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Spillover Pools and Patent Application Activity in Business Enterprises

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Spillover Pools and Patent Application Activity in Business Enterprises[1]

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Abstract

This study investigated whether technological management in the form of industry-academia-government collaboration is correlated with the results of research and development in Japanese industry. To accomplish this objective, utilizing data derived from Japan's Survey of Research and Development and the Institute of Intellectual Property's database, an empirical analysis of how spillover pools potentially available to business enterprises affect their patent application activities, was performed. Incorporating the Mahalanobis distance to take into account technological complementarity, the technological proximity between business enterprises was defined, and the spillover pools emanating from industry, academia, and government were respectively calculated. Designating the number of patent applications as the variable representing patent application activity, and considering that this variable constitutes non-negative count data, this study employed a panel poisson model to perform the estimations. The results demonstrated that spillover pools have a positive impact on patent application activity. Even when the respective spillover pools created by industry, academia, and government were analyzed, a positive impact on patent applications was evident. Further, this tendency remained intact, even when the spillover pools were calculated according to research type, i.e. basic research, applied research, and development research.

Keyword: industry-academia-government collaboration, R&D, patent, spillover

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1. Introduction

Since Chesbrough (2003) propounded the importance of open innovation, various policies have been implemented toward its realization. As defined by Chesbrough, “open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.” The “business enterprises” referred to need not be restricted to business organizations, but may encompass a wider range of organizations, including universities and public institutions. The continuing discourse surrounding open innovation forms the theoretical backdrop for industry-academia-government collaboration. However, in an analysis of open innovation, there is a need to explore the spillover effect and the extent to which the knowledge belonging to outside organizations may be acquired. If there is no spillover of knowledge from universities and public research institutions, business enterprises cannot avail of “the use of purposive inflows and outflows of knowledge”. However, due to the limited data available, the extent to which knowledge from universities and public research institutions is being used by business enterprises has not been quantified.

This study attempts to quantitatively measure the spillover from business enterprises, universities, and public research institutions, using data from Japan’s Survey of Research and Development (hereinafter, the “Survey”). Further, utilizing the Institute of Intellectual Property’s (IIP) database, it clarifies whether the spillover of research results from universities and public research institutions affects patent application activity. Specifically, adopting the spillover pool concept originated by Bloom, Schankerman, and Van Reenen (2013) as a spillover indicator, this study measures the respective spillover pools flowing from business enterprises, universities, and public research institutions. Next, it focuses on the spillover pools of universities and public institutions from which business enterprises can obtain knowledge, as well as their effect on the number of patent applications submitted, and analyzes them statistically in light of various other factors.

Jaffe (1986), Audretsch and Feldman (1996), and Bloom et al (2013) have performed empirical analytical studies of spillover effects on industrial research and development (R&D). All of these studies highlighted the potential role of spillovers in promoting industrial R&D. However, spillovers may be constrained by geographical factors (Almeida and Phene, 2004). When the knowledge sources are near each other, a business enterprise’s researchers can communicate better with outside researchers, and receive spillovers more efficiently

(Almeida and Phene, 2004). In many cases, research results are embedded as tacit knowledge in the researchers themselves, in which case interaction among the researchers leads to spillovers (Almeida and Kogut, 1999). Since the closer the researchers are to each other, the easier the interaction becomes, geographical distance from the knowledge sources influences spillovers (Singh, 2005).

Previous studies have considered spillovers solely within the industrial sphere, but there has been no comprehensive analysis of spillovers from universities and research institutions to business enterprises. Research focusing on spillovers from universities and research institutions to business enterprises exists, but the samples have been limited, and no empirical analysis of panel data at the industrial level has been performed. This study attempted to elucidate and quantify spillovers business enterprises can absorb from universities and research institutions.

To quantify the spillover pools of universities and research institutions from which business enterprises can absorb knowledge, this study used data from the Survey’s specific questionnaires. The Survey compiles the number of researchers and the amount of research expenditures in the various fields of research undertaken by business enterprises, universities, and public research institutes. By weighting and totaling the intramural research expenditures, the spillover pools were quantified. Using the IIP patent database, the number of patent applications classified according to industry and year of application were aggregated. Matching the Survey’s specific data with the IIP patent database, the effects of the spillover pools that business enterprises receive from outside organizations, on patent application activity, was statistically derived, while taking into account the research inputs, the business enterprise’s scale, the attributes of the industry to which the business enterprise belongs, and trends.

Considering that the number of patent applications is a non-negative integer, and the data used in the analysis are panel data, a panel poisson model was selected for the estimations. The results suggested that an increase in the spillover pools that a business enterprise can receive from outside organizations causes an increase in the business enterprise’s patent applications. If the spillover pools are broken down by source, i.e. business enterprises, universities, and public research institutions, and a similar analysis is performed, the results likewise indicate that an increase in each institution’s spillover pool causes the business enterprise’s patent applications to increase. Further, if the intramural research expenditures are classified according to basic research, applications research, and development research, the spillover pools measured also have a positive impact on the number of patent applications. There was no difference observed in this trend.

The structure of this paper is as follows. Part 2 organizes the Survey data relating to business enterprises, universities, and public research institutions, their individual intramural R&D expenditures, and captures the spillover pool each sector receives. Part 3 describes the estimation model and the specification method for the variables. The estimation results are presented in Part 4, and Part 5 elaborates on this study's conclusions based on those results.

2. Intramural Research Expenditures of Industry-Academia-Government and Spillover Pools

This study quantitatively analyzed the influence of spillover pools from business enterprises, universities, and pubic research institutions on patent application activity. To accomplish this, the intramural research expenditures of business enterprises, universities, and pubic research institutions were determined. In Japan, the business enterprises, universities, and pubic research institutions are surveyed under the Statistics Act by the principal statistical survey called "Survey or Research and Development". Based on the Frascati Manual, the internationally recognized statistical standard, this Survey collects information on Japan's R & D, using a universally accepted methodology to survey business enterprises, universities, and public research institutions. For business enterprises with a capital of ￥1 million or more but less than ￥100 million, the survey is based on sampling, while for business enterprises with a capital of ￥100 million or more, the survey is universal. The survey covered all of the universities in Japan[3]. All of the public research institutions surveyed were also located in Japan[4]. Since the 2002 survey (on actual 2001 data), by submitting an application for secondary use, the registered information may now be used, and the survey items pertaining to the research activities of business enterprises, public research

[3] The universities covered by the Survey include university colleges and faculties, research departments at graduate schools, junior colleges, colleges of technology, research centers attached to universities, research facilities attached to universities, inter-university research institute corporations, independent administrative agencies, and national institutes of technology.

[4] The public research institutions covered by the Survey are those specified in materials issued by regional / local governments and public organizations.

institutions, non-profit organizations, and universities can be linked to other databases and analyzed statistically. This study was mainly focused on the analysis of business enterprises, universities, and public research institutions.

The Survey covers the intramural research expenditures of business enterprises, universities, and public research institutions. Figure 1 shows a history of the total intramural research expenditures of business enterprises, public research institutions, and universities, based on the Survey's results. The inclusion of data from public research institutions only began in 1998, when they were transformed into independent administrative agencies. To compare the intramural research expenditures of business enterprises, public research institutions, and universities, the history of their total intramural expenditures since 1998 were tabulated. The statistics showed that business enterprises are the principal players in Japanese R&D expenditures, accounting for approximately 70% of the total. This tendency was constant between 1998 and 2013. After business enterprises, universities and public research institutions followed in the magnitude of their R&D expenditures.

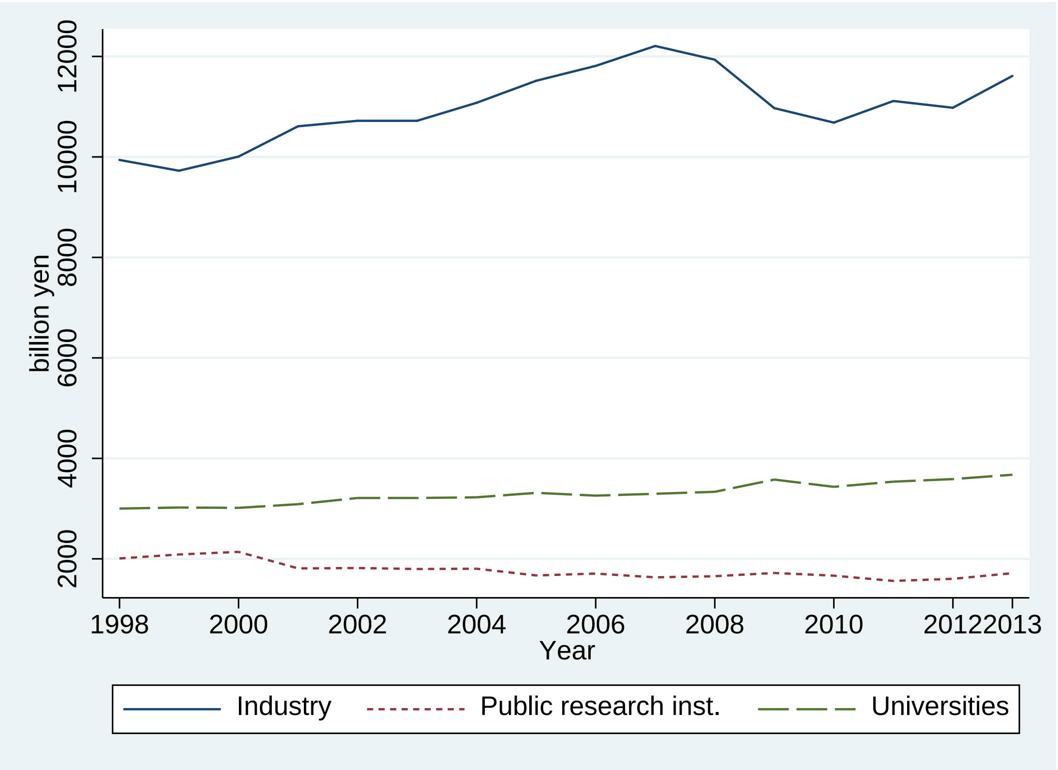

Figure 1. Intramural R&D Expenditures of Industry-Academia-Government

The Survey breaks down intramural R&D expenditures into basic research, applied research, and development research expenditures, and surveys the expenditures of business enterprises, public research institutions, and universities, classified into each of the above categories. Figures 2~4 show the amounts and ratios of the expenditures of business enterprises, public research institutions, and universities for basic research, applied research, and development research. An examination of Figure 2 concerning business enterprises reveals that the greater part of their expenditures is for development research, followed by applied research and basic research. However, the proportion allocated to basic research is meager. On the other hand, Figure 3 concerning universities shows that half of their expenditures is devoted to basic research, followed by applied research and development. In contrast with business enterprises, basic research accounts for the great majority of the expenditures, and the proportion of development research expenditures is low. As for the expenditures of public research institutions shown in Figure 4, most of the expenditures are allotted to development research, although this proportion of intramural R&D expenditures is a little less than half. These expenditures are followed by substantial expenditures for applied research and basic research in order of magnitude. Although the proportion allotted to applied research is slightly lower, relative to basic research, the amounts are almost the same. A comparison of intramural R&D expenditures among these sectors reveals significant differences in the spheres where business enterprises, universities, and public research institutions conduct their R&D. It is said that business enterprises are mainly engaged in development, while universities mainly conduct basic research. Let us verify this observation on the basis of their expenditures.

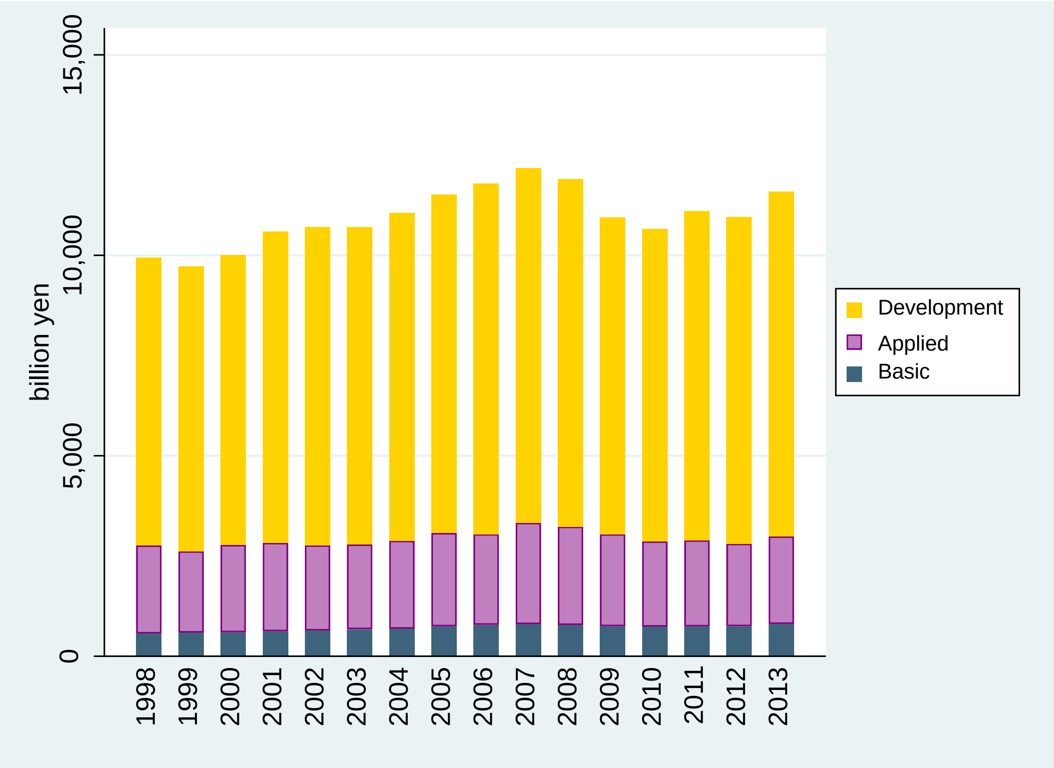

Figure 2. Breakdown of R&D expenditures in Business Enterprises

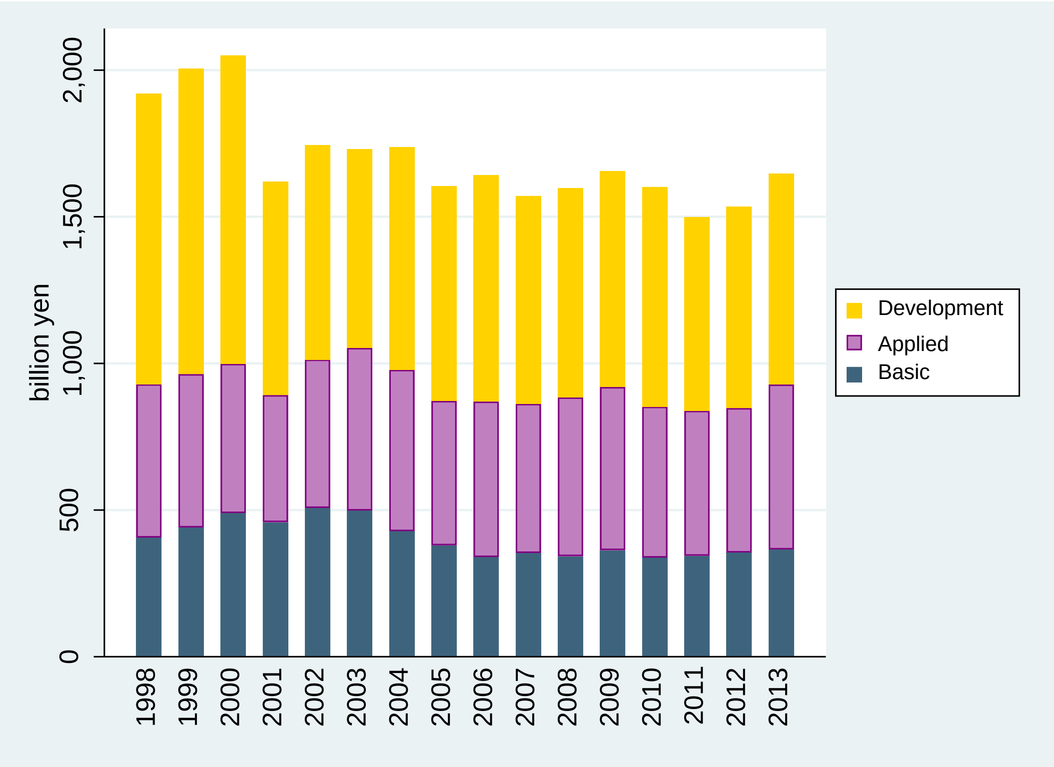

Figure 3. Breakdown of R&D expenditures in Universities

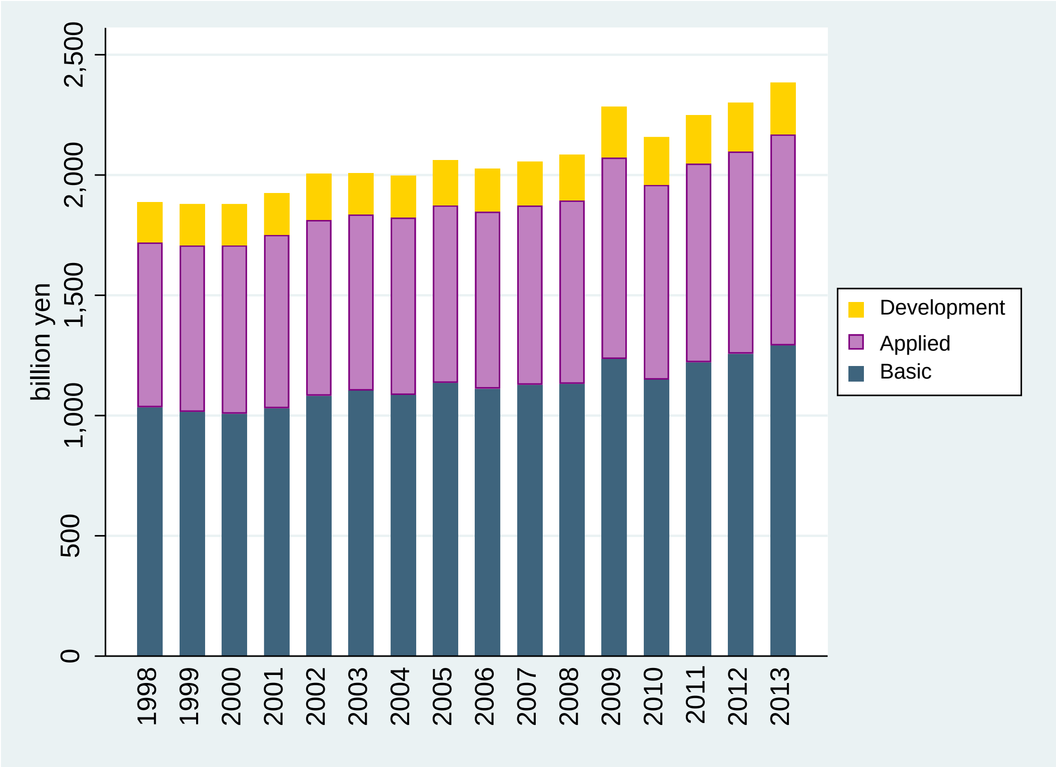

Figure 4. Breakdown of R&D expenditures in Public Research Institutions

Next, using the Survey's data, the spillover pools that business enterprises, universities, and public research institutions can avail of were calculated, and their history was traced. Using the method devised by Bloom, Schankerman, and van Reenen (2013), the Mahalanobis distance denoting technological proximity was defined and used as a weight factor to derive the total weighted R&D expenditures [5]. In the past, as in Jaffe (1986) and Bloom, Schankerman, and van Reenen (2013), the number of patents in each technological field according to international patent classifications were being used. However, as pointed out by Bloom, Schankerman, and van Reenen (2013), spillovers naturally occur among researchers; hence, the closer their specializations are, the easier it is for spillovers to occur. The spillovers that can occur among business enterprises, universities, and public research institutions consist of the totality of knowledge spillovers among those researchers. By using data on the number of each organization's researchers, classified according to their fields,

[5] The research expenditures were derived using the Ministry of Education's "Japanese Research Expenditure Deflators (Comprehensive, including Humanities and Social Sciences)" (2015).

spillovers can be measured more accurately. This study measures technological proximity by using data on the number of specialized researchers reported in the Survey on Research and Development.

Among the previous studies, many focused solely on spillover pools among business enterprises, omitting spillovers from universities and public research institutions. This may be attributed to the fact that the necessary data regarding patent bibliographies and R&D expenditures of business enterprises are relatively more accessible, while data on universities and public research institutions are more difficult to obtain. Since spillovers emanate not only from business enterprises, but also, from universities and public research institutions, if possible, the latter should also be examined. This study used data on business enterprises, universities, and public research institutions compiled by the Survey on Research and Development, to quantify and analyse spillover pools from universities and public research institutions which have not been covered by previous studies.

First, the technology vector is defined as follows:

$$T_i = [T_{i1}, T_{i2}, ..., T_{iK}] \square 1 \times K$$

Here, for instance, T_{ik} represents the share of researchers in the specialization k belonging to organization i in a particular year. $T(K,N)$ represents the sequence specified for the business enterprises, universities, and public institutions. N represents the number of organizations in a particular year. If the 3 sectors of business enterprises, universities, and public research institutions are each identified as 1 entity at the macro level, N = 3. If each business enterprise, each university, and each public research institution is considered at the micro level, this would the the total number of business enterprises, universities, and public research institutions.

Next, T is formalized as follows:

$$\tilde{T} = \left[\frac{T_1'}{(T_1 T_1')^{1/2}}, \frac{T_2'}{(T_2 T_2')^{1/2}}, ..., \frac{T_N'}{(T_N T_N')^{1/2}} \right] \square K \times N$$

$\tilde{T}\tilde{T}'$ denotes the uncentered correlation measure among the technology fields, originated by Jaffe (1986).

Here, $T_{(:,i)}$ is the iteration *i* of *T*, and the sequence is defined as:

$$\tilde{X} = \left[\frac{T'_{(:,1)}}{\left(T_{(:,1)}T'_{(:,1)}\right)^{1/2}}, \frac{T'_{(:,2)}}{\left(T_{(:,2)}T'_{(:,2)}\right)^{1/2}}, \ldots, \frac{T'_{(:,N)}}{\left(T_{(:,N)}T'_{(:,N)}\right)^{1/2}} \right] \in K \times N$$

Using this sequence, with

$\Omega = \tilde{X}\tilde{X}' \in K \times K$, we arrive at the Mahalanobis normed technology closeness

$M = \tilde{T}'\Omega\tilde{T}$. Here, the Mahalanobis normed technology closeness for organization *i* and organization *j* becomes lower as it approaches 0, and higher as it approaches 1. Using the Mahalanobis normed technology closeness *M* as the weight factor, we derive the weighted total of organization *j*'s R&D expenditures R_j $(j \neq i)$, and define this as the spillover pool S_i that organization *i* can use:

$$S_i = \sum_{j \neq i} M_{ij} R_j$$

Here, we considered business enterprises, universities, and public research organizations as organizations at the macro level. We determined the aggregate total of specialized researchers and the intramural R&D expenditures of business enterprises, universities, and public research organizations, based on their respective data, and calculated the spillover pool, taking into account the Mahalanobis distance. Figure 5 shows the yearly spillover pools from academia and government that business organizations can use. An examination of these spillover pools from universities and public research organizations available to business enterprises reveals an increasing tendency. Even after the Lehman Shock of September 2008 and the Great East Japan Earthquake of March 2011, the spillover pools continued increasing. Although the Lehman Shock and the Great East Japan Earthquake led business enterprises to reduce their intramural R&D expenditures, universities and public research institutions increased their intramural R&D expenditures, resulting in the expansion of the spillover pools available to business enterprises.

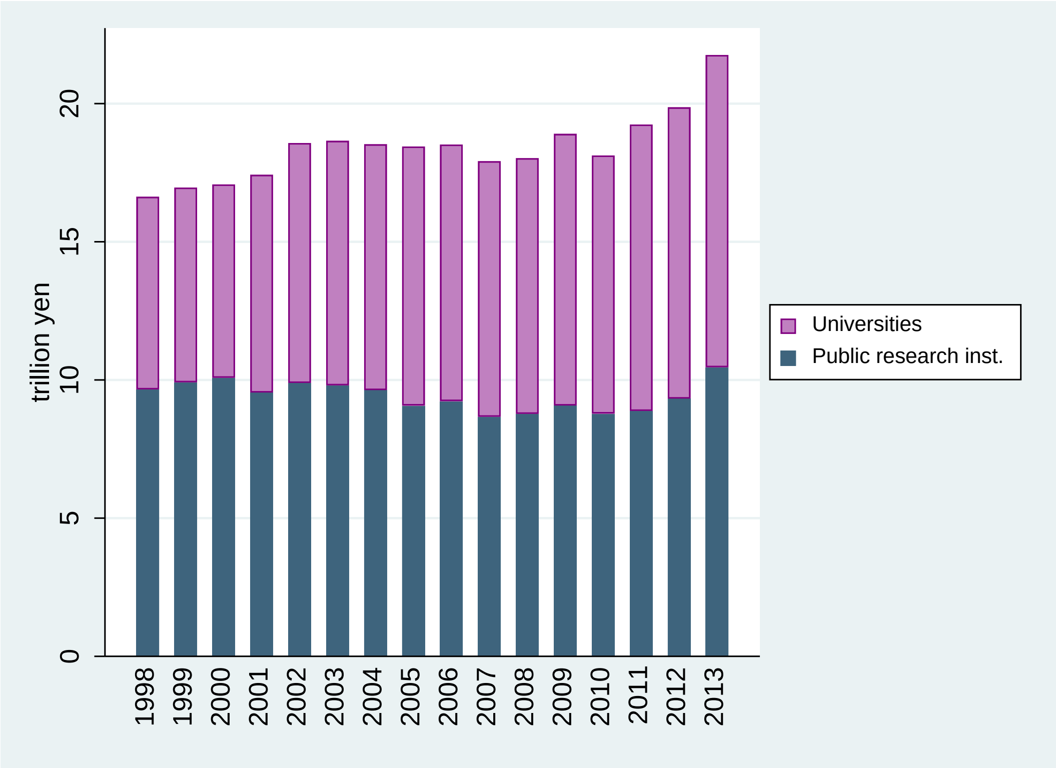

Figure 5. Spillover Pools from Universities and Public Research Institutions Available to Business Enterprises

Figure 6 shows the spillover pools from business enterprises and public research institutions available to universities, revealing that almost all of the spillover pools universities can avail of originate from business enterprises. Due to the Lehman Shock, spillover pools from business enterprises decreased, resulting in smaller spillover pools available to universities. However, an increasing trend has subsequently reappeared.

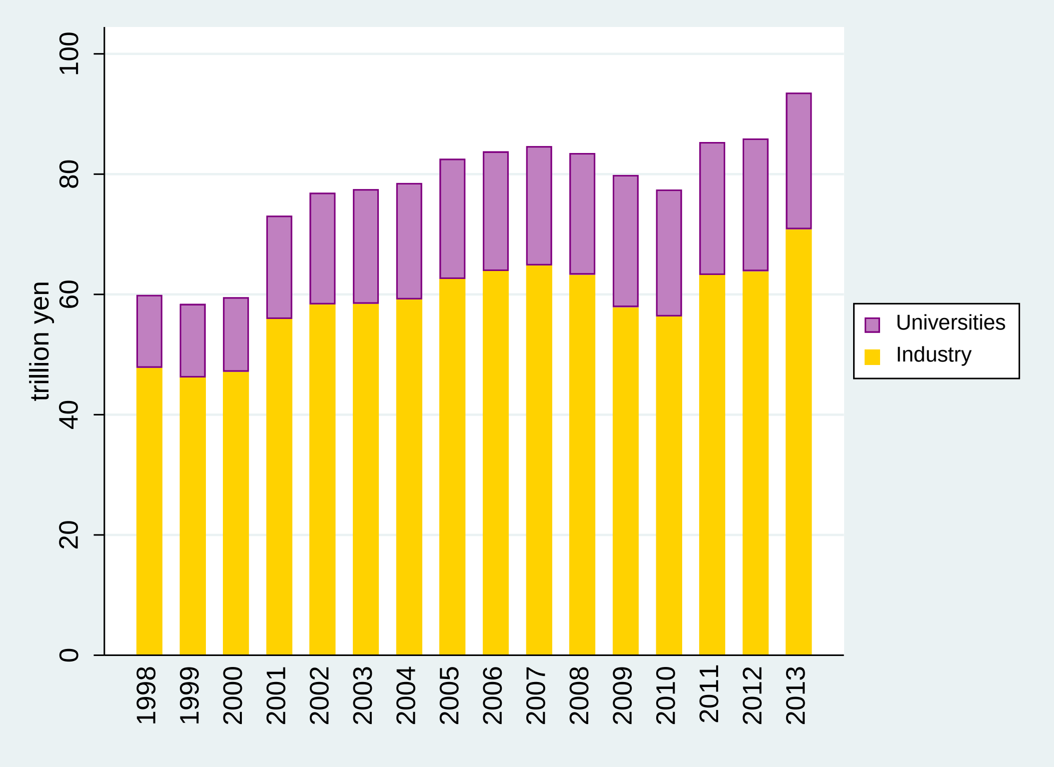

Figure 6. Spillover Pools from Business Enterprises and Public Research Institutions Available to Universities

Figure 7 shows the spillover pools from business enterprises and universities available to public research institutions. As in the case of spillover pools available to universities, almost all of the spillover pools available to public research institutions originate from business enterprises. Similarly with the universities, due to the Lehman Shock, the spillover pools from business enterprises decreased, and the spillover pools available to public research institutions diminished. However, an increasing trend subsequently reappeared.

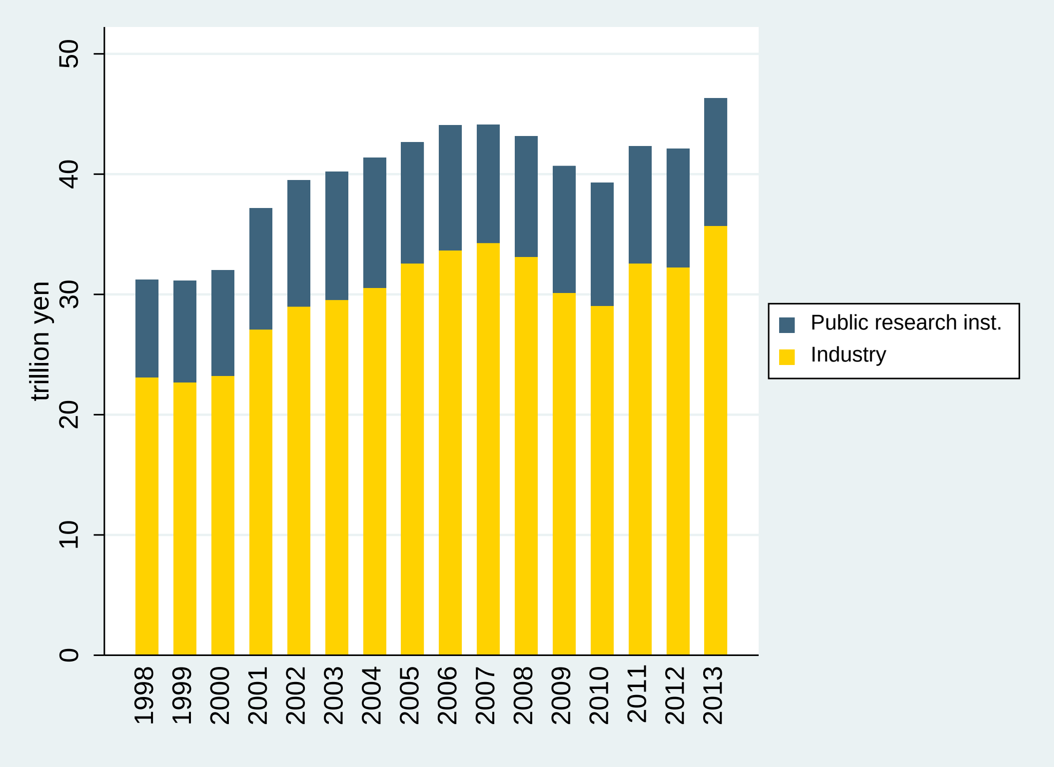

Figure 7. Spillover Pools from Business Enterprises and Universities Available to Public Research Institutions

3. Estimation Model and Data

3.1 Estimation Model

To quantitatively analyze the effects of spillover pools available to business enterprises on patent application activity, this study used the following model based on the equation used by Jaffe (1986) and Bloom, Schankerman, and Van Reenen (2013).

$$P_{it} = \alpha S_{it} + \beta R_{it} + \gamma X_{it} + \varepsilon_{it}$$

However, P_{it} represents the number of patent applications submitted by business enterprise i in year t. S represents the spillover pool, while R is the variable for the scale of R&D inputs. X represents the control variable.

Considering that when the above model performs estimations at the business enterprise level, the number of patent applications *P*, the response variable, is a non-negative integer constituting count data, we decided to use a poisson model. For count data models, negative binomial models may also be used. However, as it is presumed in a poisson model that the average and dispersion values are identical, the negative binomial model is more universal. Allison and Waterman (2002) and Guimaraes (2008) have pointed out that as a panel count data model, the negative binomial model is biased. When an analysis using panel data is to be performed, there is no consensus as to whether a poisson model or a negative binomial model should be adopted. Based on the opinions of Allison and Waterman (2002) and Guimaraes (2008), this study selected a panel poisson model for its estimations.

3.2 Data

Applying the patent equation described above to estimate the impact of spillover pools on the number of patent applications, this study used the Survey's specific questionnaire data. As described above, the Survey provides data relating to R&D activity, e.g. number of researchers per research type, R&D expenditures, etc., and basic data, e.g. number of employees and the industry to which the business enterprise belongs. The Survey's Questionnaire A data relating to business enterprises were used in the estimations. The data used in this study's analysis covered the period from 2001-2011 and reflected patent data extracted from the IIP patent database described below, complementing the registered data available for the period. Business enterprises in the manufacturing industry were the subject of this analysis. Since panel data analysis was involved, the subject companies must have submitted 1 or more applications during the period, and the sample data for the past 2 years or more must have been available.

The number of patent applications was obtained from the publicly accessible Institute of Intellectual Property database (IIP Patent Database). Each patent's bibliographic data is registered in the IIP database. Using data regarding the patent applicants and the application year, the patent data was aggregated at the applicant level and at the application year level. This study discovered that the number of patent applications dramatically decreased from 2011 to 2012. The more recent the patent application is, the less likely it is to be already registered in the database, resulting in a truncation bias. For this reason, this study only extracted data until 2011 for its analysis.

In order to mesh the Survey's data concerning researcher mobility and R&D with the number of patent applications extracted from the IIP database for the analysis, the Survey's specific questionnaire data, organized as panel data at the business enterprise level, must be matched with the IIP database data, organized as panel data at the patent applicant level. This study used the business enterprise's name and the patent applicant's name registered in the Survey as keys in the matching process[6]. As a result of the matching, unbalanced panel data consisting of 38,199 samples relating to 5,685 business enterprises from 2001 to 2011 were obtained.

As an indicator of the business enterprises' R&D inputs, the R&D expenditure stock was used in this study. The business enterprises' intramural R&D expenditures data available from the Survey constituted the stock, based on the perpetual inventory method, as follows:

$$R_{it} = (1-\delta)E_{it-1} + E_{it}$$

However, E_{it} represents the expenditures of business enterprise i during year t. Further, δ represents the obsolescence rate. This study adopted the 20% obsolescence rate proposed by Corrado, Hulten, and Sichel (2009).

This study subsumed the business enterprise's scale and attributes, as well as trends, into the control variables used in the patent formula. For the business enterprise's scale, the

[6] When the names of business enterprises and patent applicants were used in the matching, variations such as "Corporation" and "Inc." were smoothed out. Further, to facilitate more accurate matching, the inclusion of address data could have been possible, but this study did not include them. While the Survey asks for the address of the business enterprise's principal research center, the patent applicant usually specifies the address of the business enterprise's headquarters, so matching cannot be done on this basis. For this reason, in the business enterprise data used by this study, entities with identical names could not be properly analyzed. This remains a topic for future consideration.

number of employees registered in the Survey was used. For the business enterprise's attributes, using the information available from the survey, a dummy variable for the industry to which the business enterprise belongs, was incorporated into the model. To take trends into account, a dummy for the years was used.

4. Estimation Results

The variables used in this study's estimation were derived from the Survey's specific questionnaire data and the IIP database. The basic statistics are presented in Table 1. After referring to methods used in previous studies, this study examined the spillover pools reflecting technological proximity, defined using the International Patent Classification (IPC), and the spillover pools defined using data on researchers classified according to research type in the Survey. A comparison between the spillover pools calculated according to the IPC, and industry-academia-government spillover pools from business enterprises, universities, and public research institutions, calculated using data on researchers classified by research type, revealed that the average for the former was ¥595,000,000,000, and ¥5,095,000,000,000 for the latter, denoting an enormous difference. Classified according to industry-academia-government sources, the spillover pools available to business enterprises amounted to ¥4,155,000,000,000 from other business enterprises, ¥420,000,000,000 from universities, and ¥521,000,000,000 from public research institutions. The spillover pools available from other business enterprises comprised 80% of the total, while the spillover pools available from universities and public research institutions accounted for 20%. The results derived above, not only for business enterprise but also for universities and public research institutions, enabled an analysis spillover pools from various viewpoints.

As described in Section 2, the expenditures of business enterprises, universities, and public research institutions are characteristically allocated into basic research, applied research, and development research. This study analyzed the effects of the spillover pools generated by the expenditures in these research categories on the number of patent applications submitted by business enterprises. Further, this study classified the expenditures of business enterprises, universities, and research institutions into these 3 research types, and analyzed in detail their effects on the number of patent applications.

Table 1. Basic Statistics

	Obs.	mean	s.d.	min	max
Patent application	38,199	65.002	423.940	0	15093
Spillover pool using IPC (trillion yen)					
SP_ipc	38,199	0.595	0.716	0.000	5.025
Spillover pool using researcher information (trillion yen)					
SP_total	38,199	5.095	3.315	0.000	12.268
SP_basic (for basic research)	38,199	0.526	0.278	0.000	1.327
SP_applied (for applied research)	38,199	1.056	0.647	0.000	2.593
SP_develop (for development research)	38,199	3.421	2.391	0.000	8.327
SP_ind (by industries)	38,199	4.155	2.826	0.000	10.253
SP_uni (by universities)	38,199	0.420	0.249	0.000	1.372
SP_pub (by public research institutes)	38,199	0.521	0.296	0.000	1.340
SP_basic_ind (for basic research by industries)	38,199	0.233	0.132	0.000	0.581
SP_basic_uni (for basic research by universities)	38,199	0.194	0.109	0.000	0.601
SP_basic_pub (for basic research by public research institutes)	38,199	0.099	0.058	0.000	0.336
SP_applied_ind (for applied research by industries)	38,199	0.818	0.525	0.000	2.064
SP_applied_uni (for applied research by universities)	38,199	0.101	0.062	0.000	0.483
SP_applied_pub (for applied research by public research institutes)	38,199	0.138	0.075	0.000	0.367
SP_develop_ind (for development research by industries)	38,199	3.100	2.188	0.000	7.645
SP_develop_uni (for development research by universities)	38,199	0.047	0.031	0.000	0.135
SP_develop_pub (for development research by public research institutes)	38,199	0.273	0.181	0.000	0.713
R&D (billion yen)	38,199	13.303	90.381	0.000	3286.730
employment (thousand)	38,199	0.905	2.804	0.001	80.449

Tables 2 and 3 shows the estimation results from the patent formula, using the spillover pools calculated based on the Survey's Questionnaire A data on business enterprises, Questionnaire B data on public research institutions, and Questionnaire C data on universities, and the number of patent applications at the business enterprise level extracted from the IIP database. Model [1] excluded the spillover pools and included only the intramural R&D expenditure stock and the number of employees. In this model and all of the other models, the coefficients for the intramural R&D expenditure stock and the number of employees were positive and therefore significant. This signifies that using the intramural R&D expenditure stock and the number of employees as the respective control variables for the scale of R&D inputs and the business enterprise's scale did not cause any problems in the model.

An examination of the coefficients relating to the spillover pools shows that in all of the models from model [2] to model [8], these coefficients were positive and therefore significant. In model [2], the spillover pool coefficients derived as usual by using IPC, were positive and therefore significant. In model [3], which used spillover pools derived from the number of researchers classified by research type, the coefficients were also positive and therefore significant. Hence, there was no substantial difference in the signs of the coefficients caused by differences in technological proximity. In models [4], [5], and [6], the results showed that, even when broken down into basic research, applied research, and development research, the respective coefficients were positive and therefore significant. Similarly in models [8] and [9], the results showed that in the case of spillover pools available to business enterprises from other business enterprises, universities, and public research institutions, the respective coefficients were positive and therefore significant.

Models [10] to [18] show the estimation results for 9 categories based on data regarding expenditures classified by research field, and spillover pool data classified according to other business enterprises, universities, and research institutions. All of the coefficients were positive and therefore significant. The value of the partial standard regression coefficient representing the increment when the standard deviation becomes 1, was almost identical in each model.

The positive spillover pool coefficients signify that when business enterprises other than the subject business enterprise, universities, and public research institutions conduct their research activities, the subject business enterprise’s patent applications increase in number. This tendency is identical even when the spillover pools from other business enterprises, universities, and public research institutions are broken down into basic research, applied research, and development research. Based on the above observations, business enterprises avail themselves thoroughly of the research activities of other business enterprises, universities, and public research institutions, and intensify their patent application activities. Moreover, not only the development research predominantly conducted by business enterprises, but also spillovers from basic research and applied research are widely utilized, potentially promoting patent applications.

Table 2. Estimation Results (1)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Spillover pool using IPC									
SP_ipc		0.2657***							
		[0.0004]							
		(0.0023)							
Spillover pool using researcher info.									
SP_total			0.0744***						
			[0.0006]						
			(0.0006)						
SP_basic				0.7990***					
				[0.0005]					
				(0.0061)					
SP_applied					0.3688***				
					[0.0006]				
					(0.0031)				
SP_develop						0.1028***			
						[0.0006]			
						(0.0009)			
SP_ind							0.0861***		
							[0.0006]		
							(0.0008)		
SP_uni								0.7748***	
								[0.0005]	
								(0.0067)	
SP_pub									0.7722***
									[0.0005]
									(0.0061)
R&D	0.0004***	0.0002***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0004***
	[0.0001]	[0.0000]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Employment	0.0234***	0.0168***	0.0199***	0.0209***	0.0202***	0.0198***	0.0200***	0.0206***	0.0200***
	[0.0002]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]	[0.0001]
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Inudstry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
observation	38199	38199	38199	38199	38199	38199	38199	38199	38199
# of firm	5685	5685	5685	5685	5685	5685	5685	5685	5685

※ Coefficients are not enclosed in brackets or parentheses. Square brackets denote standard partial regression coefficients. Round brackets denote standard deviations.

*** denotes a significance level of 1%.

Table 3. Estimation Results (2)

	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
Spillover pool using researcher info.									
SP_basic_ind	1.6230*** [0.0005] (0.0133)								
SP_basic_uni		1.9065*** [0.0005] (0.0152)							
SP_basic_pub			3.2766*** [0.0004] (0.0267)						
SP_applied_ind				0.4491*** [0.0006] (0.0039)					
SP_applied_uni					3.4327*** [0.0005] (0.0298)				
SP_applied_pub						2.5700*** [0.0005] (0.0216)			
SP_develop_ind							0.1113*** [0.0006] (0.0010)		
SP_develop_uni								6.5768*** [0.0005] (0.0601)	
SP_develop_pub									1.2883*** [0.0006] (0.0111)
R&D	0.0003*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0004*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0003*** [0.0001] (0.0000)	0.0004*** [0.0001] (0.0000)
Employment	0.0218*** [0.0001] (0.0003)	0.0200*** [0.0001] (0.0003)	0.0219*** [0.0001] (0.0003)	0.0201*** [0.0001] (0.0003)	0.0208*** [0.0001] (0.0003)	0.0213*** [0.0001] (0.0003)	0.0199*** [0.0001] (0.0003)	0.0211*** [0.0001] (0.0003)	0.0190*** [0.0001] (0.0003)
Inudstry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
observation	38199	38199	38199	38199	38199	38199	38199	38199	38199
# of firm	5685	5685	5685	5685	5685	5685	5685	5685	5685

※ Coefficients are not enclosed in brackets or parentheses. Square brackets denote standard partial regression coefficients. Round brackets denote standard deviations.

※ *** denotes a significance level of 1%.

5. Conclusions and Discussion

Utilizing a patent formula and the Survey on Research and Development's data on the number of researchers by research type to calculate spillover pools, not only from business enterprises but also from universities and public research institutions, the effects of spillover pools on the number of patent applications submitted by business enterprises were estimated. Considering that the number of patent applications is a non-negative integer, and that the business enterprises are heterogeneous, the data for analysis was organized as panel data at the business enterprise level and the application year level, and the estimations were performed by a panel poisson model. The results demonstrated that increases in the spillover pools available to business enterprises lead to increases in their patent applications. Further, it was observed that if the spillover pools available to business enterprises are broken down according to research type, i.e. basic research, applied research, and development research, their respective increases also result in an increase in patent applications. Moreover, if the spillover pools available to business enterprises are classified according to source, i.e. other business enterprises, universities, and public research institutions, their respective increases also statistically indicate an increase in patent applications. The conclusion that increases in spillover pools have a positive impact on increasing patent applications does not change, even when there are differences in the data on research expenditures by research type, and differences among the external organizations.

This study's estimation results demonstrating that spillover pools promote patent application activity in business enterprises is consistent with relevant prospective studies. This study shows that to improve R&D efficiency, business enterprises can effectively exploit external knowledge and avail themselves of spillovers. Further, apart from the spillover from other business enterprises that a business enterprise can exploit, which various prospective studies have analyzed, this study showed that business enterprises can avail themselves of spillovers from universities and public research institutions while conducting their patent application activities. This study also quantitatively demonstrated that the research activities of universities and public research institutions exert a significant influence on the research activities of business enterprises.

The estimation results obtained from this study are highly significant for the determination of corporate R&D policies, as well as policies to promote scientific and technological innovation. These results showing that business enterprises preparing patent applications can exploit the results of R&D activities conducted by universities and public research institutions indicate that industry-academia-government collaboration can foster more efficient patent application activities on the part of business enterprises. Through industry-academia-government collaboration, business enterprises can communicate closely with researchers in universities and public research institutions. If a greater understanding of external knowledge is nurtured, business enterprises can more efficiently manage their R&D efforts and patent application activities. Although this study's results suggest that collaboration among business enterprises themselves may have a positive effect on their patent application activities, whether this positive effect will materialize or not depends largely on the interrelationships among the collaborating business enterprises. Competition between business enterprises on one hand, and universities and public research institutions on the other, is unlikely. Meanwhile, relationships among business enterprises are handled on a case-by-case basis. There are numerous possible scenarios, e.g. collaboration between rivals, between parent companies and subsidiaries, and between companies in different industries. There is a high probability that industry-academia-government collaboration, as a policy, functions to effectively promote patent applications. However, the implementation of a policy of collaboration among business enterprises in the same industry cannot be universal.

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