Effectiveness of a University–Industry Matching Program at Creating Collaborative Research

Katsuya Hasegawa, Takuma Iwata, Kazuro Kageyama
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN
hasegawa@ducr.u-tokyo.ac.jp

Abstract

To realize technological innovation based on advanced university technologies, it is important to establish collaborative research projects between universities and industry in the early stages of R&D. One way to stimulate the creation of university–industry collaborative research is to have a systematical coordinating mechanism between a university and industry. We analyzed the effectiveness of a university–industry coordination program at creating university–industry collaborative research projects. We used data from the matching program called Proprius21 at the University of Tokyo and found out that the matching program has increased collaborative studies at the University of Tokyo. We also analyzed the R&D characteristics of various firms using the relation between the firm's R&D intensity and the range of firm's R&D areas. The matching program is especially effective for large companies in ICT-related fields, although it is not so effective for efforts involving life science technologies, which are overall the most active area for university–industry collaboration. Results show that the matching program is most effective for creating collaborative studies with technology-oriented firms engaged in various business domains.

1. Introduction

The role of universities in accelerating technological innovation has become increasingly important worldwide in the past few decades. In addition to traditional roles of education and academic research, universities are expected to be involved in the commercial application of science [1][2]. Since companies in today's competitive environment cannot rely solely on their own R&D efforts to innovate, they have to leverage various external resources through open innovation [3][4][5]. Because many new technologies emerge from universities, the importance of universities as a source of technological innovation has been increasing.

As technologies become increasingly advanced and sophisticated, it is becoming increasingly difficult for industries to commercialize raw technologies derived from purely academic research. Establishing collaborative research projects between universities and industry in early stages is important to spur innovation from university studies [6][7][8].

Until recently, university–industry collaborative research projects in Japan have usually originated from personal relations between university researchers and company engineers [9][10][11]. Although advantages of having informal personal relations between universities and industry do exist [12][13], research projects arising from informal relations are usually pursued on an ad hoc basis with vague research goals and sometimes unclear responsibilities of participants. Collaborative research for corporations might be done simply to gain access to students for recruitment purposes, or merely to maintain personal relationships with professors. In such cases, there is little necessity or incentive for a corporation to pursue the technological outcome of the collaborative research. Lack of incentive is the same for the university researchers. Funding from industry is often regarded as easy-to-use donation money, not as financial support in exchange for conducting research to meet specific goals. Traditional research projects of such kinds have contributed to technology transfer to some degree [12][13], but such ad hoc research projects are inefficient at achieving technological innovation based on academic research.

An alternative approach to create university–industry collaborative research is to use a systematic coordinating mechanism between universities and corporations at the organization level, not at the personal relation level. This paper presents an examination of the effectiveness of such matching activities.

After early successes at some US research universities, universities all over the world have actively established organizations such as Technology Transfer Organizations (TTOs) and university–industry liaison offices to link their academic researchers systematically with industry counterparts. Many studies have elucidated the benefits of such intermediary organizations in transferring technologies that were developed at universities [14][15][16][17][18][19]. Despite these analyses of intermediary functions' effects on enhancing technology transfer, few studies have assessed the effectiveness of universities' intermediary function for creating collaborative research during early stages of R&D.

To analyze the effectiveness of university–industry matching activities, we used data of the industry-university matching program at the University of Tokyo called Proprius21. In addition to the data from the University of Tokyo, we used two parameters that characterize various Japanese firms' R&D attributes to analyze the effectiveness of university–industry matching programs. One parameter is a firm's R&D intensity, as measured by the ratio of a company's R&D investment to the firm's sales. Another parameter is the range of firms' R&D areas measured according to IPC classification information extracted from patent applications.

The remainder of the paper is structured as follows. After analyzing the contribution of Proprius21 Program in generating collaborative research projects at the University of Tokyo in Chapter 2, R&D characteristics of Japanese corporations are analyzed in Chapter 3. We discuss our findings related to the effectiveness of the matching program and analyze the creation mechanism of collaborative research in Chapter 4 before concluding the paper.

2. Proprius21 Program at the University of Tokyo

2.1 Program Overview

Until 2004, because all national universities in Japan were government organizations, relations with private companies were highly regulated at universities. Following major reform of the university system in 2004, each national university launched its own industry-collaborative activities to accelerate innovation based on university technologies. Proprius21 is a liaison program started in 2004 to foster university–industry collaborative research at the University of Tokyo [20][21].

Instead of relying on personal relationships between faculty members and industry, the Proprius21 Program is structured to match the university's hidden technological seeds systematically with industries that have potential business needs. The program is managed by program officers at the Division of University Corporate Relations, the university's headquarters organization, independent from schools [22]. Most program officers are senior professionals hired from industries that have widely various experiences both in R&D and in management.

The first step of Proprius21 Program usually starts with an open forum and free discussion between university researchers and company representatives. The primary goal of this phase of discussion is to explore opportunities to work together. The second step, which is usually conducted under a Non-Disclosure Agreement (NDA), is the phase to identify the specific research topic and to identify the most appropriate university researcher for the particular research topic. In the third step of the Proprius21 Program, participants from the industry and university will create a collaborative research plan with a program officer. Based on these three steps, the Proprius21 Program can match the research resources scattered throughout various departments and schools inside the university with the potential business needs that might exist in various application fields.

2.2 Program Contributions

To analyze the Proprium21 Program, we used data related to collaborative research at the University of Tokyo after the program started in 2004. The University of Tokyo, with more than 4,000 faculty members and more than 6,000 PhD students, is the largest research university in Japan. Collaborative research with industry at the University of Tokyo accounts for about 10% of all university–industry collaborative research in Japan. The university is active in many academic fields, working with many businesses.

Datasets include various information related to each collaborative research project such as affiliation of the university researchers, industry segment of the company, research area, terms of the project, and funding amounts.

We calculated the contribution of Proprius21 Program, defined as the ratio of funding amount of the research projects that have been initiated from Proprius21 Program to the total collaborative research funding amount. Figure 1 presents results along with the total collaborative research funding amount. As the figure shows, the contribution of the Proprius21 Program increased from 3.0% in 2004 to 9.1% in 2009. In addition to this contribution, in some cases the existing collaborative research projects were integrated into a Proprius21 Program during a systematic matching process of Proprius21.

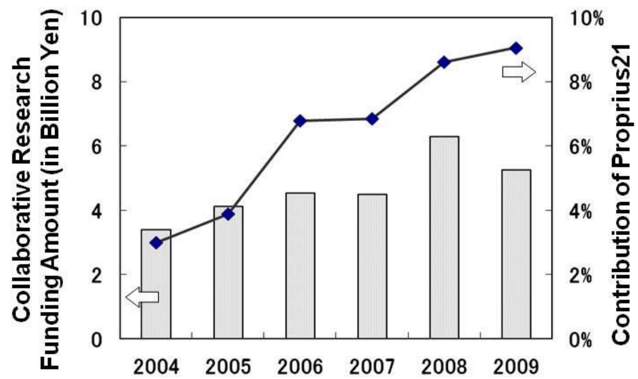

Figure 1. Total collaborative research and the contribution of Proprius21 Program.

One project created from Proprius21 was collaboration with a major electronics manufacturer in developing a robot to assist humans in everyday life [23]. In this case, after some initial discussion about the needs of the company, research proposals were solicited around the university to undertake collaborative research on concepts, devices, software and integration technology for a robot to assist humans in everyday life. Proposals were discussed with the company for four months before narrowing the field down to three research projects related to sensor technology, manipulation technology, and sensor fusion technology. Collaborative research started in 2005 with more than one million US dollars of funding from the company.

Another example is the pursuit of collaborative research with a major telecommunications company [23]. Although diverse collaborative efforts have been pursued with the company in the past, these collaborations were based on relationships with individual researchers. To integrate such individual activities, an interdepartmental information exchange scheme was established in 2007. It consisted of a promotion committee led by the senior managers of the company and the workshop to invite university researchers to discuss specific research topics in the telecommunications industry. Through these activities, six collaborative research projects, ranging from device technology to social science projects, were created during 2007–2008.

As the two examples above demonstrate, introduction of a systematic matching scheme under Proprius21 Program has been effective in creating collaborative research projects by providing a mechanism to generate collaborative research that does not rely on a personal relationship between university researchers and corporations. As Fig. 1 shows, the percentage of collaborative research projects generated out of the Proprius21 Program is increasing.

2.3 Collaborative Research in Various Research Areas

Table 1 presents a comparison of the characteristics of collaborative research among various technology fields. Life Science accounts for almost 40% of all collaborative studies. Nanotechnology / material technology, manufacturing technology and Information and Communication Technology

(ICT) are also active areas for the university to collaborate with the industry, each with around 10% share. Although environment technology accounts for only 5.5%, it is rapidly growing recently, reflecting the strong interest in clean technologies during the past few years.

Table 1. Characteristics of collaborative research in various research areas

Research Area	Share of Each Area in All Collaborative Research	Contribution of Proprius21 in Each Area
Life Science	39.8%	2.4%
Nanotech. & Material	13.7%	2.9%
Manufacturing	10.2%	5.5%
ICT	9.6%	23.5%
Infrastructure	7.2%	3.0%
Energy	6.2%	10.7%
Environment	5.5%	13.7%
Frontier	1.0%	3.2%
Others	6.8%	13.9%

When we compare the contribution of the Proprius21 Program in each research area, the number for ICT fields is especially high, with 23.5%. Environment and energy fields come next with more than 10% contribution from Proprius21 Program. However, the contributions of Proprius21 in the life science area, which is overall the most active area for university–industry collaboration, are the fewest among areas. Table 1 clarifies that whether a matching program is effective or not in creating collaborative research depends significantly on the technology area.

2.4 Hypothesis

We assume that a firm's R&D characteristics are important factors to elucidate this difference in the effectiveness of a matching program among various technology areas. Studies have investigated what kinds of firms are likely to engage in collaborative research with universities [24][25][26]. Because earlier research indicates that a firm's ability to absorb external knowledge is an important factor for a firm to innovate [15][27][28][29], we assumed that the effectiveness of a matching program depends on the firm's R&D capability. We also assumed that the matching program would be more effective for companies with broader business areas than the companies with narrow business focus because prior research suggests that innovation will emerge from external networks rather than individual firms when the knowledge base of an industry is complex and the sources of expertise are widely dispersed [30][31][32]. Hence, we predict:

Hypothesis: Firms with larger R&D activity and with broader business areas are more likely to be benefited from a matching program when creating collaborative research projects with universities.

3. Company R&D Characteristics

To confirm the hypothesis presented above, we used two parameters representing the R&D characteristics of the firms. In this chapter, after explaining the parameters we used, we demonstrate that these parameters are useful for analyzing R&D characteristics of various firms in various industries.

3.1 Analytical Methodology

One parameter we chose is the firm's R&D intensity, defined as the ratio of a firm's R&D expenditure to the amount of the firm's sales. R&D intensity is a common indicator to measure the R&D power of a firm. It was calculated from each company's financial statement report on a consolidated basis.

Another parameter that we used was the number of International Patent Classification (IPC) subclasses that a firm used in their patent applications. Using IPC subclass numbers to characterize firm's R&D characteristics is a novel approach. Because IPC classification is a comprehensive system used to categorize all technology areas, we believe that measuring the diversity of patent classification information can be expected to be a good measure not only to gauge the range of firm's R&D fields, but also to evaluate the scope of a firm's business areas.

The number of IPC subclasses used in each company's patent filing was extracted from the database on Japanese patent published by the Institute of Intellectual Property (http://www.iip.or.jp/patentdb) [33]. International Patent Classification (IPC) provides a hierarchical system of language-independent symbols for the classification of patents according to the different areas of technology. All technology areas are classified into eight sections; each section is divided into 5 to 36 classes. Each class is then divided into 515 subclasses. Although each subclass is further divided into thousands of groups and subgroups, we used classification at the subclass level because the granularity is apparently best at this level. We extracted all the subclass information associated with all the patents that each company filed and counted subclasses as an indicator to measure the range of the company's R&D fields.

We analyzed R&D characteristics of 122 leading Japanese companies in 11 industries [1] using the two parameters described above. Most of the companies we studied are companies with annual sales of more than 500 billion yen (6 billion US dollars at current exchange rates).

3.2 Analysis Results

Fig. 2 shows two-dimensional mapping of the 122 companies using the two parameters: the R&D intensity and the R&D diversity as measured from IPC subclass numbers.

As Fig. 2 shows, pharmaceutical companies are located in the area (marked as Area 1) where the R&D intensity is greater than 10% and the IPC subclass number is less than 20. It demonstrates that the pharmaceutical companies make heavy R&D investments in a narrow business domain.

Major electronics companies and automotive companies with annual sales of a few trillion yen (several tens of billion US dollars) are located in the area marked as Area 2, where the subclasses number more than 60. The reason that the subclass number is large for these companies is that these companies are usually doing businesses in various areas with

[1] For example, pharmacy companies in our analysis are Takeda Pharmaceutical Co. Ltd., Daiichi Sankyo Co. Ltd., Astellas Pharma Inc., Eisai Co. Ltd. and Otsuka Pharmaceutical Co. Ltd.

integration of various technologies. R&D intensity of all companies in this area is more than 3%. The high R&D intensity reflects the heavily technology-oriented business areas of the electronics companies.

The area marked as Area 3 in Fig. 2 corresponds to companies with R&D intensity of 3–10% and IPC subclass number of less than 60. Companies in this area are mostly companies with annual sales of around a trillion yen (twelve billion US dollars) in the electronics and device/component industries. Smaller automotive companies are also in this area. Although they are technology-oriented companies, and therefore their R&D intensity is high as these of companies in Area 2, the subclass numbers are smaller than those of companies in Area 2 because the business areas of these companies are usually not as wide as those in Area 2.

Although not evident for the companies in Areas 1–3, some common tendencies exist in each industry segment. Many metal and material industry companies are in Area 4 (less than 3% R&D intensity, 30–60 IPC subclasses). Because they are in a strongly equipment-intensive industry, the R&D intensity becomes lower than electronics and component industries. Chemical companies and heavy machinery companies are clustered in an area marked 5 (1–3% R&D intensity, fewer than 30 IPC subclasses). These industries are characterized as technology-oriented, but equipment-intensive industries with focused business domains. Modest R&D intensity and limited R&D diversity should be the result of these industry characteristics. Non-manufacturing industries such as energy, as well as non-technology industries such as food and construction, are usually located in Area 6 (less than 1% R&D intensity, less than 30 IPC subclasses), which is quite natural given the fact that R&D is not so important to do business in these industries.

To summarize the analysis of this chapter, we proposed the use of two parameters, R&D intensity and the number of IPC subclasses that a firm used in their patent application, to characterize firm's R&D characteristics. Results showed that these two parameters are good measures to identify the R&D characteristics of various industries.

4. Discussion

In this chapter, we will use the firm's R&D characteristics we described in Chapter 3 to confirm the hypothesis we stated in Section 2.4. We will analyze the difference in the effectiveness of the matching program among various technology areas that we described in Chapter 2 and discuss the effective and efficient methodology for creating university–industry collaborative studies.

4.1 Collaborative Research Creation in Drug Industry

As presented in Chapter 2, although collaborative research in life science fields is very active in general, the contribution of the matching program is low. In this section, we will

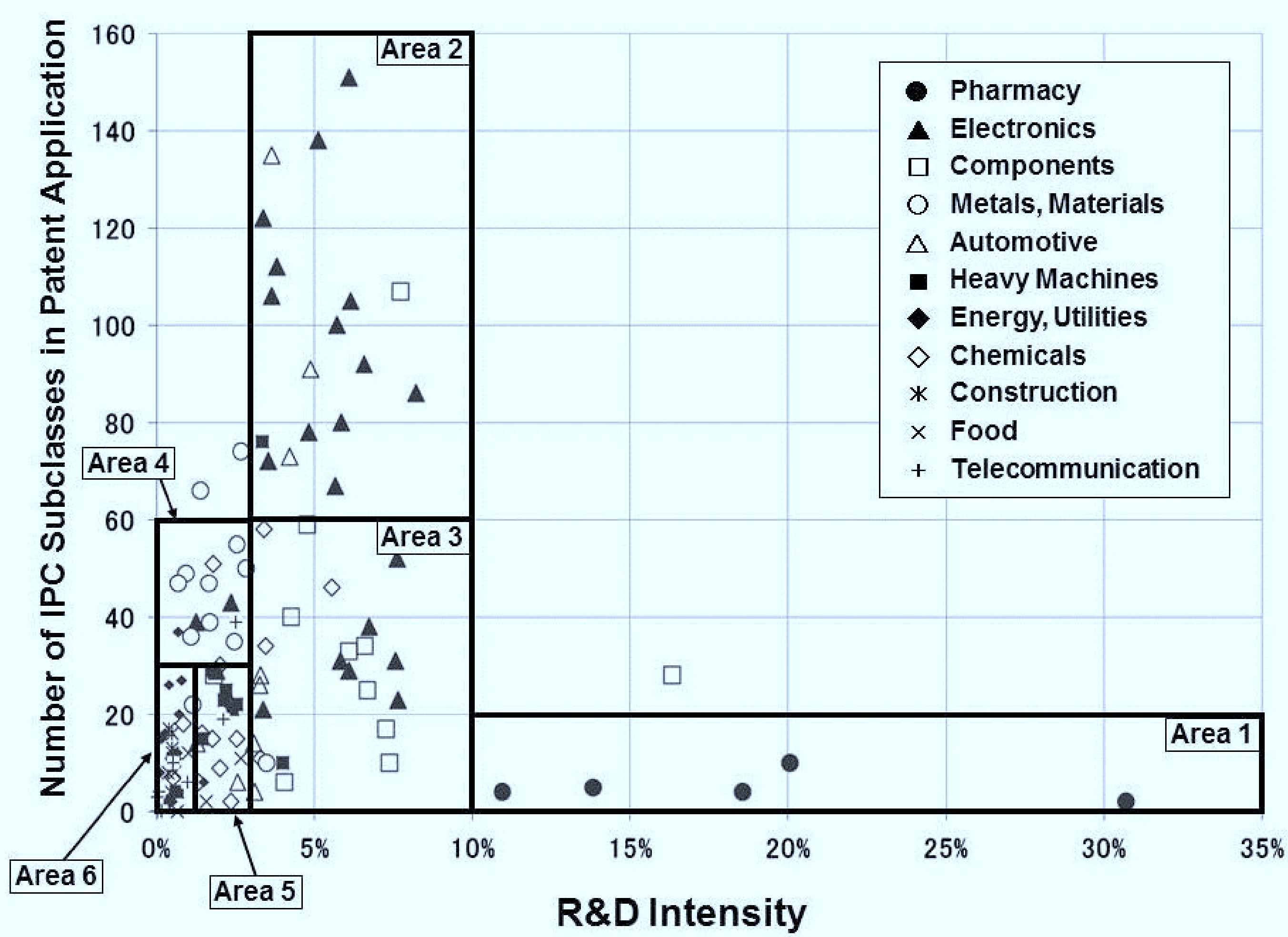

Figure 2. Relation between the R&D intensity and the range of R&D areas.

discuss the reasons for this tendency based on the analysis of R&D characteristics of pharmaceutical industry discussed in Chapter 3.

The background of active collaboration with universities in the pharmaceutical companies is closely related to the business model of the pharmaceutical industry. In the pharmaceutical business, securing a single patent of a new useful chemical compound is directly related to the success of a new business. However, the process of commercializing a new drug from a new chemical compound is long and complicated, involving many approval processes including various phases of clinical trials. Because it is common to take more than ten years from basic research to commercialization, pharmaceutical companies must make R&D investments over a very long term. Because the information about basic research is related directly to their business, pharmaceutical companies actively acquire external information that includes collaborative research with universities. Extremely heavy R&D investments made in a narrow business domain are readily apparent from the R&D characteristics of Fig. 2.

Ineffectiveness of the matching program for the pharmaceutical industry can be understood as a result of the uniqueness of the business model of the industry. Because R&D plays an important role in that industry, the R&D organizations of pharmaceutical companies are well structured. Corporate functions to manage R&D at their own research laboratories are usually centralized in the company. Corporate functions to control the external collaboration are also centralized. Because research areas for drug development are well defined, it is easy to monitor the most advanced technologies at universities, especially for a large pharmaceutical company with many in-house researchers. In addition, these companies possess established networks with academic researchers because of their long history of collaboration with universities.

Because pharmaceutical companies already have internal capabilities necessary to identify the most suitable university researchers and the capability to explore potential research needs inside a company, they do not need support from a matching program such as Proprius21. The low contribution of Proprius21 Program in generating collaborative research in life science areas is explainable in this way.

4.2 Collaborative Research Creation in Other Industries

To investigate the effectiveness of the matching program further, we analyzed the differences of the contributions of Proprius21 Program between the companies with various different R&D characteristics. The 117 companies[2] we studied in Chapter 3 were divided into four groups based on their R&D intensity and the range of R&D areas. For each group, we calculated the percentage of companies that created new collaborative research from Proprius21 Program.

Table 2 presents the result. Although 27.3% of the companies with R&D intensity of greater than 3% have created collaborative research from Proprius21 Program, it is only 8.2% for companies with R&D intensity of less than 3% that created collaborative research from Proprius21. It is clear that the matching program is effective for the companies with larger R&D intensity. Regarding the IPC subclass numbers, 30.0% of the companies with IPC subclass numbers of more than 60 have created collaborative research from Proprius21 and 12.4% of the companies with IPC subclass numbers less than 60 created collaborative studies from Proprius21. Clearly, companies with a wide range of businesses are more likely to use matching programs. If we compare the numbers between companies with both parameters high (R&D intensity > 3% and IPC subclass numbers > 60) and both parameters low (R&D intensity < 3% and IPC subclass numbers < 60), the difference is between 33.3% and 8.5%, which is also clear. These data support the hypothesis that we present in Chapter 2: "The broader the business area is and the more active the firm is in R&D, the more collaborative research will be created from matching program".

Table 2. Percentage of companies that created new collaborative research from the Proprius21 Program

	R&D Intensity < 3%	R&D Intensity ≥ 3%	Total
# of IPC Subclass ≥ 60	0.0%	33.3% (Area 2 in Fig.2)	30.0%
# of IPC Subclass < 60	8.5% (Areas 4,5,6 in Fig.2)	23.1% (Area 3 in Fig.2)	12.4%
Total	8.2%	27.3%	15.4%

The remainder of this section presents discussion of the creation process of collaborative research projects in industries other than pharmaceutical companies. Although quantitative analysis is difficult because of the wide variation among the few data points in each industry, some features are noticeable in some industries. For example, very large electronics and automotive companies are concentrated in the region in which both R&D intensity and R&D diversity are large. This region corresponds to Area 2 in Fig. 2. These companies conduct a wide range of businesses and possess a wide variety of technologies. Therefore, in general, collaborative research activities are high. It is noteworthy that much interdisciplinary collaborative research is performed in these companies. Collaboration with a university researcher is usually intended to complement the lack of internal accumulation in a certain area of technology. A matching program such as Proprius21 is suitable for creating an interdisciplinary research project. Therefore, it presents great potential to satisfy the R&D needs of such large corporations in electronics and automotive industries.

Many device and component companies and smaller electronics and automotive companies are located in the region where the R&D intensity is high but the IPC subclass numbers are low. This region corresponds to Area 3 in Fig.2. These companies tend to be R&D-oriented, but their business and technology areas are narrow. This characteristic is similar to the pharmaceutical companies in the sense that the company invests heavily in a narrow specific business area and it has no great incentive to explore for interdisciplinary research. Just like pharmaceutical companies, they tend to have well established internal information gathering functions including the network with universities. For that reason, a

[2] Pharmaceutical companies are excluded.

matching program is not so effective as for the companies in Area 2.

Companies in metal, steel and material industries are concentrated in Area 4 in Fig.2. If we calculate the percentage of companies created collaborative research from Proprius21 only for the companies in Area 4, the number is 21.4% which is close to the percentage for the companies in Area 3. These industries are likely to be equipment-intensive industries and, generally speaking, mature industries. However, the relatively larger IPC subclass number is regarded as an indication of a company's preference to diversify their businesses or to broaden their business area. Therefore, the potential exists for the matching program to play an important role for these companies. Actually, research projects initiated by Proprius21 Program with the companies in this region are often interdisciplinary research efforts.

Finally, for companies in the region where both R&D intensity and R&D diversity are low, a matching program is not so important because the companies in this region are not so active in R&D from the beginning. However, even for companies in this region, some collaborative research projects emerged from Proprius21. These projects are in a technology area that is separate from the company's core business. Company managers are considering expanding their businesses into new areas such as environment-related or new energy ventures, and started a long-term R&D project with university researchers. A matching program would be effective when a company wants to start a business in a new technology area without having either information or a network in that technology field.

As discussed in this section, collaborative research creation processes in certain industries can be characterized by their industry's R&D characteristics. A systematic matching approach to promote university–industry collaborative research is most effective for interdisciplinary collaborative research with a R&D-oriented company with a wide range of businesses.

4.3 Collaborative Research Creation Mechanism

This section presents discussion of more details related to the mechanism to create collaborative research.

In an early phase of the matching program, the Proprius21 Program prepares various opportunities for corporations to contact university researchers at various levels systematically. It includes information exchange among top management and specific research topic discussion between researchers in the front line. These contact opportunities are important for extending opportunities for creating collaborative studies.

After the open information exchange, the program proceeds into a phase that narrows down the research topic and selects researchers. One important success factor of Proprius21 Program is that a non-disclosure agreement is in place at this exploration phase. In a traditional mode of collaborative research, both university researchers and the company are hesitant to disclose their own technologies when it is uncertain if they will actually engage in collaboration. In this situation, companies must make a decision without having sufficient information about university technologies or about potential research partners. Under a non-disclosure agreement, companies can explore the most appropriate research topic and research partner by spending sufficient time for discussion about details of the research topic.

As discussed in the previous section, the Proprius21 Program is effective for creating cross-disciplinary research. Under the traditional collaborative research scheme, it is usually not easy for corporations to explore long-term interdisciplinary research because the research goals are not clear even for the corporation. The systematic matching program is effective in such interdisciplinary areas, but the effectiveness depends heavily on the program officers' abilities because they are the people to interpret the vague problem setting when even the company itself does not understand the problem. The process of identifying appropriate researchers and proposing them to the company is also important and requires skill at interpersonal relation. Over the long term, these skill sets must be systemized, but at this point it is heavily personnel-dependent.

Matching programs have other indirect effects both for people in the corporations and to university researchers. Because the relation starts systematically from the exploration phase, the commitment and motivation of the representative person from the company is clear from the beginning. Attitudes of university researchers often change in a positive way during discussions with industry personnel. Practical problem settings from the industry personnel sometimes stimulate researchers to initiate a new research project. Matching programs are not only effective for creating a research project; they are also effective in changing the mindsets of corporate and academic personnel.

5. Conclusions

As described in this paper, we investigated the effectiveness of a university–industry matching program at creating collaborative research projects by analyzing data related to a matching program, Proprius21, at the University of Tokyo as well as data related to the R&D characteristics of various Japanese firms.

The matching program has increased collaborative studies at the University of Tokyo in the past few years, but whether a matching program is effective in creating collaborative research or not depends considerably on the technology area.

It is effective to analyze R&D characteristics of respective firms using two parameters: firm R&D intensity and firm R&D range measured by the IPC subclass numbers that each company uses in patent applications. Using these two parameters, we found that the matching program is most effective in creating collaborative studies with technology-oriented firms engaged in various business domains. Large companies in ICT-related fields are most active in creating collaborative research from a matching program. We also found that a matching program is ineffective in life science technologies, which is the most active area overall for university–industry collaboration because the pharmaceutical industry, although it is heavily R&D-oriented, does not need the capabilities that a matching program provides. Pharmaceutical companies usually have their own organization to monitor and explore the most advanced university technologies and already have extensive networks with university researchers, which are the values that the matching program can provide to the companies. Our analysis confirms that firms with larger R&D activity and with broader business areas are more likely to benefit from a matching program when creating collaborative research projects with universities.

Some limitations exist for this study. Although establishing university–industry collaborative research projects in early stages of R&D is important, the ultimate goal of university–industry collaboration is to realize technological innovation through the practical use of the results of collaborative research. This study is limited to the analysis of creation process of collaborative research. Additional research is necessary to examine the actual commercialization process derived from the collaborative research. Because it has been only a few years since the Proprius21 Program was started at the University of Tokyo, it is too early to conduct quantitative research on the effects of commercialization. Another area for the future research will be to compare results obtained through this study with those from other universities. Although we believe that the analysis of the collaborative research at the University of Tokyo represents general trends of collaborative research in Japan because it accounts for about 10% of all university–industry collaborative research in Japan, future research is necessary to compare this study's results with those of other universities because there might be region-specific features.

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