Analysis of the Factors Influencing Patent Creation and Patent-based Technology Transfer in Universities

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Abstract—**It is indispensable for promoting open innovation that technology transfer from universities to private enterprises is performed successfully, and such awareness has been growing in recent years. However, it cannot be said that technology transfer has been actively implemented and has achieved the expected outcomes. It is generally difficult for universities and private enterprises to cooperate with each other. Many studies have pointed out the problems with technology transfer, but further studies are needed. We focused on patent creation and patent-based technology transfer, because universities have already created a lot of patents but have not yet conducted enough patent-based technology transfer corresponding to created patents. This study aims to reveal the factors influencing patent creation, meaning patent applications and patent rights, and patent-based technology transfer, meaning licensing and licensing income for universities. Based on the case of Japanese universities, data on patent creation, patent-based technology transfer, and influencing factors in universities were collected and analyzed. As a result, models explaining patent creation and patent-based technology transfer using influencing factors were derived. In addition, the differences between the models were grasped. Based on the results, improvements in the influencing factors of universities for promoting technology transfer are expected.**

I. INTRODUCTION

In the modern knowledge society, it is generally difficult for many enterprises to conduct all of the research and development that is necessary for their business. Open innovation, which is defined as the notion that valuable ideas can come from inside or outside a company, and can go to market from inside or outside a company as well [1], is proposed. Utilizing university resources, particularly in basic research, is one useful method to promote open innovation, and university patents are expected to play an important role. However, universities have a culture of publishing their research results as research papers and show little interest in patenting and transferring the results. Universities tend to lack appropriate systems for acquiring and transferring patents, and members of universities are generally inexperienced in dealing with patents. Although policies to promote university patents have been adopted in many countries, it cannot be said that sufficient results have been achieved. It is important to increase the number of university patents and their transfer to industries.

In considering this issue, it is necessary to understand the relationship between university patents and their influencing factors. The factors include various indexes of universities and the environments in which they operate. The relationship is expected to be comprehensive and quantitative as far as possible. Moreover, university patents involve various processes: for example, patent application, acquisition of patents, licenses of patents, and acquisition of license income. When all processes for university patents function successfully, university patents can greatly contribute to open innovation in industries. It is important to understand the relationship between the processes and influencing factors, and the differences in the relationships between the processes need to be considered. Based on such awareness, this study focuses on the comprehensive and quantitative relationship between university patents and influencing factors.

We conducted some studies that analyzed the relationship between university patents and influencing factors in the past. Yamaguchi et al. [2] collected and analyzed data on the PCT applications and influencing factors of 79 Japanese universities, and revealed that PCT applications are explained by 5 explanatory variables: joint research expenses, number of joint research, contract research expenses, number of venture companies, and single or multiple faculties. In addition, Yamaguchi et al. [3] collected and analyzed data on the technology transfer, industry-academia collaboration, basic research and other influencing factors of 85 Japanese universities, and roughly examined the three-layer structure among technology transfer, industry-academia collaboration and basic research. The former was limited to PCT applications as an explained variable, and the latter was limited to the general relationship among technology transfer, industry-academia collaboration, and basic research.

Based on above, this study aims to reveal the comprehensive and quantitative relationship between patent creation and patent-based technology transfer, and their influencing factors in universities, based on the case of Japanese universities.

II. BACKGROUND

A. Previous Studies

In this section, we review the extant studies analyzing factors that influence university patents. Table 1 presents a list

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Table 1 List of previous studies

Category	Previous study
Research activities	Geuna et al. [4], Wong et al. [5], Crespi et al. [6], Grimm et al. [7], Huang et al. [8], Sengupta et al. [9], Thompson et al. [10]
Funding	Coupé [11], Azagra-Caro [12], Lawson [13], Azagra-Caro [14], Guerzoni et al. [15], Fisch et al. [16], Szücs [17]
Institutional support	Bercovitz et al. [18], Dai et al. [19], Kawabata [20], Grimm et al. [21], Baldini et al. [22], Tseng et al. [23], Wu et al. [24], Walter et al. [25], Giuri et al. [26], Belitski et al. [27]
University type	Mathew [28]
Researcher situation	Sellenthin [29], Baldini et al. [30], Moutinho et al. [31], Göktepe-Hulten et al. [32], Davis et al. [33], Acosta et al. [34], Munshaw et al. [35]
Regional influence	Azagra-Caro et al. [36, 37], Acosta et al. [38], Hong et al. [39], Lee et al. [40], Mowery et al. [41]
Complex factors	Fisch et al. [42], Glauber et al. [43], Yamaguchi et al. [2]

of previous studies. In particular, we focus on those that reveal the factors causing differences between universities. The previous studies are classified into six categories based on the characteristics of the influencing factors.

The first is research activities. They create results that can be patented and transferred to industries. Patents and publications are closely related, although many have feared that an increase in university patenting could exacerbate financial resource and research outcome gaps among universities (Geuna et al. [4]). During 2003–2005, the patenting output of universities was significantly correlated with the quantity and quality of their scientific publications (Wong et al. [5]). The intensity of academic patenting complements publishing up to a certain level of patenting output (Crespi et al. [6]). A positive relationship between patenting and publishing activities has been demonstrated (Grimm et al. [7]). Countries with high production of papers and patents tend to produce more industry-academia collaborative papers and patents (Huang et al. [8]). A university's past performance along the research pillar strengthens the knowledge transfer pillar over time, through both commercialization and academic engagement channels (Sengupta et al. [9]). Citations to publications linked to licensed patents of which the discoveries are not covered by material transfer agreements (MTAs) are higher than those linked to licensed patents of which the discoveries are covered by MTAs (Thompson et al. [10]).

The second is funding. Funding supports research activities and consequently promotes patenting activities. The more funding academic research receives, the higher the number of university patents (Coupé [11]). There are various types of funding that can be broadly classified into public and private funding. University-owned patents are more responsive to specific public funding, while non-university-owned patents are more receptive to industrial funding (Azagra-Caro et al. [12]). Researchers who receive a large amount of industrial grants are more likely to file for a patent, and small dissemination of grants generally exerts a positive effect, irrespective of the funding source (Lawson [13]). Activities related to university-owned patents generally rely on business funding (Azagra-Caro [14]). It is noteworthy that university scientists partly funded by their own universities have a higher propensity to generate more original patents that those funded by industry or other non-university organizations (Guerzoni et al. [15]). A significant driver of patent quality and quantity is a subsidy program that promotes research excellence at selected universities; however, while such a program decreases the costs of patent applications and increases patent quantity, it does not enhance the quality of patents (Fisch et al. [16]). Owing to the EC's Seventh Framework Program, large-scale research subsidy programs, the number of project participants in general, and university participants in particular positively affect performance, but research centers do not exert positive externalities (Szücs [17]).

The third is institutional support. Three organizational capabilities of universities, information processing capacity, coordination capability, and incentive alignment, result in differences in technology transfer activities (Bercovitz et al. [18]). Institutional forces based on the Bayh-Dole Act spurred university patenting, but did not induce additional research funding (Dai et al. [19]). The effects of applicants' and inventors' status and the establishment of intellectual property headquarters at universities were found when examining patent applications by 12 Japanese national universities (Kawabata [20]). New public policy contributed to facilitating patent registrations, although professional expertise for the commercialization of knowledge as well as financial and organizational support schemes needed further improvement (Grimm et al. [21]). Universities first dealt with legislative change in IPRs by enacting isomorphic practices, then by creating a community of practices, and finally by leveraging this community to influence government reforms of IP-related matters (Baldini et al. [22]). Through evaluating the overall performance metric and patenting control ratio, a study gained understanding of the performance of the technology transfer offices (TTOs) at 20 major US universities (Tseng et al. [23]). TTOs' cost-saving measures positively influence licensing, but industry funding and TTO service effectiveness do not (Wu et al. [24]). Founding team characteristics (expert knowledge and entrepreneurial orientation) matter in weak organizational regimes, and in contrast, organizational patenting norms are the key driver of patenting in strong organizational regimes (Walter et al. [25]). The ownership arrangement of university patents and the presence of university-level support measures such as TTOs and linkages with science and technology parks are positively associated with women's involvement in academic patenting (Giuri et al. [26]). Research commercialization is not associated with the existence and awareness of TTOs or the establishment of commercialization contracts via TTOs (Belitski et al. [27]).

The fourth is university type. There are the differences in the three stages of technology transfer process between the

North American universities with medical schools and without medical schools (Mathew et al. [28]).

The fifth is researcher situation. The greater researchers' years of experience, the more likely they are to apply for patents (Sellenthin [29]). Excluding personal earnings as an incentive, it was revealed that university members who invented university-owned patents and were involved in patenting activities looked to enhance their prestige and reputation and searched for new research stimuli (Baldini et al. [30]). Scientists in general had a low propensity to become involved in patenting and licensing activities, despite the majority having no "ethical" objections to the disclosure and commercial exploitation of their inventions (Moutinho et al. [31]). Scientists' expectations of gaining financial benefits were not related to patenting activities without industrial cooperation and those of gaining or increasing reputation through commercial activities were correlated with patenting and disclosures activities (Göktepe-Hulten et al. [32]). A substantial proportion of scientists were skeptical about the impact of university patenting (Davis et al. [33]). The more diversified the patented technology in a university, the higher the frequency of new patent production in subsequent periods (Acosta et al. [34]). Human capital had a stronger influence than perceptions of resource availability on commercialization activities related to patent applications (Munshaw et al. [35]).

The fifth is regional influence. University national patents can be considered as indicators of regions' R&D efforts and patent applications denote how regions organize their university or joint research structures (Azagra-Caro et al. [36, 37]). Regional factors, such as the level of development, industrial potential, and regional higher education R&D expenditure, do not play any significant role in determining the quality of European university patents (Acosta et al. [38]). Geographic distance is an obstructive factor in achieving university-industry collaborations, and proximities in other dimensions could intervene to attenuate that negative effect (Hong et al. [39]). A strong positive relationship was found between nanoscience universities' reputation and the number of university-assigned patents, although this association is almost negligible for firm-assigned patents (Lee et al. [40]). Knowledge flows through market transactions are more geographically localized than those operating through nonmarket spillovers, and the differential effects of distance on licenses and citations are more pronounced for exclusively licensed university patents (Mowery et al. [41]).

The sixth is complex factors. Although a comprehensive analysis of factors influencing university patents is important, it is generally impossible to account for all factors due to data unavailability. After collecting and analyzing data on patent applications and the indexes of the top 300 universities, it was revealed that the propensity to apply for patents was high among US and Asian universities, whereas European universities lagged behind. Additional determinants of university patenting include the quantity of universities' publications, the technological focus in areas such as chemistry and mechanical engineering, university size, and publication quality (Fisch et al. [42]). Through analyzing patent application data on German universities, it was found that university size, university type, technical universities, and faculty profile affected patenting and the relationships among patenting experience, research breadth, research quality, and patent output (Glauber et al. [43]). The relationship between the PCT applications and influencing factors of 79 Japanese universities was revealed by Yamaguchi et al. [2].

Based on the above, the previous studies analyzing complex factors are thought to not be sufficient, and further studies are expected. Accordingly, it is meaningful for this study to focus on a comprehensive analysis of the various factors influencing university patents.

B. University Patents

In many countries, policy measures to promote university patents including the enactment of the Bayh-Dole Act and establishment of TTOs have been implemented. In regard to the Bay-Dole Act, many studies [44−45] on the relationship between university patents and the Bayh-Dole Act in the United States have been published. Outside of the United States, Baldini [51, 52] analyzed the influence of the Act in Denmark and Italy. Leydesdorff et al. [53] examined patent data on top universities across the world and further discussed the topic in a later study [54]. In Japan, the Industrial Technology Enhancement Act, the so-called Japanese Bay-Dole Act, was enacted in 2000 (tentatively enacted in 1999). Koide et al. [55] analyzed the effectiveness of the Act on the enterprises participating in national projects in Japan.

With regard to TTOs, some previous studies have already reviewed them. In Japan, the Act to Facilitate Technology Transfer from Universities to the Private Sector was enacted in 1998, and technology licensing offices (TLOs) have been established based on the Act. At present, there are 35 approved TLOs and 1 certified TLO [56]. Though an approved or certified TLO can acquire incentives from the government, the number of TLOs has decreased in recent years. Many TLOs cannot earn enough revenue to maintain their organizations, and of course, cannot recover the costs of research and development projects that created patents. A TLO model that emphasizes not the revenue of patent licenses but the revenue of creating joint activities by university researchers and enterprises was proposed [57]. Increasing the revenue of TLOs is an important issue..

According to the World Intellectual Property Organization [58], in 2017, 4 Japanese universities were listed among the top 51 PCT applicants of educational institutions, and the University of Tokyo ranked 13th, the highest among Japanese universities. Ranking first was the University of California, and American universities made up 7 universities among the top 10 and 24 among the top 51. Chinese universities made up 10 universities among the top 51, and Korean universities made up 3 among the top 10 and 5 among the top 51. It cannot be said that Japanese universities filed a large number of PCT applications. The Japan Patent Office reported that in 2017, Japanese universities filed 7,281 patent applications, which is less than the peak of 7,859 patent applications. The patent rate was 80%, which was higher than the rate of all applicants [59]. Japanese universities are expected to file more patent applications.

Based on the above, it is necessary to analyze the university patents and influencing factors of Japanese universities. It is expected that the results will be useful for improving the status of university patents.

III. METHODOLOGY

The analysis in this study was conducted in three steps. The first step was the collection of data. Data on the variables were gathered across six categories: patent activity, basic research, industry-academia collaboration, university location, university type, university scale, and student situation. These represent university patents and influencing factors, and have quantitative data available. Table 2 shows the list of variables. The patent activity shows patent creation (number of patent applications and number of patents) and patent-based technology transfer (number of license and amount of license income). The basic research indicates research papers and grants-in-aid for scientific research. The industry-academia collaboration indicates joint research projects, contract research projects and staff support. The university location means the geographical distances from industries. The university type includes founders and faculty composition. The university scale means the number of researchers and students. The student status means the number of students per researcher and difficulty of passing entrance examinations.

All data were gathered from 2014 to 2016 or FY 2014 to FY 2016 (April to March). Data related to the following variables were collected from the documents of the Ministry of Education, Culture, Sports, Science and Technology (MEXT):

Table 2 List of variables

	Category	Variable
Explained variable	Patent activity	Number of patent applications per researcher, Number of patents per researcher, Number of licenses per researcher, Amount of license income per researcher
Explanatory variable	Basic research	Number of research papers per researcher, Number of grants-in-aid for scientific research per researcher, Amount of grants-in-aid for scientific research per researcher
	Industry-academia collaboration	Number of joint research projects per researcher, Acceptance amount for joint research projects per researcher, Number of contract research projects per researcher, Acceptance amount for contract research projects per researcher, Scale of staff support for industry-academia collaboration per researcher
	University location	Gross prefectural production, Number of business establishments, Distance from Tokyo
	University type	National and public university, Single faculty, Engineering faculty, Medical faculty
	University scale	Number of researchers, Number of students
	Student situation	Number of undergraduate students per researcher, Number of graduate students per researcher, Deviation value for passing entrance examinations

number of patent applications per researcher, number of patents per researcher, number of licenses per researcher, amount of license income per researcher, number of joint research projects per researcher, acceptance amount for joint research projects per researcher, number of contract research projects per researcher, acceptance amount for contract research projects per researcher, scale of staff support for industry-academia collaboration per researcher, and number of researchers [60]. Data on the number of research papers per researcher were collected from the Web of Science [61]. For the variables on the number of grants-in-aid for scientific research per researcher and the amount of grants-in-aid for scientific research per researcher, data were collected from the documents of the Japan Society for the Promotion of Science [62]. Grants-in-aid for scientific research are competitive funds that aim to develop academic research and are delivered by peer review [63]. Data on gross prefectural production, number of business establishments, and distance from Tokyo were collected from the documents of the Japanese government [64−66]. Data related to the following variables were collected from the records of each university: number of undergraduate students per researcher, number of graduate students per researcher, national and public university, single faculty, engineering faculty, and medical faculty. Data on university type became dummy variables. Data related to deviation value for passing entrance examinations were collected from the documents of the Benesse Corporation [67]. Deviation value refers to the deviation value of engineering or medical faculties, the average of the deviation values of engineering and medical faculties, or the deviation value of the faculty conducting the most patent activities.

The second step was the analysis of influencing factors. The individual relationships between patent activities and influencing factors were analyzed. Correlation coefficients between them were calculated and discussed.

The third step was the creation of multiple regression models. Based on the above mentioned previous studies, it was understood that various factors influence university patents. Therefore, the comprehensive relationship between patent activities and influencing factors should be analyzed, and multiple regression model is suitable for such analysis. First, explanatory variables indicating negligible correlations ($0 \leqq |r| < 0.2$) with explained variables were deleted to select influencing explanatory variables. Second, explanatory variables indicating large variant inflation factors ($VIF \geqq 10$) were deleted to remove the influence of multicollinearity. Third, we extracted explanatory variables indicating sign inversions between correlation coefficients with explained variables and multiple regression coefficients, and explanatory variables indicating strong ($0.7 \leqq |r| \leqq 1$) or moderate ($0.4 \leqq |r| < 0.7$) correlation coefficients with the variables indicating sign inversions. Explanatory variables with the smallest t-value of the extracted explanatory variables were deleted to further remove the influence of multicollinearity. Fourth, the multiple regression models indicating the smallest Akaike's information criterion (AIC) [68] were adopted as the most applicable models. AIC can be calculated using (1). Based on the multiple regression models, the comprehensive relationship between patent activities and influencing factors was discussed.

$$AIC = n \times \ln(1 - R^2) + 2 \times k \qquad (1)$$

Note: "k" is the number of explanatory variables, "n" is the number of data samples, and "R^2" is the multiple coefficient of determination.

IV. Results

A. Collection of Data

Data on patent activities were collected from 277 universities, because the documents from MEXT provided information on 277 universities based on their survey responses. This represents only 35% of 782 universities that existed as of FY 2018 [69]. However, it is conceivable that the universities conducting patent activities above a certain level were included in these samples. Fig. 1 demonstrates the distribution of universities by number of patent applications. In order to obtain stable results from the analysis, 121 universities that filed 10 or more applications per year were selected as analysis subjects.

Table 3 displays the analyzed universities. They include 61 national universities, 16 public universities, and 44 private universities. Though private universities make up 77% of the 782 universities, only 36% were among the 121 universities chosen as analysis subjects. Moreover, they included 43 universities consisting of a single faculty, 78 universities consisting of multiple faculties, 93 universities with an engineering faculty, and 28 universities without an engineering faculty, 62 universities with a medical faculty and 59 universities without a medical faculty. Universities with an engineering faculty and medical faculty tended to file a large number of patent applications.

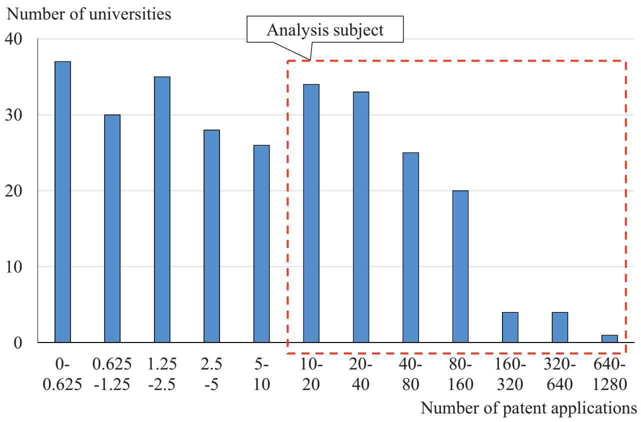

Fig. 1 Distribution of universities by number of patent applications

Table 3 Analyzed universities

	Single faculty / Multiple faculties	Engineering faculty / No engineering faculty	Medical faculty / No medical faculty	Total
National university	16	55	42	61
	45	6	19	
Public university	6	7	6	16
	10	9	10	
Private university	21	31	14	44
	23	13	30	
Total	43	93	62	121
	78	28	59	

Note: upper / lower

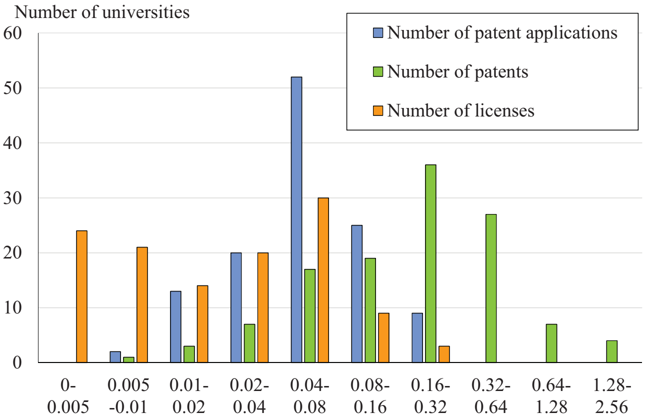

Fig. 2 Distribution of universities by number of patent applications, patents and licenses per researcher

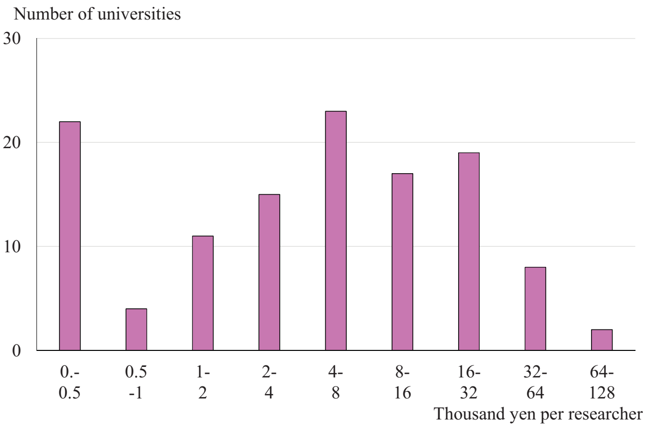

Fig. 3 Distribution of universities by license income per researcher

Figs. 2 and 3 illustrate the distribution of universities by number of patent applications, patents, and licenses per researcher and by license income per researcher. Due to the very large variations in these four variables, the horizontal axes were set as logarithmic axes. The number of patent applications and number of patents had maximum values at 0.04−0.08 and 0.16−0.04, respectively. However, the number of licenses and license income had two local maximum values at 0−0.005 and 0.04−0.08, and 0−0.5 and 4−8, respectively. It was found that the 121 universities could be classified roughly into 2 groups: universities with hardly any licenses or license income and universities with licenses and license income over a certain level.

Based on the above, data on the 4 explained variables and 20 explanatory variables of the 121 universities were collected.

B. Analysis of Influencing Factors

The individual relationships between patent activities and influencing factors were analyzed in six categories. The analysis was based on the explanatory variables with p-values

Table 4 Correlations with basic research

	Number of research papers per researcher	Number of grants-in-aid for scientific research per researcher	Amount of grants-in-aid for scientific research per researcher
Number of patent applications per researcher	0.453 ***	0.569 ***	0.562 ***
Number of patents per researcher	0.499 ***	0.593 ***	0.593 ***
Number of licenses per researcher	0.542 ***	0.605 ***	0.634 ***
Amount of license income per researcher	0.599 ***	0.473 ***	0.630 ***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

less than 0.05. The first category is basic research. Table 4 presents the correlations with basic research. Though grants-in-aid for scientific research are one funding system, they were included under basic research because strong correlations with basic research have been found [3]. Moderate correlations were found in all of the cells. It can be said that basic research certainly has a positive influence on all patent activities.

The second category is industry-academia collaboration. Table 5 presents the correlations with industry-academia collaboration. The scale of staff support for industry-academia collaboration was included not under institutional support but under industry-academia collaboration. Strong correlations in 4 cells, moderate correlations in 12 cells, and weak correlations ($0.2 \leqq |r| < 0.4$) in 3 cells were found. The correlations were relatively stronger in number of patent applications and number of patents, and relatively weaker in number of licenses and amount of license income. The scale of staff support for industry-academia collaboration has a roughly positive influence on patent activities.

The third category is university location. Table 6 presents the correlations with university location. University location indicated prefectures where universities are mainly located. Only negligible correlations were found in all of the cells. The reason is that many private universities are located in metropolises. On the contrary, national universities are distributed across all prefectures, and the status of prefectures is reflected in the scales and faculties of national universities to a certain extent.

Table 5 Correlations with industry-academia collaboration

	Number of joint research projects per researcher	Acceptance amount for joint research projects per researcher	Number of contract research projects per researcher	Acceptance amount for contract research projects per researcher	Scale of staff support for industry-academia collaboration per researcher
Number of patent applications per researcher	0.822 ***	0.809 ***	0.525 ***	0.542 ***	0.436 ***
Number of patents per researcher	0.782 ***	0.747 ***	0.478 ***	0.464 ***	0.426 ***
Number of licenses per researcher	0.572 ***	0.659 ***	0.448 ***	0.422 ***	0.230 *
Amount of license income per researcher	0.323 ***	0.571 ***	0.369 ***	0.559 ***	0.055

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

Table 6 Correlations with university location

	Gross prefectural production	Number of business establishments	Distance from Tokyo
Number of patent applications per researcher	-0.007	0.004	-0.053
Number of patents per researcher	-0.032	-0.040	-0.058
Number of licenses per researcher	0.030	0.024	-0.021
Amount of license income per researcher	0.054	0.057	-0.097

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

Table 7 Correlations with university type

	National and public university	Single faculty	Engineering faculty	Medical faculty
Number of patent applications per researcher	0.282 ***	0.296 ***	0.295 ***	-0.369 ***
Number of patents per researcher	0.355 ***	0.229 *	0.375 ***	-0.283 ***
Number of licenses per researcher	0.325 ***	0.077	0.298 ***	-0.136
Amount of license income per researcher	0.200 *	0.026	0.154	0.096

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

Table 8 Correlations with university scale

	Number of researchers	Number of students
Number of patent applications per researcher	-0.100	-0.157
Number of patents per researcher	-0.073	-0.121
Number of licenses per researcher	0.137	0.021
Amount of license income per researcher	0.479 ***	0.166

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

The fourth category is university type. Table 7 presents the correlations with university type. Positive weak correlations in nine cells and negative correlations in two cells were found. In other words, national and public, and single universities with engineering faculties and without medical faculties indicated positive correlations. The reason for the negative correlations is the large number of researchers at the universities with medical faculties. The correlations were relatively stronger in number of patent applications and number of patents, and relatively weaker in number of licenses and amount of license income.

The fifth category is university scale. Table 8 presents the correlations with university scale. Only a moderate correlation was found in one cell. The reason for this correlation is that some national universities with large numbers of researchers gain large amounts of license income. These universities include seven former imperial universities.

The sixth category is student situation. Table 9 presents the correlations with student situation. A strong correlation in one cell, moderate correlations in two cells, and weak correlations in two cells were found. Number of graduate students has a positive influence on patent activities. The reason for these positive correlations is that graduate students support

Table 9 Correlations with student situation

	Number of undergraduate students per researcher	Number of graduate students per researcher	Deviation value for passing entrance examinations
Number of patent applications per researcher	-0.131	0.690 ***	-0.119
Number of patents per researcher	-0.161	0.710 ***	-0.109
Number of licenses per researcher	-0.153	0.571 ***	0.046
Amount of license income per researcher	-0.159	0.310 ***	0.262 ***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

researchers in conducting patent activities through their research activities. Though the correlations were negligible, number of undergraduate students had a negative influence on patent activities. The reason for the negative correlations is that a large number of undergraduate students becomes an educational burden on researchers that disturbs their patent activities. Regarding the deviation value for passing entrance examinations, it can be said that universities with high deviation values tend to acquire large amounts of license income.

The above analysis makes it clear that basic research, industry-academia collaboration, university type (except for medical faculties), and number of graduate students have roughly positive influences on patent activities. Further, it is evident that the correlations were relatively stronger in patent creation (number of patent applications and number of patents), and relatively weaker in patent-based technology transfer (number of licenses and amount of license income).

C. *Creation of Multiple Regression Models*

The comprehensive relationships between patent activities and influencing factors were analyzed. Four multiple regression equations were derived. Of the 80 candidates for explanatory variables, 32 were deleted due to negligible correlations. Seven of the remaining 48 candidates were deleted due to large VIFs. Twenty candidates were deleted due to sign inversions. Four of the remaining 21 candidates were then deleted due to AIC. As a result, 17 explanatory variables were selected and 4 multiple regression equations were derived.

Table 10 demonstrates the multiple regression equations. Number of patent applications, number of patents, number of licenses, and amount of license income were explained by six, six, two, and three explanatory variables, respectively, and the multiple coefficients of determination were 77.6%, 70.7%, 45.3%, and 47.7%, respectively. The F-values were 65.8, 45.9, 48.9, and 35.6, respectively, and all the significances of F-values were much less than 0.01. The p-values of 14 explanatory variables were less than 0.05 and the p-value of one explanatory variable was more than 0.05. Patent creation was relatively sufficiently explained and patent-based technology transfer was relatively insufficiently explained.

Table 10 Multiple regression equations

	Number of patent applications per researcher			Number of patents per researcher			Number of licenses per researcher			Amount of license income per researcher (thousand yen)		
	Multiple regression coefficient	Standardized multiple regression coefficient	p-value	Multiple regression coefficient	Standardized multiple regression coefficient	p-value	Multiple regression coefficient	Standardized multiple regression coefficient	p-value	Multiple regression coefficient	Standardized multiple regression coefficient	p-value
Number of research papers per researcher										3.53	0.256	0.008
Number of joint research per researcher	0.0815	0.216	0.029									
Acceptance amount for joint research per researcher (thousand yen)	0.0826	0.486	0.000	0.332	0.390	0.000	0.0876	0.616	0.000	14.9	0.340	0.000
Scale of staff support of industry-academia collaboration per researcher				0.00161	0.117	0.040						
National or public university	0.0146	0.121	0.034	0.104	0.172	0.003	0.0146	0.145	0.045			
Single faculty	0.0137	0.113	0.027	0.127	0.209	0.002						
Engineering faculty				0.0999	0.145	0.046						
Medical faculty	-0.0217	-0.186	0.002									
Number of researchers										0.00389	0.272	0.001
Number of graduate students per researcher	0.00545	0.100	0.162	0.0777	0.286	0.000						
Constant	0.0164			-0.172			-0.00224			-5.56		
R^2		0.776			0.707			0.453			0.477	
F-value		65.8			45.9			48.9			35.6	
Significance of F-value		0.000			0.000			0.000			0.000	

Regarding the explanatory variables, one variable in basic research, six variables in industry-academia collaboration, seven variables in university type, one variable in university scale, and two variables in student situation were included in the multiple regression models. In particular, the acceptance amount for joint research projects was included in all models, and only medical faculties indicated a negative multiple coefficient. The most influential explanatory variable was acceptance amount for joint research projects per researcher, which was common to four multiple regression models. Amount of license income, number of research papers, and number of researchers had certain influence. It is conceivable that famous universities including the seven former imperial universities have an advantage in acquiring license income.

From the above, four regression models were derived, and the quantitative influence of the explanatory variables on patenting activities was revealed.

V. Discussion

The results revealed in section B of chapter Ⅳ are partially supported by a number of previous studies. The positive influence of research activities (number of research papers) was indicated by Geuna et al. [4], Wong et al. [5], Crespi et al. [6], Grimm et al. [7], Huang et al. [8], Sengupta et al. [9], Thompson et al. [10], Fisch et al. [42], and Glauber et al. [43]. The positive influence of funding (grants-in-aid for scientific research, joint research and contract research) was indicated by Coupé [11], Azagra-Caro et al. [12,14], Lawson [13], Guerzoni et al. [15], Fisch et al. [16], Szücs [17], and Yamaguchi et al. [2]. The positive influence of institutional support (scale of staff for industry-academia collaboration) was indicated by Bercovitz et al. [18], Dai et al. [19], Kawabata [20], Grimm et al. [21], Baldini et al. [22], Tseng et al. [23], Wu et al. [24], Walter et al. [25], and Giuri et al. [26].

In contrast, a positive or negative influence by university location was not found in this study. However, a regional influence was indicated by Azagro-Caro et al. [36, 37], Hong et al. [39], Lee et al. [40], and Mowery et al. [41]. As mentioned in section B of chapter Ⅳ, a significant influence by university location might be found if the focus is limited to national universities. Table 11 shows the correlations with the locations of national universities. A moderate correlation in one cell and weak correlations in nine cells were found. As for distance from Tokyo, the shorter the distance, the larger the number of patent applications and patents. It can be said that university location has a roughly positive influence on patent activities as far as national universities go.

Four multiple regression models were created in section C of chapter Ⅳ. Though the most influential explanatory variable that was common to all four models was the acceptance amount for joint research projects, it is conceivable that this variable might have been selected instead of the other variables. Table 12 shows the variables having correlations with the acceptance amount for joint research projects per professor, provided that the correlations are limited to strong or moderate correlations. Acceptance amount for joint research projects had strong correlations with the amount of grants-in-aid for scientific research, number of joint research projects, and acceptance amount for contract research projects, and moderate

Table 11 Correlations with university location (national universities)

	Gross prefectural production	Number of business establishments	Distance from Tokyo
Number of patent applications per researcher	0.385 ***	0.419 ***	-0.301 *
Number of patents per researcher	0.299 *	0.317 *	-0.252 *
Number of licenses per researcher	0.301 *	0.314 *	-0.153
Amount of license income per researcher	0.344 **	0.350 **	-0.194

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

Table 12 Variables having correlations with acceptance amount for joint research per researcher

	Number of research papers per researcher	Number of grants-in-aid for scientific research per researcher	Amount of grants-in-aid for scientific research per researcher	Number of joint research projects per researcher
Acceptance amount for joint research projects per researcher	0.631 ***	0.646 ***	0.742 ***	0.808 ***

	Number of contract research projects per researcher	Acceptance amount for contract research projects per researcher	Number of graduate students per researcher
Acceptance amount for joint research projects per researcher	0.595 ***	0.775 ***	0.653 ***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p \ll 0.01$.

correlations with number of research papers, number of grants-in-aid for scientific research, number of contract research projects, and number of graduate students, and these unselected variables certainly have a positive influence on patent activities.

Based on these results, it is necessary to improve the explanatory variables in the four multiple regression models and the unselected variables that influence patent activities. In particular, the variables in basic research and industry-academia collaboration and the number of graduate students should be improved. The deviation value for passing entrance examinations is expected to be improved so as to increase the amount of license income. However, the variables university type and number of researchers are generally difficult to improve.

The results have limited application to other countries, because the situation and characteristics of universities differ by country. When utilizing the results in other countries, it is necessary to consider such difference. We do believe the results provide useful information for other countries.

In this study, available and quantitative data were collected and analyzed, and data restrictions became limitation. Though patent creation was explained sufficiently, patent-based technology transfer could not be explained sufficiently. In regard to future studies, in order to acquire more sufficient models explaining the patent activities of universities, it is necessary to collect qualitative and quantitative data on universities' management, systems, organizations and cultures, researchers' characteristics, and regional influences on universities.

VI. CONCLUSION

This study aimed to reveal the comprehensive and quantitative relationship between patent creation and patent-based technology transfer, and their influencing factors in universities. Data on 121 Japanese universities were collected and analyzed. As a result, it was understood that basic research, industry-academia collaboration, university type and number of graduate students have an influence on patent activities, and in particular, the number of researchers and deviation value for passing entrance examinations have an influence on the amount of license income. Moreover, four multiple regression models were created to explain patent activities using influencing factors.

In terms of policy implications, it is necessary to improve the explanatory variables in the four multiple regression models and the unselected variables that influence patent activities. As for future studies, it is necessary to collect qualitative and quantitative data on universities' management, systems, organizations and culture, researchers' characteristics, and regional influences on universities to create more sufficient models to explain patent activities.

Finally, we hope that the results are useful in general to university management and for planning policy measures.

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