

Trends in and Factors Influencing PCT Applications by Japanese Universities

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Abstract—To promote the creation of innovations, it is imperative that new technologies by universities are patented and transferred to private companies. This study aims to reveal the trends in and factors influencing PCT applications by Japanese universities. Data on 4,158 applications for 2008–2012 were collected from the J-PlatPat database and those for university performance, research activities, and industry–academia collaboration were compiled from documents of universities and the Japanese government. The results revealed that PCT applications are mainly filed in the engineering and medicine fields, of which 45.4% are joint applications with private companies. In addition, we perform a multiple regression analysis to obtain the number of PCT applications per professor using five explanatory variables ($R^2 = 70.7\%$). The results elucidated that PCT applications were influenced by industry–academia collaboration and faculty structure. In conclusion, it is conceivable that PCT applications by Japanese universities have the potentialities for technology transfers from universities to private companies.

I. INTRODUCTION

Prompt patenting by universities of their new technologies and the smooth transfer of these technologies to private companies are essential to promote innovation creation. According to the 4th Science and Technology Basic Plan [10], the Japanese government should strengthen its support for universities to acquire patents within and outside of Japan as a policy measure to promote science and technology innovation. To this effect, the Intellectual Property Strategic Program 2015 [22] deems necessary policy measures to improve the utilization ratio of university patents, which include the evaluation of universities' industry–academia collaboration and proof of concept, that is, technology transfers from universities to small and medium-sized enterprises (SMEs).

Given this growing awareness, in 1998, the Act on the Promotion of Technology Transfer from Universities to Private Business Operators (TLO Law) was enacted, followed by the Act on Special Measures for Industrial Revitalization (Article 30, also the Japanese version of the Bayh–Dole Act) in 1999. To strengthen universities' intellectual property systems, several TLOs approved by the TLO Law were established, of which 46 TLOs exist in Japan (Japan Patent Office (JPO) [37]). During FY 2003–2007, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) [34] conducted the Development Project of University Intellectual Property Headquarters, which included the establishment of 34 intellectual property

headquarters at universities.

As a result of these policy measures, the number of university patents has significantly increased, although their utilization remains limited. According to MEXT [37], in FY 2014, Japanese universities filed 9,157 patents applications, acquired 31,002 patents, and generated a licensing income of 1,992 million yen. However, this increase in licensing income from the previous status is still less than the number of patents. This is because Japanese universities file numerous patents applications and acquire patents without evident prospects that their patents will be capable of industrial applications. It is generally difficult for universities to examine the capability of industrial applications for each patent and many of them have applied for and acquired patents in response to MEXT's policies to increase university patents.

There are various types of patent applications and domestic and PCT applications differ by circumstance. In general, PCT applications entail higher costs and efforts than domestic ones, and therefore, universities filing PCT applications must conduct a more stringent examination of their usefulness. However, because of the need to provide documents in a foreign language and communicate with foreign patent offices, Japanese universities often find the process cumbersome.

According to the World Intellectual Property Organization (WIPO) [56], in 2014, five of Japanese universities were listed among the top 51 PCT applicants for educational institutions and Kyoto University ranked 14th, the highest of Japanese universities. American universities ranked 11th and 13th and Korean and Singaporean universities ranked 10th and the 12th. Although Japanese universities filed a few PCT applications considering that Japan as a whole accounted for 19.8% of the world's applications, a significant number of their technologies were considered important. Thus, a study on PCT applications by Japanese universities can provide key insights to promote technology transfers from universities to private companies. Accordingly, this study aims to reveal the trends in and factors influencing PCT applications by Japanese universities.

II. BACKGROUND

In this section, we review the literature for studies analyzing factors influencing university patents.

The Bayh–Dole Act, the first of which was enacted in 1980 in the United States, is one of the most historically

significant events in terms of university patents. Since then, similar acts and laws promoting technology transfers have been implemented across countries and numerous studies have been conducted on the relationship between university patents and the Bayh–Dole Act in United States [21], [41, 42, 43], [47], [48], [51]. Outside of the United States, Baldini [7] analyzed the influence of the Act in Denmark and Italy [9]. Leydesdorff et al. [32] examined patent data for top universities across the world and further discussed the topic in a later study [33]. The present study, however, does not focus on the Bayh–Dole Act, but the ensuing policy measures that were implemented for university patents.

A key factor influencing university patents is funding that supports research activities and promotes patenting activities; the more funding academic research receives the higher the number of university patents [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 [3]. Researchers who receive a large amount of industrial grants are more likely to file for a patent, and small dissemination of grants generally exert a positive effect, irrespective of the funding source [30]. Activities for university-owned patents generally rely on business funding [6]. It is noteworthy that university scientists partly funded by their own universities have a higher prosperity to generate more original patents than those funded by industry or other non-university organizations [20]. 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 costs of patent applications and increases patent quantity, it does not enhance the quality of patents [14].

The second influencing factor is research activities producing 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 [15]. During 2003–2005, the patenting output of universities was significantly correlated with the quantity and quality of their scientific publications [53]. Grimm et al. [19] in their study demonstrated a positive relationship between patenting and publishing activities.

Third is public support researchers receive from public infrastructure and their experience in using the patenting system; the greater the years of experience the more likely researchers are to apply for patents [49]. Grimm et al. [18] found that 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. Studies have also examined the influence of researchers' personal factors. Excluding personal earnings as an incentive, Baldini et al. [8] found that university members who invented university-owned patents and involved in patenting activities

looked to enhance their prestige and reputation and for new research stimuli. Moutinho et al. [40] found that scientists in general had a low prosperity to become involved in patenting and licensing activities, despite the majority having no “ethical” objections to the disclosure and commercial exploitation of their inventions. Göktepe-Hulten et al. [17] showed that scientists' expectations of gaining financial benefits were not related with patenting activities without industrial cooperation and those of gaining or increasing reputation through commercial activities were correlated with patenting and disclosures activities. A substantial proportion of scientists were skeptical about the impact of university patenting [12].

To the effect of regional influence, university national patents can be considered an indicator of regions' R&D efforts and patent applications denote how regions organize their university or joint research structure [4, 5]. 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 [31]. The more diversified the patented technology in a university, the higher the frequency of new patent production in subsequent periods [1].

Although a comprehensive evaluation of factors influencing patents is important, it is not possible to account for all of the above-mentioned factors owing to data availability. Fisch et al. [13] collected and analyzed data for patent applications and the indexes of the top 300 universities and 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, technological focus in areas such as chemistry and mechanical engineering, university size, and publication quality. Glauber et al. [16] analyzed patent application data for German universities and found that university size, university type, technical universities, and faculty profile affected patenting and relationships among patenting experience, research breadth, research quality, and patent output.

According to Fisch et al. [13], 10 Japanese universities were ranked among the top 300 universities. WIPO [55] announced the universities with high ranking in terms of PCT applications, although this information is limited and the status of several Japanese universities is yet to be revealed. Therefore, we review preceding studies analyzing patents by Japanese universities. Several studies have been conducted on the patents of specific universities and technological fields; however, we focus on research analyzing patents by Japanese universities and in technological fields.

Kyoto Comparative Law Center [29] collected data for PCT and direct applications for Japan, the United States, and Europe by six Japanese universities and 22 American universities for 2004–2007. It presented the numbers of applications, technological fields, filing countries, and those with priority right claims and accordingly, compared

Japanese with American universities. On the basis of these analyses, an overseas patent application strategy for Japanese universities and policy measures promoting international patent applications were suggested.

As for studies examining patent applications including PCT applications, the following seven studies were referenced. MEXT [36] conducted a survey on industry–academia collaboration among Japanese universities for each fiscal year. It revealed the survey results for FY 2003–2014 and the numbers of patent applications and licenses and the amount of licensing income for each university for FY2008–2014. Kanama et al. [26] collected and compared patent application data for three universities—Tsukuba University, Hiroshima University, and Tohoku University—published from 1993 to 2006. The National Institute of Science and Technology Policy (NISTEP) [45] examined patent application data for the top 52 universities and top 5 public research institutes in 2006 and compared the patent portfolios of the 57 universities and institutes across eight fields. Mitsubishi Research Institute, Inc. [38] analyzed the patent applications of universities and TLOs whose patents were granted or refused from 1998 to 2008 and conducted a comparative analysis between university and industrial patents, revealing the characteristics of patents applied after national university corporation, trends of deficient descriptions, and qualitative trends of the scope of rights. The University of Tokyo [52] studied industry–academia collaboration patent applications, including university and private company inventors, from 1964 to 2008, and data for private companies and universities. The results revealed that the quantity of applications increased as a result of policy measures (e.g., the 1998 TLO Law) aimed at promoting industry–academia collaboration, joint applications with private companies increased particularly after the national university corporation in 2004, and the quality of applications did not decline post 2000. Kawabata [27] examined patent applications by 12 national universities that filed more than 300 applications during FY 2001–2006 and demonstrated the effects of applicants and inventors' status and the establishment of intellectual property headquarters at universities. Finally, using patent data for Japanese universities, Motohashi et al. [39] revealed that university–industry collaboration (UIC) policies increased the number of UIC patents in the late 1990s and the quality of these patents did not decline during this period.

From the reviewed literature, it appears that collecting data for PCT applications and indexes and activities of Japanese universities and comprehensively analyzing the relationship between PCT applications and factors influencing them are crucial. We applied a multiple regression analysis to examine and formulate this relationship, which is unique feature of this study.

III. METHODOLOGY

We conducted this study using the following four steps.

First, we collected data for PCT applications by all Japanese universities using J-PlatPat [44], not the WIPO database [54]. J-PlatPat is a database for industrial property rights published by the National Center for Industrial Property Information and Training under the jurisdiction of JPO. Although some of the PCT applications were filed by Japanese universities to foreign countries, we assumed that all translated documents by default were submitted to JPO. The submission deadline for translated documents is 30 months, and therefore, the most recent year for available data is 2012. Accordingly, we collected PCT applications from 2008 to 2012. The keywords used for our searches on J-PlatPat were “university,” “educational corporation,” and the names of TLOs [23]. In the case of private universities, the applicants generally included educational corporations, whose names could not always be retrieved using “university.” In some cases, the applicants were TLOs instead of universities. We focused on Japanese universities to examine applicants and inventors, excluding all data for applications by foreign universities.

Second, we analyzed the trends of PCT applications. The applications were classified into technological fields on the basis of IPC [57] and then further categorized into applicant types: university applications or joint applications with private companies.

Third, we collected data on universities' performance, research activities, and industry–academia collaboration activities. Data were gathered from FY 2007 to FY 2011 because we assumed a time lag between technology development and patent applications. The data for the following categories were collected: (1) university scale (2) student status (3) research funds (4) industry–academia collaboration (5) difficulty level of entrance examinations, and (6) university type. Data for categories (1), (2), and (6) were collected from the university websites and the University Rankings site [2]. Data for category (6) served as dummy variables. Data for categories (3) and (4) were compiled from Japanese government documents [36], university websites, and the University Rankings site [2]. We referred documents by the Japan Society for the Promotion of Science (JSPS) for data on the grants-in-aid for scientific research [24] and the survey results of NISTEP for data on university-oriented venture companies [46]. Data for category (5) were collected from the University Rankings site [2].

Finally, we analyzed the factors influencing PCT applications. To do so, we conducted a multiple regression analysis including dummy variables. The explained variable is number of PCT applications per professor and the explanatory variables are those indicating university performance and activities.

The explanatory variables were selected using the following method. We first excluded variables with small correlation coefficients and attempted to remove any multicollinearity. Second, variables with large variation inflation factors (VIF) were deleted. Third, variables causing sign inversions between single and multiple correlation coefficients were identified, and among these, variables with

the lowest correlation coefficients were deleted. This analysis was repeated until all variables causing sign inversions were eliminated. Finally, we selected the most applicable model using Akaike's information criterion (AIC) [28]. Variables with the lowest t-value (absolute value) or largest p-value were deleted in order and the AIC of each model was calculated. The model with the lowest AIC was selected as the most applicable multiregression model.

IV. RESULTS

A. PCT applications

We collected data for a total of 4,158 PCT applications and created a database of these applications for the purpose of this study. The database included information on applications and publications dates,

IPC indexes, applicants, and applicant types (university applications, joint applications with domestic companies, joint applications with foreign companies, and joint applications with domestic companies and foreign companies). Fig. 1 shows the number of PCT applications by Japanese universities and its overall trend for 2008–2012. The highest number of applications is 908 in 2010 and the lowest is 714 in 2008, with an average of 831.

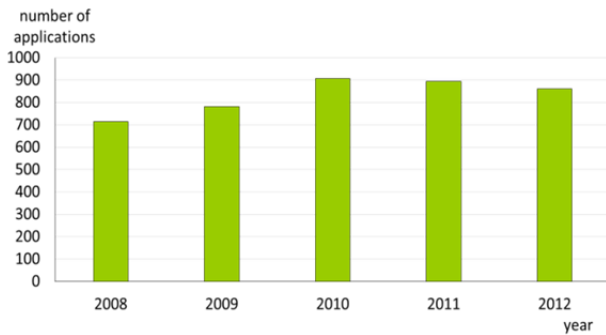


Fig. 1 Transition of PCT applications of Japanese universities

B. PCT application trends

Fig. 2 depicts the distribution of Japanese universities'

PCT applications by IPC [57]. The field with the highest number of applications was chemistry and metallurgy (36.2%), followed by human necessity (23.9%), physics (17.0%), and electricity (12.8%). Those with few applications and large deviations are fixed constructions; textiles and paper; and mechanical engineering, lighting, heating, weapons, and blasting.

To further examine these classifications, category C included applications for chemical products and metallic material; category A included applications for pharmaceutical products; category G covered those for measuring instruments, optical instruments, and computers; and category H comprised electric and electronic devices. Thus, the PCT applications were mainly concentrated in the fields of engineering and medicine.

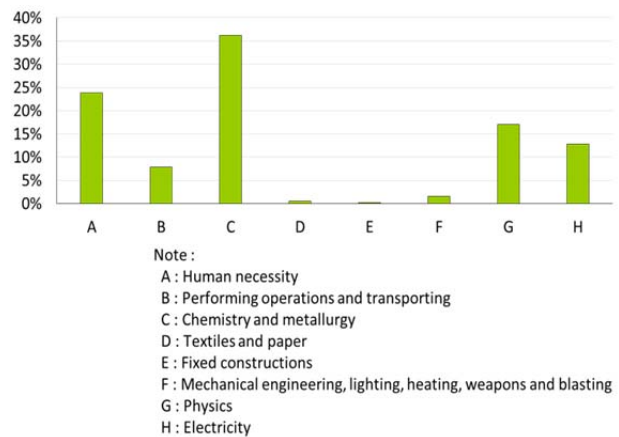


Fig. 2 Distribution of PCT applications of Japanese universities by IPC

Table 1 presents the ratios of joint applications to applicants excluding universities. Of the total, joint applications with private companies and joint applications with domestic private companies accounted for 45.4% and 44.5%. The private companies in this study also included few domestic and foreign public institutes and universities.

Table 1 Ratios of joint applications with the applicants excluding universities

year	2008	2009	2010	2011	2012	Total
Joint applications with domestic companies	47.9%	42.5%	42.2%	43.9%	46.5%	44.5%
Joint applications with foreign companies	0.4%	0.1%	1.0%	0.9%	0.8%	0.7%
Joint applications with domestic companies and foreign companies	0.3%	0.5%	0.0%	0.1%	0.1%	0.2%
(University applications)	51.4%	56.9%	56.8%	55.1%	52.6%	54.6%

IPC	A	B	C	D	E	F	G	H
Joint applications with domestic companies	42.5%	51.1%	45.8%	67.7%	42.9%	41.2%	41.5%	48.6%
Joint applications with foreign companies	0.6%	1.0%	0.9%	0.0%	0.0%	0.0%	0.4%	0.7%
Joint applications with domestic companies and foreign companies	0.2%	0.2%	0.3%	0.0%	0.0%	3.1%	0.3%	0.2%
(University applications)	56.7%	47.7%	53.0%	32.3%	57.1%	55.7%	57.8%	50.4%

The ratio for joint applications was 43.1% to 48.6% during 2008–2012, with the difference between the highest and lowest being 5.4%. The ratio for joint applications in eight fields by IPC [57] was 42.2% to 67.7%, with the difference between the highest and lowest being 25.6%.

C. University performance and activities

Fig. 3 shows the numbers of universities by total applications filed. A total of 171 universities filed applications and the highest number of applications was 321, followed by 298 and 272. About 34 universities filed one application and 92 universities filed nine or less applications. To analyze the relationship between the number of applications and university performance and activities, universities (79) that filed 10 or more applications were selected.

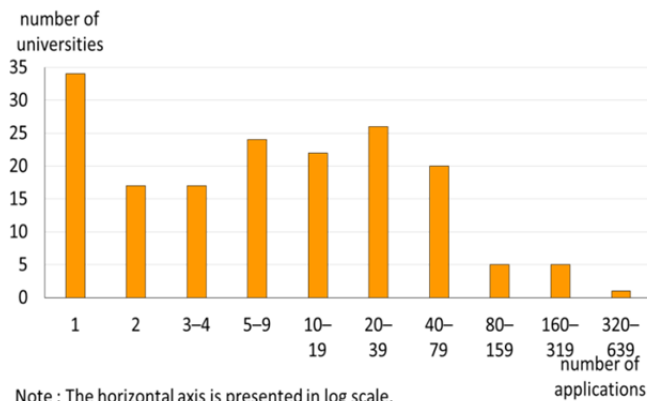


Fig. 3 Number of universities by numbers of applications

Table 2 presents the details of universities that filed 10 or more applications: 53 universities (67.1%) were national universities, eight were public universities (10.1%), and 18 were private universities (22.8%). The top 10 universities with more than 100 applications comprised nine national universities and one private university. Data for the performance and activities of these 79 universities were then collected for an average of five years to remove any influence of annual fluctuations.

Fig. 4 illustrates the number of universities by total applications filed per professor. A total of 25 universities reported total applications filed per professor of 0.005–0.01, with many universities distributed within and around this range. The highest number of applications per professor was 0.0436 and reported by a national single faculty university.

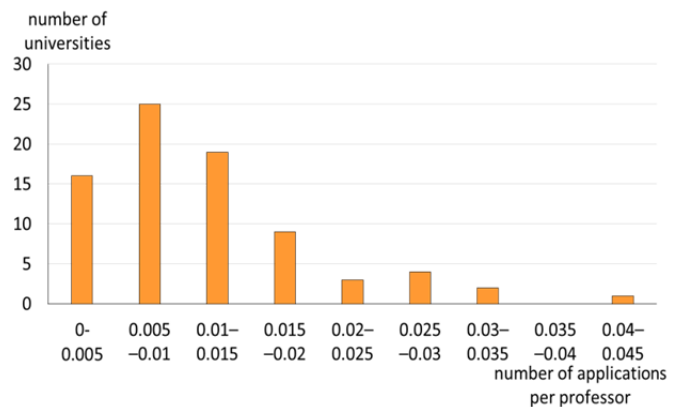


Fig. 4 Number of universities by total applications filed per professor

Table 2 Universities with more than 10 applications

National universities (53 universities)	University of Tokyo (321), Kyoto University (298), Tohoku University (272), Osaka University (219), Hokkaido University (182), Kyushu University (172), Tokyo Institute of Technology (149), Nagoya University (126), Okayama University (124), Hiroshima University (88), Kumamoto University (63), Shizuoka University (60), Chiba University (58), Kyushu Institute of Technology (57), Tokushima University (53), Nagasaki University (52), Yamaguchi University (51), Tsukuba University (49), Tokyo University of Agriculture and Technology (49), Kobe University (48), Nagoya Institute of Technology (45), Tokyo Medical and Dental University (44), Shinshu University (44), Nara Institute of Science and Technology (44), Toyohashi University of Technology (40), Kyoto Institute of Technology (40), Kagoshima University (39), Niigata University (38), Gunma University (37), Toyama University (34), Kanazawa University (33), Yokohama National University (31), Gifu University (31), Nagaoka University of Technology (29), Yamanashi University (29), Tottori University (27), Mitazaki University (27), Mie University (25), Ehime University (24), Hamamatsu University School of Medicine (23), Saitama University (20), Kagawa University (19), Tokyo University of Marine Science and Technology (18), University of Electro-Communications (18), Japan Advanced Institute of Science and Technology (16), Saga University (16), Akita University (15), Kochi University (15), Obihiro University of Agriculture and Veterinary Medicine (14), Shiga University of Medical Science (14), University of the Ryukyus (13), Iwate University (10), University of Fukui (10)
Public universities (8 universities)	Osaka Prefecture University (70), Yokohama City University (37), Sapporo Medical University (26), Nagoya City University (23), Osaka City University (19), University of Shizuoka (17), University of Kitakyushu (15), Kyoto Prefectural University of Medicine (13)
Private universities (18 universities)	Keio University (113), Nihon University (52), Tokyo University of Science (50), Waseda University (45), Kltasato University (33), Kurume University (28), Kinki University (25), Tokai University (23), Doshisha University (22), Shibaura Institute of Technology (21), Tokyo Women's Medical University (20), Ritsumeikan University (20), Fukuoka University (18), Kansai University (17), Jichi Medical University (15), Saitama Medical University (15), Juntendo University (11), Kanagawa University (11)

Note : The number of applications are provided in ()

Fig. 5 provides the numbers of universities by total applications files per professor and by founders for each university type and Fig. 6 shows the numbers of universities by total applications filed per professor and by faculty structure (multiple or single faculty universities). Note that multiple faculty in one field, for example, science and technology, were assumed to be single faculty. Differences were found between national, public, and private universities and between multiple and single faculty universities. The numbers of applications per professor of national universities were significantly larger than those of public universities, and those of public universities were significantly larger than those of private universities. The numbers of applications per professor of single faculty universities were larger than those of multiple faculty universities.

Table 3 Explanatory variables for university performances and activities

(1) University scale	Number of professors, Number of undergraduate and graduate students, Budget amount
(2) Student status	Number of undergraduate students per professor, Number of graduate students per professor
(3) Research funds	Budget amount per professor, Expenses of grants-in-aid for scientific research per professor
(4) Industry-academia collaboration	Joint research expenses per professor, Number of joint research per professor, Contract research expenses per professor, Scholarship donations per professor, Number of venture companies per professor
(5) Difficulty level of entrance examinations	Deviation values for clearing entrance examinations
(6) University type	Founder (national, public or private university), Faculty structure (multiple or single faculty university)

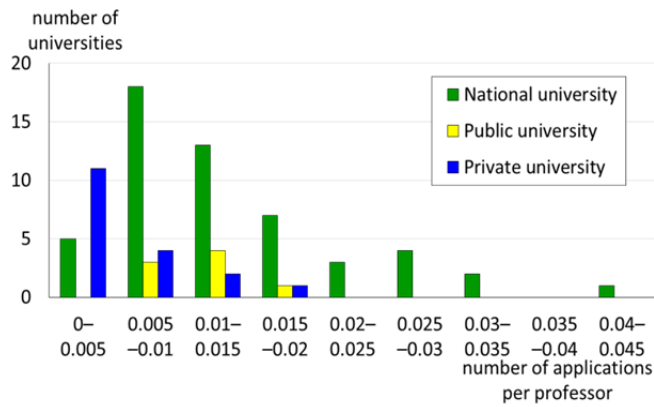


Fig. 5 Number of universities by total applications filed per professor and by faculty structure

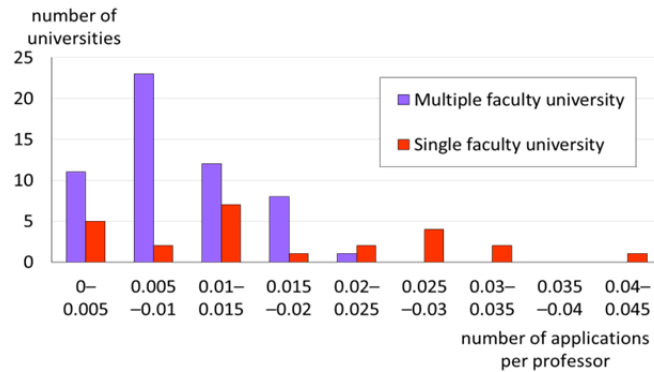


Fig. 6 Number of universities by total applications filed per professor and by founders

Table 3 lists the explanatory variables for university performance and activities. Although scholarship donations [50] prohibit any reimbursement, they are offered to professors as part of industry-academia collaboration activities. As for university type, founder (national, public, or private university) and faculty structure (multiple or single faculty) were adopted as per the results in Figs. 5 and 6. Data for the explanatory and explained variables were for an average of five years.

D. Factors influencing PCT applications

Table 4 presents the correlation coefficients for the number of PCT applications per professor and university performance and activities and the average of the former in dummy variables. Number of professors, scholarship donation expenses per professor, and deviation value for passing entrance examinations were excluded from this stage owing to the low correlation ($0 \leq |r| < 0.2$). The variables for university scale including number of professors showed weak correlations ($0.2 \leq |r| < 0.4$) or little correlation and all of the signs of the correlation coefficients were negative. Scholarship donation expenses per professor showed little correlation, whereas the other variables in the industry-academia collaboration category showed strong ($0.7 \leq |r| \leq 1$) or medium correlations ($0.4 \leq |r| < 0.7$). Deviation value for passing entrance examinations indicated the scholastic ability of students, although it showed low correlation. As for university types, founder and faculty structure showed significant differences in averages.

Next, we conducted analyses to remove multicollinearity. Table 5 presents the correlation coefficients between university performance and activities. We found strong correlations between number of undergraduate and graduate students and budget amount and among number of graduate students per professor, expenses of grants-in-aid for scientific research per professor, joint research expenses per professor, number of joint research per professor, contract research expenses per professor, and number of venture companies per professor. In addition, medium correlations mainly for budget amount per professor, expenses of grants-in-aid for scientific research per professor, number of joint research per professor, contract research expenses per professor and number of venture companies per professor were found. Because these correlations can cause multicollinearity, it is necessary to examine these variables and omit appropriate ones.

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Table 4 Correlation coefficients for number of PCT applications per professor and university performance and activities

University performance and activities	Number of professors	Number of undergraduate and graduate students	Budget amount	Number of undergraduate students per professor	Number of graduate students per professor	Budget amount per professor	Expenses of grants-in-aid for scientific research per professor
Correlation coefficients	-0.138	-0.205	-0.285	-0.226	0.687	-0.374	0.621
t-value	-1.224	-2.032	-2.611	-2.032	8.302	-3.535	6.958
p-value	0.225	0.046	0.011	0.046	3.E-12	7.E-04	1.E-09

University performance and activities	Joint research expenses per professor	Number of joint research per professor	Contract research expenses per professor	Scholarship donation expenses per professor	Number of venture companies per professor	Deviation value for passing entrance examinations
Correlation coefficients	0.721	0.727	0.678	0.143	0.708	-0.157
t-value	9.135	9.284	8.102	1.266	8.785	-1.393
p-value	7.E-14	3.E-14	6.E-12	0.209	3.E-13	0.167

University performance and activities (University type)	Founder			Faculty structure	
	National university	Public university	Private university	Multiple faculty university	Single faculty university
"Averages number of PCT applications per professor"	0.0133	0.0112	0.0057	0.0092	0.0168

Table 5 Correlation coefficients between university performance and activities

	Number of undergraduate and graduate students	Budget amount	Number of undergraduate students per professor	Number of graduate students per professor	Budget amount per professor	Expenses of grants-in-aid for scientific research per professor	Joint research expenses per professor	Number of joint research per professor	Contract research expenses per professor	Number of venture companies per professor
Number of undergraduate and graduate students	1									
Budget amount	0.744	1								
Number of undergraduate students per professor	0.658	0.200	1							
Number of graduate students per professor	0.131	-0.168	0.109	1						
Budget amount per professor	0.429	0.654	0.325	-0.358	1					
Expenses of grants-in-aid for scientific research per professor	0.087	0.166	-0.334	0.565	-0.246	1				
Joint research expenses per professor	0.044	0.035	-0.174	0.742	-0.291	0.779	1			
Number of joint research per professor	-0.231	-0.389	-0.160	0.731	-0.560	0.409	0.742	1		
Contract research expenses per professor	0.091	0.143	-0.234	0.643	-0.227	0.872	0.844	0.605	1	
Number of venture companies per professor	-0.004	-0.189	-0.068	0.734	-0.298	0.421	0.566	0.680	0.544	1

Table 6 presents the evaluation of the explanatory variables by VIF. VIFs for all variables were less than 10 and no variable was deleted at this stage. However, eight variables showed VIFs greater than five, indicating their potential to cause multicollinearity.

Table 6 Evaluation of the explanatory variables by VIF

Explanatory variables	Number of undergraduate and graduate students	Budget amount	Number of undergraduate students per professor	Number of graduate students per professor	Budget amount per professor
VIF	9.842	9.085	5.017	5.158	3.283
Explanatory variables	Expenses of grants-in-aid for scientific research per professor	Joint research expenses per professor	Number of joint research per professor	Contract research expenses per professor	Number of venture companies per professor
VIF	8.398	7.612	7.089	7.571	2.690

Next, we conducted an analysis to identify variables causing sign inversions and delete them to remove any multicollinearity. Variables showing sign inversions were found using multiple regression analysis and grouped accordingly. Variables with the lowest correlation coefficient with the explained variable in each group were deleted. In addition, dummy variables showing reverse orders of averages were excluded. The multiple regression analysis with the new variables was then conducted and the above analysis was repeated until no such variable could be found.

The analysis proceeded as follows. A multiple regression analysis was conducted for 12 explanatory variables, of which number of undergraduate and graduate students, expenses of grants-in-aid for scientific research per professor, and founder (national, public, or private university) were deleted. Of the remaining nine explanatory variables, budget amount, number of undergraduate and graduate students per professor, and budget amount per professor were deleted, leaving us with a total of six explanatory variables: number of graduate students per professor, joint research expenses per professor, number of joint research per professor, contract research expenses per professor, number of venture companies per professor, and faculty structure. No such variable was found thereafter.

Following is the equation for the multiple regression model by AIC (Kondo et al. [28]).

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

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

The results for the evaluation of the explanatory variables by AIC (Table 7) revealed five variable models as the most applicable when AIC showed the lowest value (-87.0).

Table 8 shows the multiple regression equation including five explanatory variables—number of venture companies per professor, faculty structure, number of joint research per professor, contract research expense per professor, and joint research expenses per professor—in descending order of t-values or ascending order of p-values. All explanatory

variables, except the dummy variables, positively influenced the explained variable. For the dummy variable university type, single faculty universities had a stronger positive influence than multiple ones. The multiple coefficient of determination (R^2) is 70.7%.

Table 7 Evaluation of the explanatory variables by AIC

Number of explanatory variables	Number of graduate students per professor	Joint research expenses per professor	Number of joint research per professor	Contract research expenses per professor	Number of venture companies per professor	Faculty structure	AIC
6	○	○	○	○	○	○	-85.2
5	○	○	○	○	○	○	-87.0
4			○	○	○	○	-86.7
3			○	○	○		-81.7
2				○	○		-73.0
1					○		-52.8

Table 8 Multiple regression equation

Equation	t-value	p-value	R^2
Number of PCT applications per professor =	-	-	70.7%
0.00292	3.329	0.001	
+ 0.424 × Joint research expenses (100 million yen) per professor	1.455	0.150	
+ 0.00905 × Number of joint research per professor	1.689	0.096	
+ 0.120 × Contract research expenses (100 million yen) per professor	1.624	0.109	
+ 0.0981 × Number of venture companies per professor	3.340	0.001	
+ { 0 (Plural faculties university) 0.00322 (Single faculty university)	2.677	0.009	

V. DISCUSSION

The above analysis demonstrates that PCT applications were mainly filed in engineering and medicine fields, indicating that faculties with the highest number of application are those of science and engineering and medical science, dentistry, and pharmacy. In general, it is said that these two fields are more active in industry-academia collaboration activities than other fields. Single faculty universities comprising engineering- and medicine-related faculties reported high values for number of PCT applications per professor.

We also found that of the total applications filed, joint applications accounted for 45.4%. According to MEXT [35], the ratios of joint domestic patents to joint foreign ones for universities and private companies were 44% and 35% in FY 2008. Although accurately comparing this data may not be possible, the ratio of joint PCT applications significantly coincides with that of joint foreign patents. In addition, it can be said that the number of joint PCT applications is higher than that of joint domestic applications.

According to the multiple regression analysis, the number of PCT applications per professor can be understood using five explanatory variables—number of venture companies per professor, number of joint research per professor, contract research expenses per professor, and joint research expenses per professor—in the industry-academia collaboration and

faculty structure categories. In other words, single faculty universities are more likely to collaborate with venture companies, produce a large amount of joint research, acquire a higher amount of contract research, and file more PCT applications. We then selected four variables under the industry–academia collaboration category. Venture companies generally need entrepreneurial university professors and systematic university support. Joint research requires a broad cooperative relationship with numerous private companies including SMEs. To cover the expenses of joint research, close relationships must be established with large enterprises and R&D companies. Accordingly, we found that joint and contract research expenses per professor were strongly correlated with expenses of grants-in-aid for scientific research per professor, indicating the need for a higher number of basic research. The relationship between PCT applications and industry–academia collaboration activities is understandable given the technology transfers by patents. We selected faculty structure as a dummy variable and found 24 single faculty universities, including 11 engineering universities and 10 medical universities. This supports our finding that applications are mainly filed in the fields of engineering and medicine. We excluded founder as another dummy variable owing to its reverse order of averages caused by correlations with other variables.

In addition to the five variables, two variables showed medium correlations with the explained variable: number of graduate students per professor and expenses of grants-in-aid for scientific research per professor. It is conceivable that graduate students contributed to both joint and contract research, which positively influenced PCT applications. By contrast, it showed a negative and weak correlation with PCT applications, possibly because of the high work load assigned to them by professors.

Grants-in-aid for scientific research, a competitive research fund for all academic fields in Japan, is offered to researchers on the basis of the peer reviews of their research [25]. Funding acquired by universities can be treated as an indicator of the level of basic research in each university. However, realizing utility as well as direct and indirect applications of research results may take a while and by then, private companies may thus lose interest. Nevertheless, it is interesting that grants-in-aid for scientific research had a medium correlation with PCT applications.

From the multiple regression models, we derived an R^2 value of 70.7%. However, to obtain higher R^2 values five variables must be added to the current multiple regression models. Moreover, we excluded seven variables demonstrating medium or weak correlations with the explained variable were deleted when examining for multicollinearity using AIC. We leave the identification of new variables or the combination of variables to increase the R^2 for a future study.

VI. CONCLUSIONS

This study aimed to reveal the trends in and factors influencing PCT applications by Japanese universities using 2008–2012 data for patent applications, university performance and research activities, and industry–academia collaboration activities.

The results reveal that PCT applications were mainly filed in the fields of engineering and medicine, and 45.4% of them were joint applications with private companies. In addition, the multiple regression analysis provided the number of PCT applications per professor using five explanatory variables ($R^2 = 70.7\%$) and demonstrated that the applications were influenced by industry–academia collaboration and faculty structure. Thus, it can be concluded that PCT applications by Japanese universities have the potentialities of technology transfers from universities to private companies.

Our research findings offer the following policy implications. It is necessary to promote industry–academia collaboration activities including those with venture companies and joint and contract research to increase PCT applications. In addition, support for basic research including grants-in-aid for scientific research should be strengthened and graduate schools enhanced. It can be assumed that an increase in PCT applications will contribute to the promotion of technology transfers.

However, a limitation of this study is that the results are derived from the data for Japanese universities, and therefore, may not be generalizable to other countries. Nevertheless, related literature contains similar results. For example, private funding and university type were found to influence university patents [30], [6], [16]. In addition, this study analyzed PCT applications, which are assumed to be more useful than other patent applications. Thus, future research should analyze domestic as well as overseas patents for universities and the establishment of licensing procedures and related income.

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