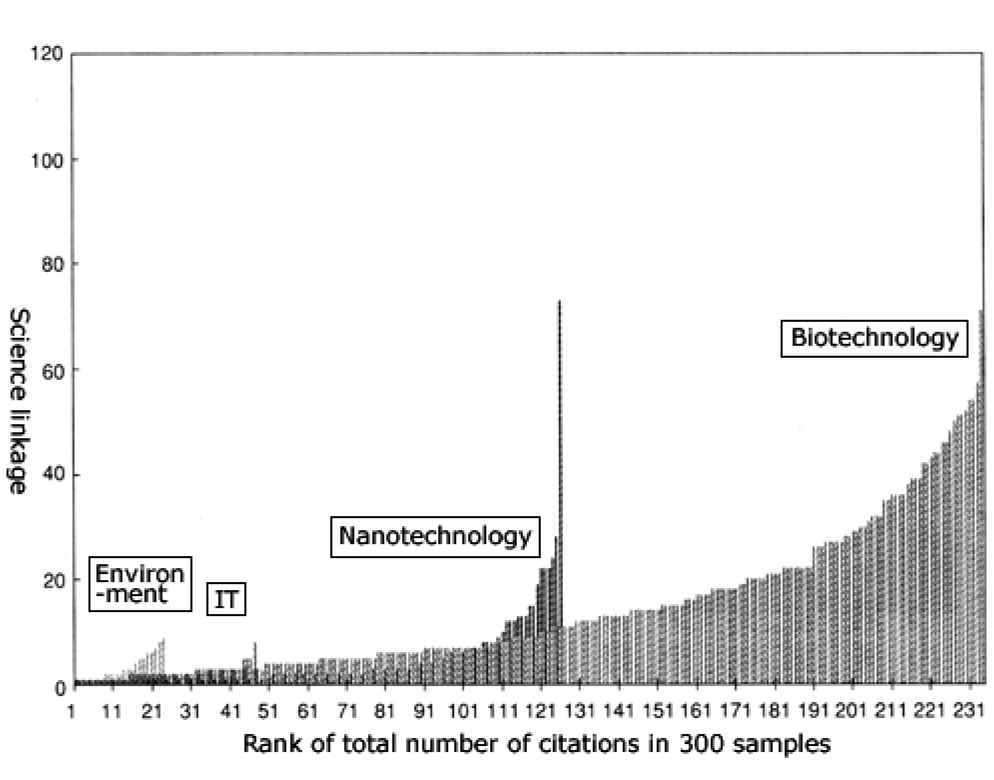


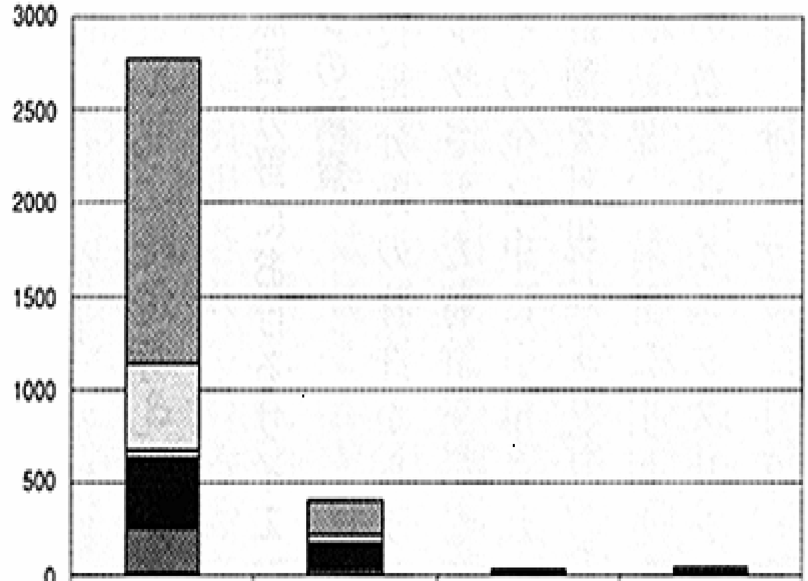
Figure 1: Number of citations per patent by technology area and by rank (excluding those without citations)

Area	cited papers total	per patent	cited patents total	per patent
Random Sample	179	0.6	1,749	5.83
Biotechnology	3,439	11.46	1,102	3.67
Nano-technology	597	1.99	2,125	7.08
IT	95	0.32	927	3.09
Environment	77	0.26	1,193	3.98

Table 1. Science Linkage by Technical Areas
(300 randomly sampled for each 4 areas from Japanese patents)

We collected as many academic papers cited in patents for technologies in the four priority areas as possible. Specifically, we tried to collect those papers cited in the sample patents for our analysis, using the Science Direct database of scientific literature, to which the University of Tokyo subscribes, as well as the collection of volumes at the University of Tokyo libraries. More than 4,000 titles were thus collected and analyzed. Based on the address of the organizations to which the authors of these scientific papers are affiliated.

In the biotechnology area, which demonstrates the greatest degree of science linkage, we examined some 2,800 papers, for which we were able to identify the address of the authors' research institutions. Meanwhile, those based on research activities at universities and national research institutes accounted for 78% of the papers collected for this study, while those based on corporate research represented only 13% (see **Figure 2**).



	Biotechnology	Nanotechnology	IT	Environment
Universities	1636	190	12	22
National research institutes	473	38	0	12
Other public research institutes	40	14	4	1
Corporations	366	130	18	8
Individuals	10	2	1	0
Others	242	30	1	0
Unidentified	10	0	0	0

Figure 2: Type of institutions with which authoring researchers are affiliated

Papers authored by researchers affiliated with universities and public research institutes accounted for 59% of the papers cited in the nanotechnology field, while those written by corporate researchers comprised 33% of the total. Papers authored by corporate researchers accounted for 50% of research papers cited in IT patents, exceeding the 44% written by researchers at universities and public research institutes. This indicates that corporate R&D activities are quite robust in the IT area. Papers authored by researchers affiliated with universities and public research institutes represent 81% of research papers cited in environmental technology patents, with the remaining 19% written by corporate researchers. Such heavy reliance on academic and public-sector research may be characteristic of this particular field of technology[3].

In summary, we discovered that the science linkage indexes among different patent classifications differ significantly from each other. The technologies related to biotechnology were by far the closest to science. It suggests that the process of creating new technology in bio-industry differs from that in other industries. As we will describe in following sections, the informal technology transfer between universities and private sector in Japan looks more efficient than formal one, in many of technology-based industries. However, in the science-based industry, there exist some problems such as de facto preferential treatment to the large firms, disincentive to firms for farther development caused from unclear IP (Intellectual Property) rights and so on (Kneller, 2003). We believe that although informal communication will retain its important roles in the future, Japanese innovation system should be modified from these viewpoints.

3. CASE STUDY: CAPACITY TO ABSORB NEW SCIENCES

Rosenberg suggested that even though the appropriability of the results of basic research is low, it is economically rational for a firm to invest its own capital in basic research because : (i) by being the first to invent the firm can earn greater profits using the results of the basic research (first-mover advantage); basic research results allow the firm's researchers to (ii) determine the best direction for applied research; (iii) evaluate the technology developed as an outcome of applied research; (iv) monitor research conducted outside the firm; and (v) participate in the scientific community comprised of universities and other organizations (Rosenberg, 1990, pp. 165-174).

A case study of TOTO Ltd., a Japanese manufacturer of sanitary wares, provides us an excellent example of how the ability for evaluating outside technologies brought a big business chance to a firm. Up until quite recently, the genetic and molecular mechanism of olfaction had not been scientifically understood. Indeed, the 2004 Nobel Prize in Physiology or Medicine was awarded to Richard Axel and Linda B. Buck, whose landmark paper was published as late as in 1991. They cloned olfactory receptors, showing that they belong to the family of G protein coupled receptors. By analyzing rate DNA, they estimated that there were approximately one thousand different genes for olfactory receptors in the mammalian genome. This research opened the door to the genetic and molecular analysis of the mechanisms of olfaction[4].

A firm's absorptive capacity is not, however, simply the sum of the absorptive capacities of its employees, and it is distinctly organizational. Absorptive capacity refers not only to the acquisition or assimilation of information by an organization but also to the organization's ability to exploit it. In order to understand the sources of a firm's absorptive capacity, U.S. scholars had so far focused their investigations on the structure of communication between the external environment and the organization, including the existence of gatekeepers and their related roles (Allen, 1977). However, as will be described below, our case study about a Japanese manufacturer indicates that the arguments about absorptive capacity should be focused more on *technical* rather than *organizational* aspects.

Since 1978, TOTO had already been developing the key technology of analysis and synthesis of bad smell as the results of their persistent in-house scientific endeavor. There are many kinds of bad smells which accompany with human livelihood such as toilette, sweat, tobacco or garbage. However, odors are invisible and the sensitivity of smells varies greatly among individuals and it depends on acclimation. Odors are usually described in six levels of human sensory evaluation as shown in **Table 2**.

level	Human sensory evaluation
0	Odor free
1	Faint odor（sensory threshold）
2	Detectable odor（identification threshold）
3	Apprehensible odor
4	Strong odor
5	Overpowering odor

Table 2: Sensory evaluation of odor

In order to be treated as the research target, however, they should be measured quantitatively and regenerated repeatedly. The sensory evaluation levels of bad smells depend on the concentration of causative agents. The relationship were formulated as; $Y = A \cdot \log X + B$ (Y represents for the level of sensory evaluation, X represents for the concentration). Constant values A and B are intrinsic for each agent. For example, trimethylamine has much larger B compared to ammonia, although they belong to the same nitrogenous family. As the results, trimethylamine can be sensed even in the low ppb order (at the second level of sensory evaluation), meanwhile ammonia can be sensed only when the concentration reaches 400 times higher as shown in **Figure 3**.

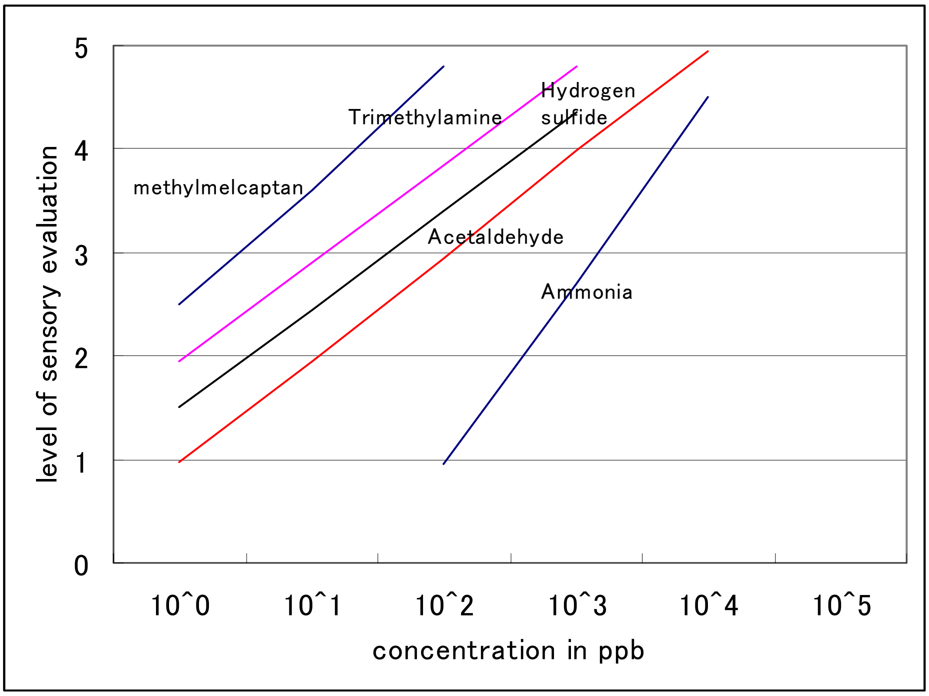


Figure 3: relationship between concentration and sensory level of odorants
*Data from TOTO website

The researchers in TOTO had gathered a lot of air samples and materials from bad-smelling facilities, analyzed and identified the compositions of bad smells, and successfully synthesized the smells as shown in the **Table 3**.

	Odorant	Hospital room	Toilette	Urine	Stool	Sweat
Nitrogenous family	Ammonia	x	x	x		x
	Trimethylamine	x	x	x		
Sulfurous family	Hydrogen sulfide	x	x		x	
	Methylmercaptan	x	x		x	
Organic family	Acetaldehyde	x				
	Acetic acid	x				x

*Data from TOTO website

Table 3: Typical odorants of bad smells

The accumulated knowledge and technologies were essential in appreciating, assessing and absorbing new technologies developed at University of Tokyo. Dr. Fujishima at the University of Tokyo discovered the unique photocatalytic properties of titanium dioxide which subsequently came to be known as the "Honda-Fujishima effect" and published a paper in Japan in 1969, although it had not gained public attention. In 1972, however, this discovery was published on the Nature magazine (Fujishima and Honda, 1972, p.37) and then came under the spotlight because it was thought to be applicable for hydrogen production and to become the solution for the energy crisis. However, those research activities had leveled down gradually, because the efficiency of photocatalytic hydrogen production on titanium dioxide is very low.

Titanium dioxide produces free-radicals and those are very efficient oxidizers of organic matter. Dr. Hashimoto, who had been engaged in photo-catalyst research at Okazaki Institute for Molecular Science, joined Fujishima Lab. at University of Tokyo in 1989. He carried an idea on the use of titanium dioxide as a photo-catalyst for the decomposition of organic compounds[5] into Fujishima Lab. In 1991, TOTO initiated a contact with the University of Tokyo research team to develop photo-catalytic tiles coated with titanium dioxide[6]. In 1994, these tiles were brought into market. These tiles possessed antibacterial properties, meaning that any bacteria on the surface were eliminated by the titanium dioxide, which also prevented yellowing and controlled odors. These tiles were a big hit with consumers and became the first step toward the practical application of photo-catalyst.

The continuing collaborative research between Fujishima Lab. and TOTO Ltd., furthermore, discovered another unique character of titanium dioxide, i.e., photo-induced *super-hydrophilic* property (Wang and others, 1997, pp. 431-432). This property was first discovered by TOTO researchers, and the discovery was published by the Nature in

1997. The University of Tokyo made a theoretical contribution, therefore, they were co-authors of this publication. This property, however, is not the part of photo-redox reaction, but is more important for the *self cleaning* effect of titanium dioxide coated tile as it contributes for rinsing chemical compounds away. Without super-hydrophilic property, the practical application of photo-catalytic titanium dioxide could not have achieved as we see today. Based on these technologies, TOTO had developed many kinds of sanitary products and self cleaning products such as exterior ceramic tiles (in 1996) and sophisticated active deodorizer (in 2001).

This TOTO case study substantiates what was suggested by Rosenberg, but in different sequences. First of all, basic research had produced the key technology of analysis and synthesis of bad smell, and made it possible to effectively monitor research conducted outside the firm. By use of the smell synthesizer designed based on results of basic research, they can evaluate the technology developed as an outcome of applied research made elsewhere, thus determine the best direction for their own applied research. With scientific accomplishments made by the company, they can participate in the scientific community comprised of universities and other organizations, and this participation produces further discoveries, which finalize the product development process.

According to the survey made by Cohen et al. (Cohen, Nelson and Walsch, 2002, p.1), although pharmaceuticals is unusual in its assignment of considerable importance to patents and license agreements involving universities and public laboratories, respondents from this industry still rated research publications and conferences as a more important source of information. For most industries, patents and licenses involving inventions from university or public laboratories were reported to be of little importance, compared with publications, conferences, informal interaction with university researchers, and consulting.

They conclude that the results of these U.S. studies consistently emphasize that the relationship between academic research and industrial innovation in the biomedical field differs from that in other knowledge-intensive sectors. In addition, these studies suggest that academic research rarely produces "prototypes" of inventions for development and commercialization by industry—instead, academic research informs the methods and disciplines employed by firms in their R&D facilities. Finally, the channels rated by industrial R&D managers as most important in this complex interaction between academic and industrial innovation rarely include patents and licenses.

4. MACRO STUDY OF NATIONAL INNOVATION SYSTEM

Now that we have made a micro study of the Japanese national innovation system, we can move on to the macro study on the Japanese national system of innovation. At a 1990 meeting of the Joint High-Level Committee, discussions were held on initiatives under the auspices of the Head of Government U.S.-Japan Science and Technology Agreement signed in 1988. Innovation and how it occurs in the two countries were major themes of the discussions, which were led by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry (MITI), and Assistant Secretary for Technology Policy, U.S. Department of Commerce (DOC).

Given the importance of innovation in the broader sense of research, development and commercialization of world-class goods and services, the two countries agreed to undertake a study to begin to understand the elements of these issues. Accordingly, DOC and MITI organized a Technology Transfer Joint Study Panel. This Study Panel was composed of Japanese and U.S. representatives from academia and industry (Morin and Kodama, 1993). Round table panel members held discussion sessions in Washington on March of 1992, and in Tokyo on July of 1992. The round tables examined technology transfer in the context of industry, government laboratories and universities, as well as the overall infrastructure (e.g., policies and institutions) of technology transfer systems. The discussion was largely framed by the "receiver-active paradigm." The receiver-active paradigm is analogous to the more familiar technology-push/market-pull description of how technology is transferred. In essence, this model holds that successful technology transfer is largely dependent on the receiver rather than the sender. That is, aggressive receivers can obtain technology from passive senders, but passive receivers are unlikely to obtain technology from even the most aggressive senders. Viewed in the framework of this paradigm, the differences between the U.S. and Japanese technology transfer systems are striking. In addition, panelists recognized that there are various types of technology and that each technology should be transferred in the most appropriate manner. Finally, much of what the Joint Panel studied could be more accurately described as "technology management," of which technology transfer is a part.

In order to establish a consistency in description between micro and macro studies, we will frame the macro description around the receiver-active paradigm, the concept derived form the micro study of university-industry linkage. Then, what are the most appropriate measures of university-industry linkage, which accommodate the receiver-active paradigm?

The widely used measures such as the number of TLOs at universities and of university-based startups, are obviously not appropriate because the sheer concept of TLOs are reflection of the sender-active paradigm, in which university become active in marketing of their research outputs. These kinds of indicators, however, are being actively published by various Japanese Governmental branches. Before going further into our arguments around the receiver-active paradigm, we will cite some examples of such indicators published in Japan. In 1998, the Japanese government legislated the so-called TLO law, and the budget for the university-industry linkage formation has increased from 425 billion yen in 2002 to the estimated 688 billion in 2005. In 2001, METI (Ministry of Economy, Trade and Industry) published the Hiranuma plan in which 1,000 university-based startups should be established in the following three years. Indeed, this objective had been easily accomplished as the METI claims that 1,112 university-based startups are existent as of 2004, although that number was only 95 companies in 1995, as shown in **Table 4.**

Year	Accumulation of Startups
1995	95
1996	116
1997	148
1998	201
1999	287
2000	429
2001	594
2002	784
2003	983
2004	1,112

Sources: METI

Table 4. Number of University-based Startups

As to the financial support to establishing TLOs around universities, METI raised 300 million yen in 1998, MEXT (Ministry of Education, Culture, Sports, Science and Technology) did 2.4 billion yen in 2003, and METI made again 900 million yen for the so-called super-TLOs. Nikkei Business Magazine (Nikkei Business, 2005, pp. 27-41), however, estimates that one quarter of these 1000 startups are no longer in operation, and that 90 percent of those might be in danger of bankruptcy when the government subsidy would be ceased. The management crisis might not be confined to those startups, but extended to the university TLOs. Since the majority of Government subsidies are budgeted on 5 years-term, the support to many universities will be terminated in 2-3 years. Without government's financial support, many of TLOs are not viable, Nikkei reports.

From the viewpoints of TLOs, on the other hand, the number of patents should be the most important measure of university-industry linkage. As far as the university-industry linkages in the United States are concerned, however, Agrawal and Henderson (Agrawal and Henderson, 2002, p.44) of MIT (Massachusetts Institute of Technology) made a comprehensive study of papers written by and patents awarded to MIT professors of mechanical and of electrical engineering. They concluded that *patenting* activities are by no means the *dominant* channels for the diffusion of knowledge.

The followings are their findings:

1) The majority of professors have never obtained any patent in their last ten years;
2) The number of patents per professor is fewer than that of papers;
3) At an individual professor level, no correlation exists between the number of patents and that of papers;
4) Very often, the company which cites MIT papers is not the same company which cites MIT patents.

Based on these findings, they conclude that patenting is not a "substitute" of writing papers for professors whose primary responsibility is to conduct basic research, but that patenting is rather "complimentary" to paper publications.

In order to characterize the Japanese system, Pechter and Kakinuma (Pechter and Kakinuma, 1999, pp. 102-127) have chosen to look at university-industry research collaboration in Japan through the window of co-authored papers, a useful approach because co-authorship is an indicator of a broad range of collaborative activity. They investigated the co-authorship between professors and company researchers. To make it sure that the system should be analyzed around the concept of receiver-active paradigm of university-industry linkage, they analyzed co-authorship between university and industry researchers from the perspective of industry. They chose a 16-year period, 1981-1996, for their study. Searching a comprehensive database from the Institute of Scientific Information of publications in which at least one author is affiliated with an organization located in Japan, they created a subset containing all papers in the database published with at least one author from a firm located in Japan. This subset contains 110,588 papers.

They then performed various processes in order to determine the co-authorship patterns of these papers, by assigning each author affiliation to an institutional sector based on information in the author's address. The sectors they used were academia, industry, and other (including national laboratories, public corporations and non-university hospitals). **Figure 4** shows a breakdown of papers by Japanese industry from 1981 to 1996: those authored intramurally (within a single firm), by multiple firms, by a firm and a university, and by a firm and an organization in the "other" category. These data contain both domestic and international collaborators of the Japanese-based firms.

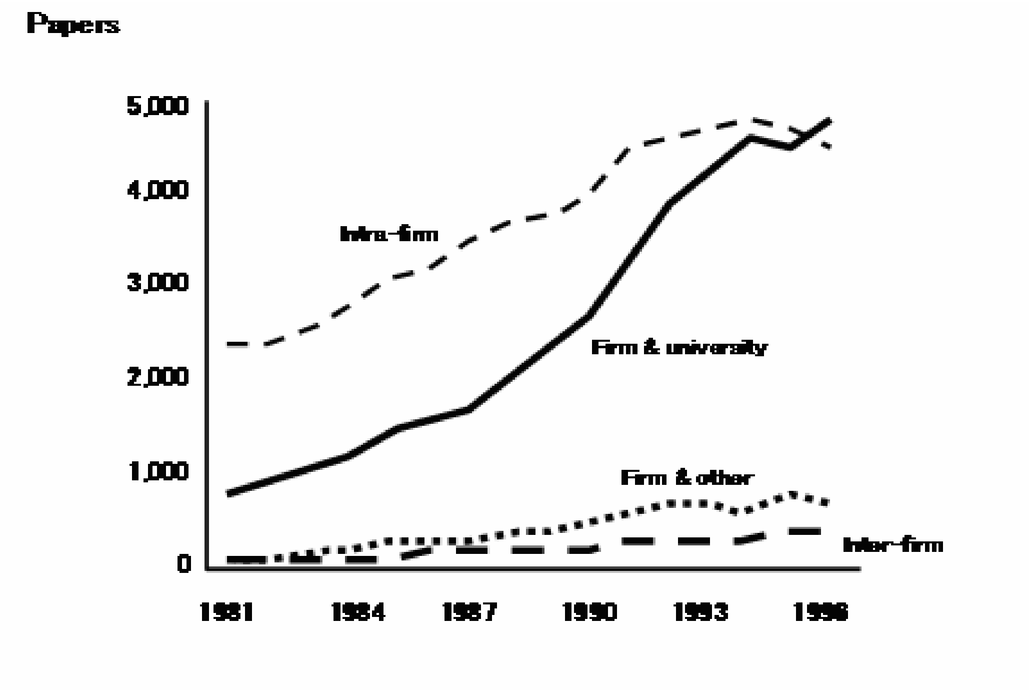


Figure 4. Japanese Industry Papers by Mode of Collaboration
(Source: Institute of Scientific Information)

Total publication by researchers in Japanese industry, the sum of the four lines in the figure, increased steadily, from 3,433 papers in 1981 to three times that figure at 10,450 papers in 1994. From 1994 to 1996, however, growth has faltered. Of these papers, 70.3% were authored intramurally (this includes single authors as well as multiple authors in the same firm) in 1981, but by 1996 this has dropped to 43.3%. On the other hand, papers authored jointly with a university researcher went up from 23.1% in 1981 to 46.4% in 1996, *overtaking* intramurally authored papers. The portion of papers authored jointly with another firm was only 2.8% in 1981 and grew much less dramatically to 3.5% in 1996. Coauthored papers with the "other" category rose from 3.8% to 6.8% over the period.

This analysis reveals that university researchers have been significant collaborators with industry researchers and that this significance has intensified over the past two decades, while inter-firm collaboration is of only minor importance when it comes to publication. In other words, collaboration with universities has become the *dominant* mode of industrial research instead of the past mode of intramural research within a company and of inter-company research in a given industrial sector. These data are truly significant in the context of debates premised on the weak university-industry linkage view of Japan. This is because these figures are remarkably close to corresponding figures in the United States. **Figure 5** shows an international comparison of co-authorship ratios among the United States, the United Kingdom and Japan. According to Science and Engineering Indicators - 1998 (National Science Board 1988), the portion of U.S. industry papers coauthored with academia grew from 21.6% in 1981 to 40.8% in 1995. Thus, in spite of anecdotal evidence to the contrary, the empirical evidence suggests that industry and academia in Japan interact in the research process at least as much as, if not more than, in the United States.

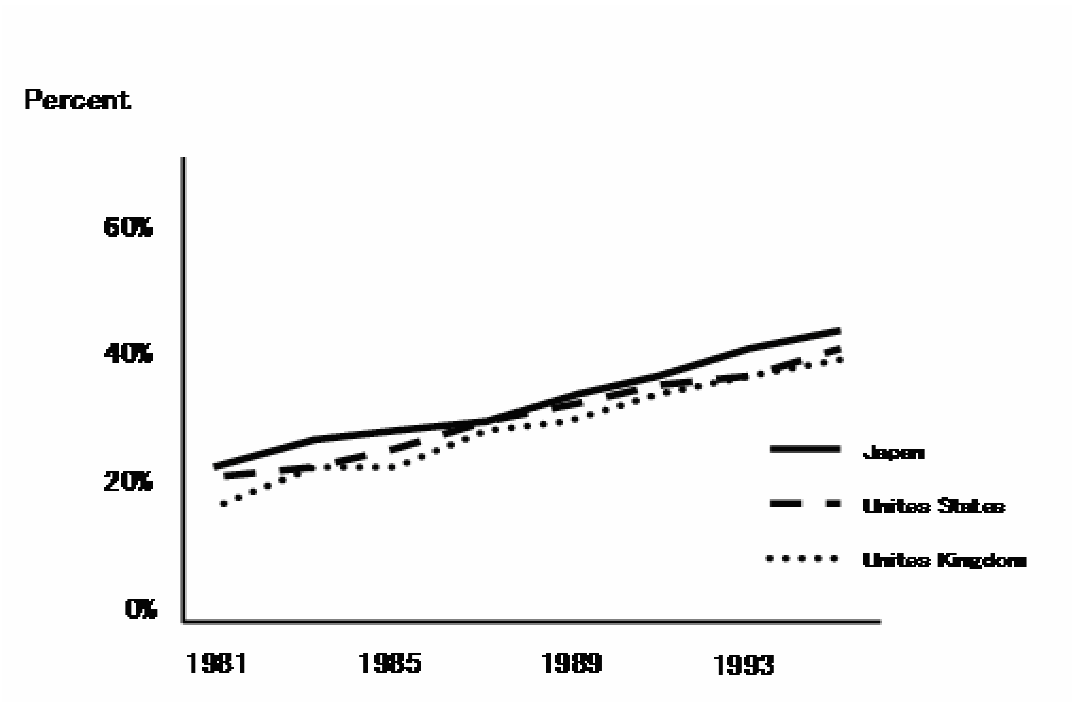


Figure 5. Co-authorship Rations in the United Kingdom, the United States and Japan (Source: Institute of Scientific Information)

Then, what is the Japanese mechanism for technology transfer? It has been based on individual networks and the informal transfer of technologies. In many cases, technology transfer in Japan takes place through a channel that differs significantly from that in the United States (Kodama, 1985, pp. 198-204). In the United States, intellectual property rights to inventions made by professors most commonly belong to the universities; in Japan, they generally go back to individual inventors, who most commonly transfer the title of their inventions to private companies for little or no fees without filing for patents. When these companies decide to file patent applications for the acquired intellectual property, the faculty inventors are listed as joint applicants or only as inventors. In cases in which the companies file unilaterally, without listing the faculty member's name, the patents are officially listed as having been filed by the private sector, and the inventive activity within the academic community does not appear in the public data.

Why don't the Japanese professors file for patents on their own discoveries? First, because of economic disincentives: The Japanese system imposes high transaction cost upon inventors. A second inhibiting factor is the legacy of the university disturbances of the late 1960s, when radical students led protests against university collaborations with the private sector. Only recently has this collaboration between academics and the business community come to be viewed in a positive light, but academic allergy to university-industry collaboration still prevents many academics from participating in technology transfer at their universities (Kodama, 2000, p. 3).

All what was described above about Japan indicate that most university inventions are transferred *informally* by the inventors. Therefore, we tried to estimate the number of patent applications filed by companies on inventions transferred directly from university inventors. The JBA (Japan Bio-industry Association, 1988) compiled a list of 2,897 names of its own individual members who are university faculty and also successful 1995 and 1996 university applicants for Government Grant-in-Aid in life science fields of research. JBA survey estimated that university faculty members were listed as inventors on 8,743 out of a total of 23,274 patent applications in genetic engineering in the period of 1987-1997, 38% of Japanese applications (874 of 2,327 applications annually). Out of a sample of 252 applications, 72% were filed by private companies. None were filed by the universities themselves.

Based on this survey, Kneller (Kneller, 1999, pp. 410-438) suggests that the number of patent applications filed by companies on inventions transferred directly from university inventors is probably over 600 annually and may even exceed 1,000. In 1996, 3,261 patent applications filed by US and Canadian universities (AUTM, 1998). He concludes that the number of patentable Japanese university discoveries transferred to industry is probably not remarkably less than in the United States, considering that (1) the population of Japan is roughly half that of the United States, and that (2) government support for biomedical university R&D in Japan is much less than in the United States while biomedical inventions account for the majority of patents and approximately two-thirds of active licenses by most U.S. universities.

To summarize, we succeeded in manifesting the existence of receiver-active paradigm of technology transfer, by an in-depth study on the patent application behavior of the Japanese university professors. What is essential is that technology is to be found out for appropriate applications by industrial receivers. It is not marketed by active professors.

5. COMPLIMENTARITY BETWEEN AUTHORSHIP AND INVENTIONSHIP

Since we described the system by measuring the co-publications and co-applications of patents, we are interested in understanding how the system works. Especially, in order to demonstrate that receiving firms are playing proactive roles in transferring technologies, we are going to look into the dynamic and complimentary relationship, if any, between scientific publication and patent applications. Over the past 10 years, we have collected data on papers and patents published by engineering professors at the University of Tokyo and could make a comparison with the corresponding data on MIT professors (Suzuki, 2004). In total, 392 professors who were registered during 1991-2002 are investigated. Out of this total, 83 professors are those of mechanical and electrical engineering. Now, we can make a comparison between the University of Tokyo and MIT, by matching of our data to MIT data of 304 faculty members collected by Agrawal.

In order to identify papers published by these 392 UT professors, we purchased Institutional Citation Report from Thomson Scientific Inc., and counted the number of papers published by individual professors and the number of citation to these papers every year from 1992 to 2001. We also compiled the co-authors for each paper. As for patent database, we used the patent publication by Japanese patent office. Inventors and applicants are matched with the names of 392 professors with their address. Thus, we could retrieve 2,115 patents during the 10 years. This number should be compared with 186 patents that are registered by the University of Tokyo. It becomes clear that the patents registered officially by the University of Tokyo compose only 10 percent of patents which are invented by UT professors.

The change in number of patents and of total claims is shown in **Figure 6**. As can be seen, the number of patents stays around 200-300 per year, but the number of total claims increased from 800 in 1991 to 1,500 in 2000.

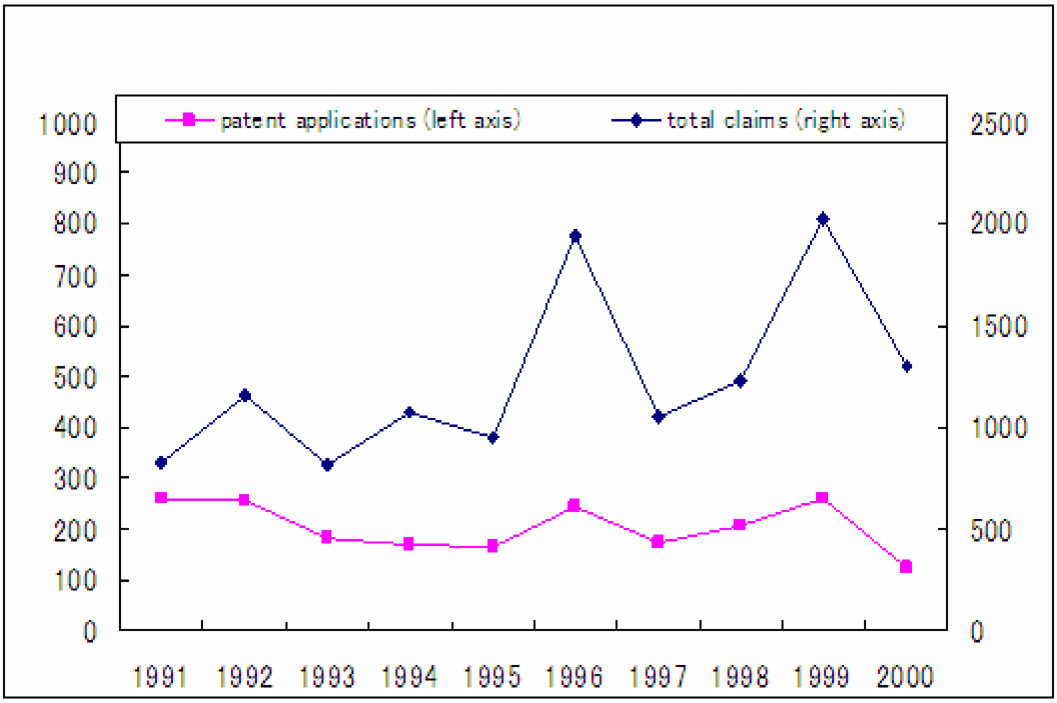


Figure 6. Total Number of Patent Application and Claims of UT Professors

By matching of our data to MIT data of 304 faculty members collected by Agrawal, we can make a comparison between the University of Tokyo and MIT. It is to be noted that the MIT data are based on the faculty members' registered patents, while the UT data are based on professor's application. The results are shown in **Figure 7**.

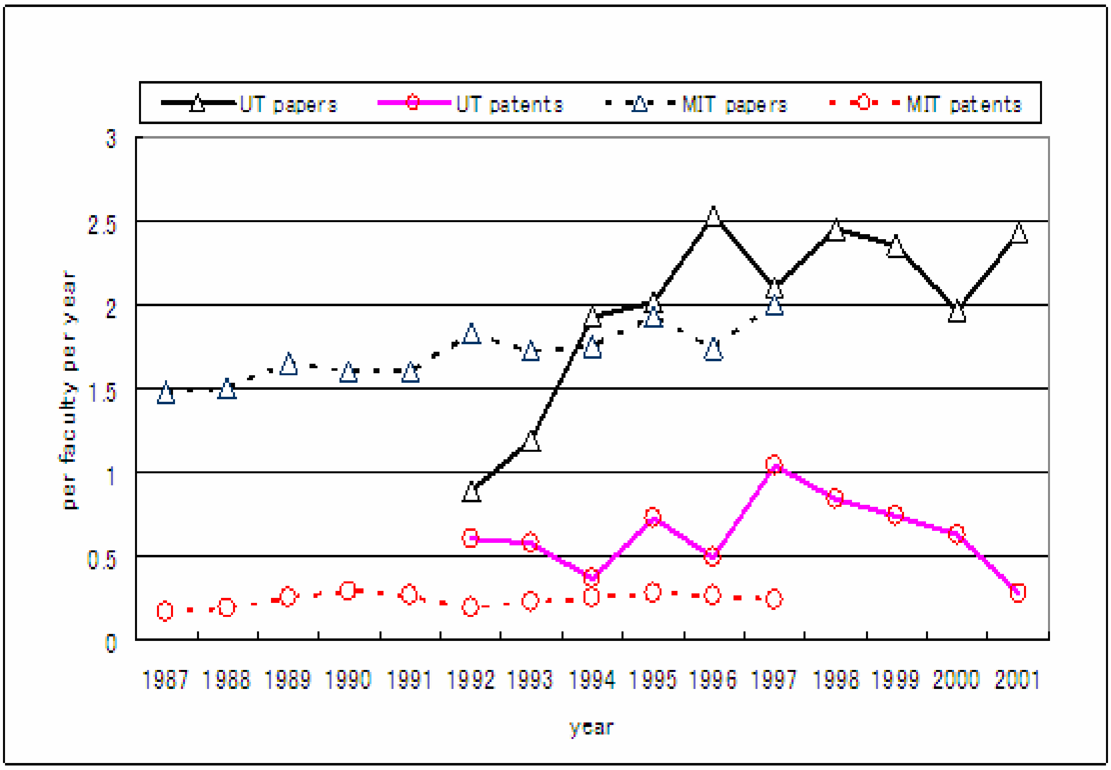


Figure 7. Average Number of Papers and Patents per Professor (UT and MIT)

As can be seen, the number of papers increased both at UT and MIT. The number of patents, however, did not change. It should be also noted that the number of papers per professor at UT is equivalent to that of MIT, in spite of the fact that the inclusion of only English-written papers in the database obviously favors the MIT professors.

Now, we can go investigating the relation between the number of patents and that of papers. The scattered diagram is shown in **Figure 8**. A quick look at this diagram makes us believe that a positive correlation is observed between those two kinds of numbers. However, those five professors who are extremely high both at papers and patents give a substantial influence on total landscape of the relationship. By excluding those five irregular points from regression analysis, no significant causality is found out.

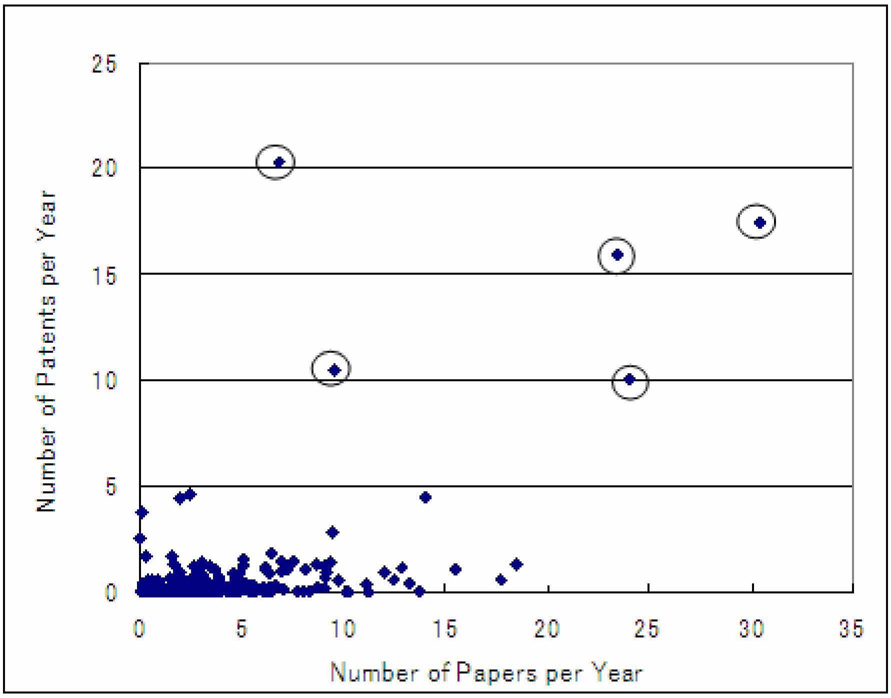


Figure 8. Number of Papers and Patents of UT Professors

As described before, the majority of the patents are those registered by private companies with university professors co-authoring key papers with corporate researchers or appearing as co-inventors with private companies. Therefore, we investigated how professors and companies are collaborating. Our results are shown in **Figure 9**.

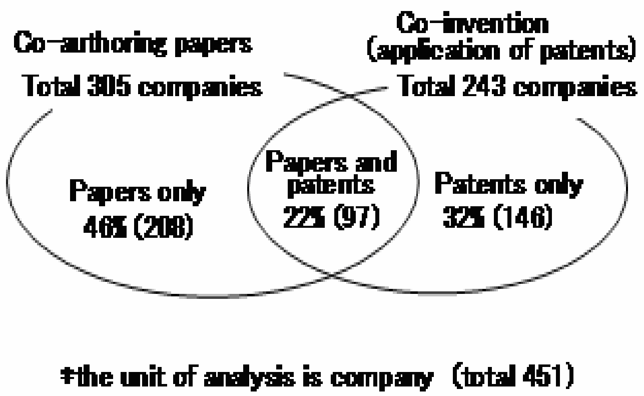


Figure 9. How Professors and Companies are Collaborating

Nearly 46 percent of collaborations are with co-authorship, with 32% of these collaborations being with only patent applications, and 22% of them being with both co-authorship and patent. In the case of MIT professors, only 3% of collaborations are with both co-authorship and patents. This indicates that Japanese companies do not obtain licensing from universities unilaterally but are developing *absorptive capacity* by sending employees to university labs and through joint research with university professors. However, the recent move by the government to encourage public universities to promote technology transfer through TLOs might dilute the informal collaborations which existed and worked well so far.

The complimentary relation between co-authorship and co-patenting indicates how the receiver-active paradigm works, and gives a good evidence to the proactive attitude of receiving Japanese firms in technology transfer. By collaboration through co-authorship, the process of technology transfer is initiated and the two parties can share the common understanding how the scientific discoveries are to be transformed into useful technologies. Only after these mutual understanding is accomplished, they go to patent applications. In other words, without joint collaboration in research, companies cannot be active in understanding and receiving the university research.

6. CONCLUDING REMARKS

In order to avoid the mechanical comparison between the United States and Japan, we paid a sufficient attention to the exceptional nature of biomedical research in terms of its reliance on university research. By measuring the science linkage indexes among different Japanese patent classifications, we discovered that the technologies related to biotechnology were by far the closest to science, and suggested that the difference in university-industry linkage between the United States and Japan is mainly due to the substantial differences in government support for biomedical research between these two countries.

A case study on a Japanese manufacturer of sanitary wares theorizes the process of the receiver-active paradigm in the following order: basic research produces the key technology of analysis and synthesis, and makes it possible to effectively monitor research conducted outside the firm; by use of the knowledge of synthesizing based on results of basic research, they evaluate the technology developed as an outcome of applied research made elsewhere, thus determine the best direction for their own applied research; and then, the companies can participate in the scientific community comprised of universities and other organizations, and this participation produces a further discoveries, which finalize the product development process. Based on the case study made, we hypothesize that the Japanese innovation system is built on the receiver-active paradigm of technology transfer, while that of the United States is built on the sender-active paradigm. And we made an attempt to validate our hypothesis by investigating behaviors of all the participants, university professors, company researchers, and corporate and/or technology managements in Japan, and by empirical studies based on data of publication and patenting.

What are the implications to national policy? We can say at least that there exists two distinct types of national innovation system, i.e., receiver-active versus sender-active system. The effectiveness of these two systems dependent on the following items: industrial structure in terms of resource-based or manufacturing-based economy, software-based or hardware-based industry; industrial management, in terms of scientists-dominated or engineers-dominated technology development, top-down style or bottom-up style of decision-making; and, perhaps societal/academic structure, in terms of egalitarianism or achievement-based mobility.

Although Japanese universities are in transition in many aspects in these days, it remains uncertain whether those policies based on the sender-active paradigm i.e. TLOs, Bahy-Dole type regime, support for university startups, fit well for Japanese system. We believe that there should be many alternative way to enhance receiver activities and capacities which in turn spill-over to and stimulate Japanese university.

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NOTES

[1] In the case of technologies related to non-tradable goods intended solely for the domestic market, and those related to goods that have no export competitiveness, patent applications are not filed overseas because there is no advantage in protecting intellectual property rights abroad; research on these technologies cannot be done by analyzing patent applications made outside Japan. In addition, the study of Japanese patents is important to conduct an international comparison with patents submitted to overseas patent offices such as the USPTO and EPO.

[2] The filtering program for biotechnology patents was based on an algorithm made to resemble Anderson's study as much as possible. We thus extracted patents that either fell under a very narrow area of the international technology classification within the IPC, or included keywords related to the human genome. For IT-related patents, we used "G06F: Electrical digital data processing" and "H01L: Semiconductor devices; electric solid-state devices not otherwise provided for" under the international technological classification. These technological areas are only a part of the IT sector and this should be borne in mind when interpreting the results. The filter for nanotechnology patents was based on the filter used in the "Survey of Technology Trends Regarding Nano-level Material Technology" (June 5, 2001) conducted by the Technology Evaluation and Research Division of the Ministry of Economy, Trade and Industry's Industrial Science and Technology Policy and Environment Bureau. For environmental technologies, we extracted patents that fell under "ZAB: Those related to environmental protection technologies" under the "faceted classification codes" that the Japan Patent Office has established based on different standards from the IPC, and which it uses together with those of the IPC. References: Anderson J, Williams N, Seemungai D, Narin F, Olivastro D. 1996. Human genetic technology: Exploring the links between science and innovation. *Technology Analysis and Strategic Management* 8(2): 135-156.

[3] The extraction of the reference cited from all of patent documents by humans is impossible. To overcome the limits of manual cited paper extraction, and to measure the science linkage of a large number of patents, it is necessary to automate the extraction of cited scientific papers. Fortunately, Japanese patents are almost entirely in electronic form since 1994, so it is comparatively easy to use computers. Therefore, if the extraction of cited papers can be automated reasonably, it should be possible to measure science linkage over comprehensive technology areas for all patents in the database. (Source: S. Tamada, Y. Naito, K. Gemba, F. Kodama, J. Suzuki, and A. Goto, "Science linkages in technologies in Japan", Conference program of 10th ISS(International J. A. Schumpeter Society) Conference, Milan, 2004)

[4] http://www.answers.com/topic/richard-axel

[5] The decomposition property of organic compounds itself had been discovered by Kawai and Sakata at National Institute of Molecular Sciences, and it was published by the Nature Magazine in 1980 (Kawai, T. & Sakata, T. “Conversion of carbohydrate into hydrogen fuel by a photocatalytic process,” Nature 286, 1980, 474-476).

[6] The coating technology was developed by TOTO with the scientific advices from the University of Tokyo.