Determinants of University-Industry-Government Collaboration: Evidence from Japan

Hiromi Saito*

This paper empirically analyses the determinants of university-industry-government collaboration using more comprehensive data for firms in Japan than previous works. In particular, we focus on industrial characteristics and access to universities and public research institutes, in addition to firm size. As a result of our estimation, we find that any collaboration depends on firm size. Some collaboration also depends on the number of firm researchers of industry to which each firm belongs. Access to universities and public research institutes does not affect collaboration as much. The results of our analysis may be useful to firms in managing innovation, to governments in planning science and technology policy, and to universities and public research institutes in knowing the potential value of basic research for industrial application.

JEL Codes: L21, L24, L29

1. Introduction

Recent reports indicate that it is difficult for firms to research and develop independently (a culture termed 'Not Invented Here'; NIH). This can be attributed to factors like intense global competition, short-term product cycles, upgrading of technology, or dealing with complex technology. Therefore, the R&D strategy of firms has shifted from independent R&D to R&D employing external research outcomes. Such an R&D strategy is referred to as 'open innovation'.

Under open innovation, firms collaborate with external partners or leverage external research outcomes. In particular, universities and public research institutes attract more attention as external partners. They play a large role in 'basic research'. Basic research is public goods, having the characteristic of non-excludability and non-rivalness (Stiglitz and Walsh, 2005). There is usually initial uncertainty as to whether the outcomes of basic research would lead to industrial application, and its cost is high. Therefore, conducting basic research independently is a high-risk undertaking for firms. On the other hand, universities and public research institutes are at an advantage in basic research because they can conduct it relatively independently of the market. University-industry-

*National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato-ku, Tokyo, 106-8677, Japan. Email : hiromi_saito@grips.ac.jp

government collaboration is a way for firms to absorb the outcomes of research by universities and public research institutes.[i]

Concepts and theoretical frameworks regarding university-industry-government relations are sophisticated. For example, Etzkowitz and Leydesdorff (2001) and Etzkowitz (2008) have formulated many concepts and theories on university-government relations, which they represented as a triple-helical structure (the triple helix). Hence, we need empirically analyse university-industry-government relations to validate such sophisticated concepts.

In particular, it would help university-industry-government to explain empirically which firms collaborate with universities and public research institutes, or what types of collaboration they choose, that is, the determinants of university-industry-government collaboration. Firms would need such evidence for developing innovation. Universities and public research institutes can recognize the value of their research outcomes on the basis of such evidence and accordingly deciding the directions of future research. Government can use them for formulating science and technology policy or industrial policy, to encourage the application of basic research outcomes by universities to industries.

Of course, there are many previous studies on these issues. However, they have not achieved universal results because many focus on case studies. Although there are also some empirical studies, the data they use are wholly constructed with restricted samples from the point of view of firm size or industry type. If firms introduce external research outcomes because doing independent research and development is difficult, small size firms would do so even more. Hence, we cannot test these concepts without samples that include small size firms. Moreover, most previous works focused on the manufacturing industry. However, the importance of the services sector is being recognized as shown by the advancement of service science. Therefore, it would be useful to capture the reality of university-industry-government collaboration in even non-manufacturing, including service, industries using large data. Further, only a few studies consider the accessibility of universities and public research institutes to firms.

Therefore, this paper analyses the determinants of university-industry-government collaboration on the basis of questionnaire data for firms in Japan. These data cover most industries and do not restrict firm size in the sample, unlike previous works. In addition, we can analyse how firms' access to universities and public research institutes affects university-industry-government collaboration using information on natural scientists attached to universities and public research institutes, by each prefecture.

2. Literature Review

As previously mentioned, firms tend to introduce external research outcomes or link with external partners. 'Open innovation' refers to the organic connection of ideas inside and outside of firms and the creation of values (Chesbrough, 2006). In particular, universities and public research institutes ('academia') are important for firms as sources of outside research outcomes. They dominate high-risk basic research that private firms cannot undertake. The academic community provides scientific knowledge through basic research. In a number of recent cases, basic research findings have been used in advanced industrial applications. Mansfield (1991) empirically explained that at least 10% of new product manufacturing methods would not have seen the light of day until much later if it were not for this basic research. We believe that the assimilation of scientific knowledge from academia is an important R&D strategy that can help corporate performance and lead to all-round development in the industry.

In the past, surveys were conducted on how firms in Japan evaluate the usefulness of public research outcomes when forming collaborations. RIETI (2003) surveyed the status of collaboration with external partners. This study was conducted with 7442 firms; these firms met the conditions of more than 50 employees, capital of more than 30 million yen, belonging to the manufacturing, wholesaling/retailing industry, or being part of the service sector, and undertaking research and development. The response rate was 10.8% (802 of 7442 firms). Many firms answered 'development of new products and technologies' and 'upgrading R&D potential', as their concrete evaluation of academic-industrial collaboration. Moreover, small and medium enterprises tend to engage in such collaboration for 'development of new products and technologies', whereas large firms tend to conduct research such as 'upgrading R&D potential' and 'publication of papers'. When firms additionally evaluate how much the public research outcome affects their sales and benefits, 3.6% say it makes 'a large contribution'; 14% say 'contribution enough to meet research spending'; 44.4%, 'contribution to meet a part'; and 38%, 'rare contribution'. However, we should note that the data provided by RIETI's 2003 survey are only for firms with more than 50 employees and more than 30 million yen in capital. In addition, the data cover mostly the firms in the manufacturing, wholesaling, and retailing industries.

RIETI (2004) also surveyed 5000 firms sampled randomly from R&D-oriented firms, defined as firms that applied for more than three patents in 2001. The response rate was 11.5% (557 firms). Many firms answered that they obtained special knowledge and technology that they did not previously have by collaborations with national test research institutes. However, we should note that the data are skewed towards the technology field, because the effectiveness of patent protection for an invention largely depends on the field. For example, the research outcome in biotechnology tends to lead to important patents including research tools, whereas many important inventions are produced in secrecy, without applying for patents, in the field of microelectronics. In addition, protection by copyright is more common than protection by patents in the software industry.

Motohashi (2005) analysed the data from the 2003 RIETI survey and the basic research on firms' behaviours. He analysed academic-industrial collaborations and the effects of R&D activities on productivity, using the number of retentions in patents invented by themselves as dependent variables, and the firm's age and cross terms, with or without collaboration in 1997, as independent variables. However, Motohashi encounters two problems. First, the 2003 RIETI database he used has some bias towards manufacturing. Second, there is a possibility of endogeneity in the estimation. 'With or without collaboration' may be a choice variable, although he used it as an independent variable.

Okamuro (2006) analysed how the choice of partners affects the outcome and the achievement of the objective of academic-industrial collaboration for small and medium enterprises, using his original survey. However, Okamuro (2006) also encounters some problems. First, the estimation may include bias by endogeneity. This is because 'With or without joint research' or 'choice of partners' may be a choice variable. Second, Okamuro also displays bias towards manufacturers.

These studies document the actual status of external links in R&D for Japanese firms, but are somewhat restricted with regard to surveyed firms, firm size, or industry. Hence, they do not necessarily provide a comprehensive explanation of why firms might choose a particular type of collaboration. Therefore, this paper empirically analyses the factors that determine a firm's collaboration with universities and public research institutes on the basis of comprehensive data that include small firms and non-manufacturing firms, which, as far as we know, previous surveys have not focused on.

3. Data

We made our own survey sheet for this survey. The actual survey was done by the research company Teikoku Databank,[ii] to which the National Graduate Institute for Policy Studies and the Office of Economic and Industrial Research in the House of Representatives entrusted the survey. Specifically, our survey was carried out along with the 'TDB Survey of Business Trends', which Teikoku Databank has been conducting every month. The survey method required online submission over the Internet. As for the target companies of the survey, the companies that agreed to cooperate with the survey were the targets. The targets included all types of industries and were scattered across Japan. In addition, this survey did not restrict firm size in the sampling. The survey period ran from 17 December 2008 to 5 January 2009.

The research company made the survey request to the target companies by e-mail along with a URL that they would need to access. The person received the e-mail and answered online and then sent the answer. All the questions were presented at once. The respondents could change answers by returning to the questions that they had previously answered. It should also be noted that the respondent could leave a particular question unanswered. The survey request was sent to the headquarters of each firm; the department was not specified.

Fifty percent of the respondents were at management level. The respondents who were not management were asked to reply as the firm, not as an individual.[iii]

In this survey, we requested responses from 20,455 firms and obtained effective answers from 10,731 firms. The rate of response is 52.5%. The strength of the 'TDB Survey of Business Trends' is that the number of target firms is unparalleled in number, and the body of respondents included firms in much broader categories of business, including some much larger in size, in comparison with preceding surveys. Saito and Sumikura (2010) show the detailed results of our survey.

However, we designed the entry questionnaire so that respondents could stop answering questions if they did not conduct R&D or had not done so in the past, if they did not introduce the outcomes of external research or had not done so in the past, or if they had not used in-house or external research outcomes for their business. As a result, we were left with about 5360 firms (response rate: 26%). Table 1 shows the definitions and descriptive statistics of data in this paper. Results of descriptive statistics for industrial attribute variables indicate that these data are from a sample that includes various industries, although the largest number of respondents was from the manufacturing industry—44%.

However, it is difficult to interpret the estimation results indicated by the industrial dummies. Therefore, we created a variable that characterized each industry attribute. 'Firm-Researcher' indicates number of researchers belonging to firms by industry. We assume that university-industry-government collaboration requires not only scientists belonging to universities and public research institutes but also researchers belonging to firms. This is because firms cannot absorb knowledge from universities and public research institutes without in-house researchers. We obtained data about 'Firm-Researcher' from the 'Survey of Research and Development' in 2008.[iv]

We created some area variables to control for access to basic research in specific areas. 'N-univ scientist', 'Pu-univ scientist', and 'Pr-univ scientist' are the number of natural scientists belonging to universities in a prefecture where each firm has its central office.[v] 'Tech-co scientist' is the number of natural scientists belonging to technical colleges in each prefecture.[vi] In addition, 'Pu-Institutes scientist' is the number of natural scientists belonging to public research institutes in each prefecture. These indicate the accumulation of human resources conducting basic research in each area. We assume that it might be easy to access basic research when there are many universities and public research institutes in proximity to firms.

Table 1 Definitions and Descriptive Statistics

Name	Definition	Unit	Obs	Mean	S. D.	Min	Max	Main datasource
Industrial attributes								
Agriculture	1 if a respondent belongs to agriculture, forestry and fisheries, 0 otherwise.	dummy	5360	0.0032	0.0562	0	1	GRIPS firm survey
Finance	1 if a respondent belongs to finance, 0 otherwise.	dummy	5360	0.0054	0.0734	0	1	GRIPS firm survey
Building	1 if a respondent belongs to building, 0 otherwise.	dummy	5360	0.1179	0.3225	0	1	GRIPS firm survey
Real estate	1 if a respondent belongs to real estate, 0 otherwise.	dummy	5360	0.0121	0.1095	0	1	GRIPS firm survey
Manufacturing	1 if a respondent belongs to manufacturing, 0 otherwise.	dummy	5360	0.4425	0.4967	0	1	GRIPS firm survey
Wholesale	1 if a respondent belongs to wholesale, 0 otherwise.	dummy	5360	0.2522	0.4343	0	1	GRIPS firm survey
Retail	1 if a respondent belongs to retail, 0 otherwise.	dummy	5360	0.0276	0.1639	0	1	GRIPS firm survey
Traffic/warehousing	1 if a respondent belongs to traffic or warehousing, 0 otherwise.	dummy	5360	0.0159	0.1249	0	1	GRIPS firm survey
Service	1 if a respondent belongs to service, 0 otherwise.	dummy	5360	0.1220	0.3273	0	1	GRIPS firm survey
Other	1 if a respondent belongs to other, 0 otherwise.	dummy	5360	0.0011	0.0334	0	1	GRIPS firm survey
Industrial variables								
Firm-Researcher (log)	Number of researchers belonging to firms in each prefecture. However, we took logarithm of it for estimation.	number (logarithm)	5147	10.4370	2.5121	4.9345	12.9727	Survey of Research and Development
Firm size								
Employee (log)	Number of employee. However, we took logarithm of it for estimatiton.	number (logarithm)	5310	3.8578	1.4618	0	10.3356	GRIPS firm survey
Area variables								
N-univ scientist	Number of natural scientist belonging to national university in each prefecture. However, we weighted it by ratio of population in each prefecture for total population.	number (weighted)	5360	397.9968	211.6345	0	1754.8390	Nationwide list of research institutes in Japan
Pu-univ scientist	Number of natural scientist belonging to public university in each prefecture. However, we weighted it by ratio of population in each prefecture for total population.	number (weighted)	5360	67.4011	51.6543	0	417.7215	Nationwide list of research institutes in Japan
Pr-univ scientist	Number of natural scientist belonging to private university in each prefecture. However, we weighted it by ratio of population in each prefecture for total population.	number (weighted)	5360	512.6879	424.8300	0	1207.4630	Nationwide list of research institutes in Japan
Tech-co scientist	Number of natural scientist belonging to technical college in each prefecture. However, we weighted it by ratio of population in each prefecture for total population.	number (weighted)	5360	42.4367	38.5364	0	175.6522	Basic survey of school
Pu-Institutes scientist	Number of natural scientist belonging to pblic institutes in each prefecture. However, we weighted it by ratio of population in each prefecture for total population.	number (weighted)	5221	129.1909	89.6798	33.4328	408.0645	Survey of Research and Development
Paper	Ratio of natural scientific paper for every natural scientist in each prefecture.	ratio	5221	0.6718	0.2522	0.2439	1.5891	Index of science and technology

Continued

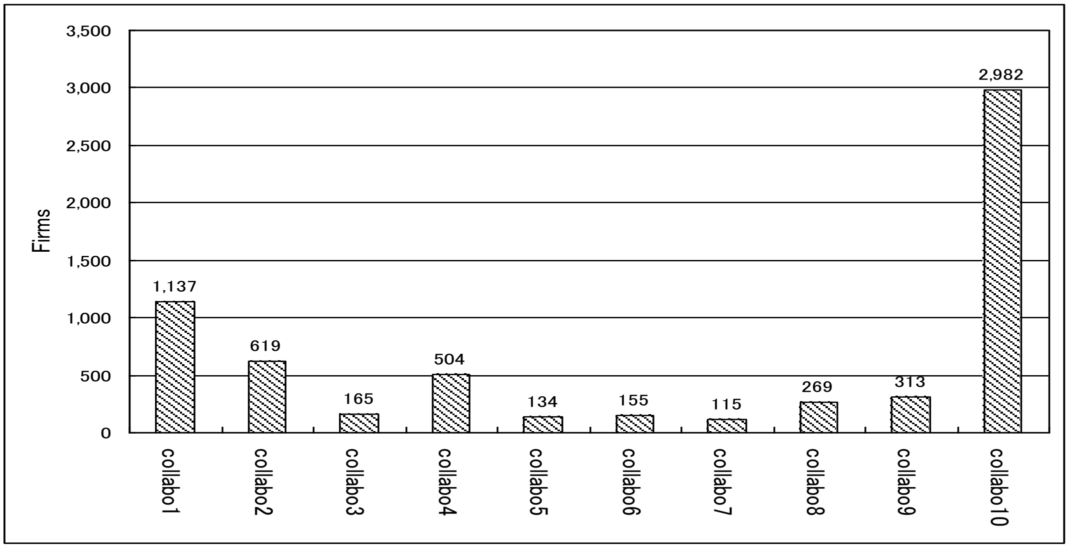
Name	Definition	Unit	Obs	Mean	S. D.	Min	Max	Main datasource
Questions								
collabo1	1 if a respondent has jointed research with universities and public research institutes over the last decade, 0 otherwise.	dummy	5360	0.2121	0.4089	0	1	GRIPS firm survey
collabo2	1 if a respondent has sponsored research for universities and public research institutes over the last decade, 0 otherwise.	dummy	5360	0.1155	0.3196	0	1	GRIPS firm survey
collabo3	1 if a respondent has sent and received researchers between your company and universities/ public research institutes (interns are excluded) over the last decade, 0 otherwise.	dummy	5360	0.0308	0.1727	0	1	GRIPS firm survey
collabo4	1 if a respondent has contributed research fund to universities and public research institutes over the last decade, 0 otherwise.	dummy	5360	0.0940	0.2919	0	1	GRIPS firm survey
collabo5	1 if a respondent has been transferred technology from universities and public research institutes (with licence contract of patent property and know-how) over the last decade, 0 otherwise.	dummy	5360	0.0250	0.1561	0	1	GRIPS firm survey
collabo6	1 if a respondent has been transferred technology from universities and public research institutes (without licence contract of patent property and know-how,for example, technical guidance etc.) over the last decade, 0	dummy	5360	0.0289	0.1676	0	1	GRIPS firm survey
collabo7	1 if a respondent has participated in the venture business that started from universities (provided human resources, capital, and technology) over the last decade, 0 otherwise.	dummy	5360	0.0215	0.1449	0	1	GRIPS firm survey
collabo8	1 if a respondent has interchanged research sample (material) over the last decade, 0 otherwise.	dummy	5360	0.0502	0.2184	0	1	GRIPS firm survey
collabo9	1 if a respondent has collaborated in other ways wInfo-telecomh universities and public research institutes over the last decade, 0 otherwise.	dummy	5360	0.0584	0.2345	0	1	GRIPS firm survey
collabo10	1 if a respondent has not collaborated in any ways wInfo-telecomh universities and public research institutes over the last decade, 0 otherwise.	dummy	5360	0.5563	0.4969	0	1	GRIPS firm survey

We obtained data on the 'N-univ scientist', 'Pu-univ scientist', and 'Pr-univ scientist' from the 'Nationwide List of Research Institutes in Japan' for 2008–2009,[vii] 'Tech-co scientist' from the 'Basic Survey of Schools' in 2008,[viii] and 'Pu-Institutes scientist' from the 'Survey of Research and Development' in 2008.[ix] However, the 'Pu-Institutes scientist' might include not only natural scientists but also researchers in the humanities and social sciences. We could not distinguish them. However, we use these data, though second best, because we assume that most public research institutes in this survey conduct natural science research and that researchers in the humanities and social sciences might also collaborate with firms.

However, it is natural that these data depend on population size because universities are often established in populous neighbourhoods. Therefore, we used these variables divided by the ratio of population in each prefecture to the nationwide population. We obtained this 2008 population ratio from the 'System of Social and Demographic Statistics',[x] in 2010. We also used a number of national scientific papers produced in each prefecture as an index to measure research capacity in each area. However, we assigned weights to them because the distribution of scientists is skewed for similar reasons as the above area variables. Therefore, we used natural scientific papers divided by natural scientists (researchers in universities, technical colleges, and public research institutes) in each prefecture.

We asked respondents 'How have you collaborated with universities or public research institutes during the last 10 years?' in our original questionaire. The responses are shown in Figure 1. Among the alternatives, the percentage of companies marking 'we have no such experience (collabo 10)' were the highest. The next highest were 'joint research (collabo 1)', 'contract research (collabo 2)', and 'contributing funds to universities and public research institutes to support research (collabo 4)', in that order.

Figure 1 Result of Reply for original questionnaire



N=5360, Multiple answers

Next, we examine differences in university-industry-government collaboration between industries. Table 2 shows cross-table university-industry-government collaboration by industry. Here, we exclude 'other' in industry and collabo 10 in the response results when we interpret the results in the cross-table. This is because we gather from the descriptive statistics that the number is very few (approximately 6 firms) and we know little about their industry. In addition, it would mean little to interpret collabo 10, 'we have no such experience', by industry here.

Table 2 Cross-table

	collabo1	collabo2	collabo3	collabo4	collabo5	collabo6	collabo7	collabo8	collabo9	collabo1
Agriculture	29.4	23.5	0.0	5.9	0.0	0.0	0.0	0.0	5.9	52.9
Finance	17.2	3.5	3.5	20.7	0.0	0.0	3.5	3.5	10.3	48.3
Building	18.0	7.9	2.9	6.0	2.7	3.6	1.4	4.6	7.4	61.6
Real estate	7.7	7.7	0.0	4.6	1.5	1.5	0.0	0.0	3.1	81.5
Manufacturing	28.9	14.1	4.2	12.8	2.9	3.5	2.3	6.2	5.4	47.5
Wholesale	12.5	10.0	1.3	6.4	1.8	2.3	1.9	5.2	6.3	61.5
Retail	7.4	5.4	2.0	2.7	0.7	2.0	1.4	1.4	8.1	68.9
Traffic/warehousing	5.9	8.2	3.5	0.0	1.2	0.0	1.2	5.9	3.5	71.8
Service	20.8	11.0	3.4	9.6	3.2	2.3	3.2	2.3	4.9	60.1
Other	33.3	33.3	16.7	0.0	0.0	0.0	0.0	0.0	0.0	50.0

Agriculture and manufacturing are actively involved in 'joint research (collabo 1)' judging from the results of 29.4% and 28.9%, respectively. On the other hand, service is also relatively high, 20.8%. In addition, other industries seem to conduct more or less joint research. This implies that we should also consider industries other than manufacturing in analysing determinants of university-industry-government collaboration. We also found a similar result in ‘contract research (collabo 2)’. It shows characteristics of industry that Finance are active to ‘contributing fund (collabo 4)’.

However, these results of cross-table analysis cannot in themselves sufficiently explain the determinants of university-industry-government collaboration. It is possible that cross-table analysis includes spurious correlations. In addition, some factors other than industrial attributes can affect collaboration. Therefore, we analyse the determinants of university-industry-government collaboration while controlling for various factors, for example, area variables. In addition, we use the number of employees as a proxy of firm size.

4. Methodology

We took responses to original questions about the experiences of university – industry -government collaboration, whether a firm has collaborated with universities and public institutes or not, as dependent variables in each formation using a probit model.[xi] We express as an unobservable latent variable, Y_i^*, whether a respondent *i* has collaborated with universities and public research institutes for the past 10 years, in each formation.

$$Y_i^* = X_i\beta + \varepsilon_i \qquad \varepsilon_i \sim N(0, \sigma^2) \qquad \text{(i)}$$

$$Y_i = 0 \qquad if \quad Y_i^* < \mu_1$$

$$Y_i = 1 \qquad if \quad \mu_1 \le Y_i^* \qquad \text{(ii)}$$

X_i is a vector of each firm *i.* It expresses an industrial dummy for industrial factors, number of employees as a proxy of firm size, a dummy representing the prefecture where the central office is located as a proxy of regional characteristics, and so on[xii]. We take Y_i as the observable variable, which takes 1 if a firm has collaborated with universities and public research institutes for the past 10 years in each formation and 0 otherwise; μ_1 is the threshold value; μ_1 and β are parameters to be estimated. The error term is ε_i. We also use robust standard error to correspond to heteroskedasticity by small and large firm size. We take the log of the number of employees to account for the size of variance. This is also true for ‘Firm-Researcher’. In addition, we use the accumulation of natural scientists in each prefecture as explanatory variables to control for characteristics of the area. Table 3 shows correlation matrix between variables. In estimation, we chose variables correlating poorly with each other as independent variable because we should avoid multicollinearity.

Table 3 Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Employee (log)	1																	
2 Firm-Researcher (log)	0.2442*	1																
3 N-univ scientist	0.021	−0.0202	1															
4 Pu-univ scientist	−0.0232	0.0084	−0.2405*	1														
5 Pr-univ scientist	0.0376*	−0.1168*	−0.1487*	−0.1464*	1													
6 Tech-co scientist	0.0013	0.0095	0.6276*	0.0390*	−0.3975*	1												
7 Pu-Institutes scientist	−0.0480*	0.0853*	0.3381*	0.1899*	−0.7829*	0.5774*	1											
8 Paper / natural scientist	0.0059	−0.0669*	−0.3307*	0.0972*	0.3951*	−0.5588*	−0.6387*	1										
9 collabo1	0.1991*	0.1711*	0.0637*	−0.0028	−0.0557*	0.0652*	0.0696*	−0.0504*	1									
10 collabo2	0.1109*	0.0650*	0.0295*	−0.0097	−0.0099	0.0175	0.0111	−0.002	0.1712*	1								
11 collabo3	0.1168*	0.0633*	0.0243	0.0026	0.0301*	0.005	−0.0289*	0.0465*	0.1639*	0.1241*	1							
12 collabo4	0.1516*	0.0998*	0.0191	−0.0153	0.0159	0.0018	−0.0232	0.0078	0.3083*	0.2636*	0.2018*	1						
13 collabo5	0.0381*	0.0286*	−0.0145	0.0006	0.0027	−0.0236	−0.0066	0.0049	0.1702*	0.1373*	0.1313*	0.1473*	1					
14 collabo6	0.0562*	0.0323*	−0.0056	0.0178	−0.0138	0.0139	0.0179	−0.0126	0.0909*	0.1043*	0.1654*	0.1334*	0.1539*	1				
15 collabo7	0.0138	0.0157	−0.013	0.0038	0.0031	−0.0203	−0.0104	0.0419*	0.0793*	0.0642*	0.0968*	0.0894*	0.0709*	0.0705*	1			
16 collabo8	0.0075	0.0261	−0.0148	0.0360*	−0.0213	0.0154	0.0277	−0.0163	0.0691*	0.1062*	0.0447*	0.0887*	0.0711*	0.0605*	0.0743*	1		
17 collabo9	−0.022	−0.0177	0.0277	−0.0101	−0.008	0.0226	0.0054	−0.0134	−0.1013*	−0.0578*	−0.0205	−0.0576*	−0.0346*	−0.0178	−0.0317*	−0.0122	1	
18 collabo10	−0.1858*	−0.1329*	−0.0544*	−0.0001	0.0574*	−0.0564*	−0.0573*	0.0442*	−0.5777*	−0.4000*	−0.2006*	−0.3580*	−0.1786*	−0.1926*	−0.1619*	−0.2552*	−0.2613*	1

* indicates that the value are significant at the 5% level.

5. Results

Table 4 shows estimation results except for collabo 7~9 because we could not obtain robust results for them. Here, we estimated the marginal effect for convenience of interpretation. In estimations for collabo 1~6, number of employees as a proxy of firm size is positively significant. This robustly shows that firm size is a necessary condition for university-industry-government collaboration, no matter what form the collaboration takes.

In the estimation for collabo 1, 'Firm-Researcher', that is, firm researchers in industry, is positively significant. This implies that industries having many firm researchers tend to research jointly with universities and public research institutes. This result is natural because firms could not conduct joint research with universities and public research institutes without in-house researchers. 'Pu-Institutes scientist', that is, scientists of public research institutes in each prefecture, is also positively significant. This implies that firms tend to engage in joint research with universities and public research institutes when there are many scientists of public research institutes in a prefecture where firms' central offices are located. However, we note that 'Pu-Institutes scientist' might not affect the implementation of joint research that much because the marginal effect is relatively small, 0.036% point.

In estimation for collabo 2, 'Firm-Researcher' is also positively significant in addition to employee. However, other variables, namely, area factors are not significant. Therefore, we suppose that contract research depends on firm size and in-house researchers, but does not depend on the accumulation of human resources in basic research. Certainly, in 'contract research', firms just have to delegate research but might not need access to universities and public research institutes in real study implementation. Both collabo 2 and collabo 4 –contributing fund-- demonstrate the variable of contributing funds to universities and public research institutes to support research.

On the other hand, in the estimation for collabo 3 implying 'exchanges of researchers between firms and universities/public research institutes (interns excluded)', some area variables are positively significant. From the result for 'Pr-univ scientist', we found that 'exchanges of researchers between firms and universities/public research institutes' depend on the number of scientists belonging to a private university. This might imply that private universities are actively involved in exchanges. However, the number of scientists belonging to private universities does not affect the exchange of researchers that much because the marginal effect is 0.002% point. From the result for 'Paper', we also found that the exchange of researchers depends on the output of natural scientific papers per scientist of universities and public research institutes. In the estimation for collabo 5 and 6, 'technology transfer with a licence contract' and 'technology transfer with or without a licence contract', only the variable of employee is positively significant. This means that technology transfer depends only on firm size, regardless of licence contract.

6. Discussion

If the reason for collaboration with an external partner—in particular, universities and public research institutes—is to reduce costs because independent R&D is expensive, more small and medium enterprises would tend to collaborate with universities and public research institutes. However, our estimation results were different from what were expected. Any university-industry-government collaboration depends on firm size. That is, larger firms tend to collaborate with universities and public research institutes. This implies that firms collaborate with them not only to reduce costs but also purely for the sake of increasing their R&D capacity.

Other results are relatively consistent with the content of collaboration. As stated above, since joint research requires not only scientists from universities and public research institutes but also researchers in-house at firms, 'Firm-Researcher' as an industrial variable is positively significant for collabo 1. This suggests that it is very important in joint research to match scientists of universities and public research institutes with researchers of firms. We also found an effect from the accumulation of scientists in public research institutes. This is natural when we consider the characteristics of joint research, that is, it involves collaborative work. However, the effect of it was small. In addition, joint research might not depend that much on area factors.

Therefore, it might be natural that area factors are not significant in collabo 2, 'contract research', for which firms do not necessarily need the presence of scientists from universities and public research institutes. On the other hand, because firms need human resources to absorb and apply outcomes from contract research, 'Firm-Researcher' is positively significant.

Since firms need to send in or have scientists from universities/public research institutes, collabo 3—'exchanges of researchers between firms and universities /public research institutes (interns excluded)'—depends on firm size. It ''is posi tively significant for the same reason that 'Firm-Researcher' is. On the other hand, the number of scientists at a private university affects collabo 3 to some extent but the effect is not that large. Rather, the effect of paper is largest among signify cant factors, 3.4% point. This might suggest that an active regional environment for R&D encourages the exchange of human resources for research. However, as mentioned previously, it is possible that 'paper'—output of papers per scientist of universities and public research institutes in an area—does not affect the exchange of researchers but rather the exchange of researchers affects the output of papers. We should note this.

On the other hand, it is not enough to interpret the estimation results of 'Firm-Researcher' in collabo 4, that is, 'contributing research fund into universities and public research institutes'. This is because it is difficult for us to find explicit reasons for firms needing firm-researchers in order to fund research. It is interesting that technology transfers, 'collabo 5' and 'collabo 6', depend only on firm size regardless of whether there are licence contracts. Technology transfer is the exchange of outcomes already achieved, whereas joint research and contract research involves uncertainty as to whether they can really produce outcomes. Therefore, technology transfers might be purely business for firms.

7. Conclusion

This paper analysed the determinants of university-industry-government collaboration, while controlling for industrial characteristics and access to regional universities and public research institutes, which previous works have not treated as a whole. We expect our findings to facilitate university-industry-government collaborations. These findings would help firms more effectively manage innovation using knowledge from universities and public research institutes. They would also help the government formulate useful policies to link universities and public research institutes with industries. In addition, universities and public research institutes would have a better idea of the contributions their outcomes can make.

Of course, this research has some limitations. We could not find the explicit effects of area factors for university-industry-government collaboration. Further, we did not consider the differences in characteristics or quality among universities and public research institutes. Therefore, we assume that future studies should control for this factor by weighting the amount of funds that universities and public research institutes in each prefecture receive.

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Table 4 Estimation Results

	collabo1				collabo2				collabo3			
	Marginal Effect	S.E.	z-value		Marginal Effect	S.E.	z-value		Marginal Effect	S.E.	z-value	
Employee (log)	0.04924	0.00425	11.41	***	0.02331	0.00326	7.03	***	0.01056	0.00146	6.8	***
Firm-Researcher (log)	0.02161	0.00237	9.05	***	0.00560	0.00185	3.02	***	0.00285	0.00086	3.28	***
N-univ scientist	0.00004	0.00004	1.26		0.00001	0.00003	0.45		0.00000	0.00001	0.14	
Pu-univ scientist	-0.00008	0.00013	-0.63		-0.00005	0.00010	-0.5		0.00003	0.00005	0.65	
Pr-univ scientist	0.00001	0.00002	0.43		0.00000	0.00002	0.15		0.00002	0.00001	2.56	**
Tech-co scientist	0.00012	0.00023	0.52		0.00020	0.00018	1.09		-0.00004	0.00009	-0.4	
Pu-Institutes scientist	0.00036	0.00015	2.41	**	0.00004	0.00011	0.31		0.00010	0.00006	1.54	
Paper	0.02688	0.03082	0.87		0.01285	0.02365	0.54		0.03491	0.01110	3.09	***
Observation	4970				4970				4970			
Pseudo R2	0.0625				0.024				0.0736			
Log likelihood	-2433.0779				-1741.7618				-648.77657			
	Wald chi2(8)	287.93	***		Wald chi2(8)	74.69	***		Wald chi2(8)	84.04	***	

	collabo4				collabo5				collabo6			
	Marginal Effect	S.E.	z-value		Marginal Effect	S.E.	z-value		Marginal Effect	S.E.	z-value	
Employee (log)	0.02443	0.00293	8.05	***	0.00378	0.00160	2.33	**	0.00571	0.00162	3.46	***
Firm-Researcher (log)	0.00855	0.00166	5.08	***	0.00123	0.00088	1.39		0.00120	0.00093	1.28	
N-univ scientist	0.00002	0.00003	0.83		-0.00002	0.00001	-1.25		-0.00002	0.00002	-1.24	
Pu-univ scientist	-0.00005	0.00009	-0.53		-0.00006	0.00004	-1.3		0.00005	0.00005	1.09	
Pr-univ scientist	0.00000	0.00001	0.23		0.00000	0.00001	-0.42		0.00000	0.00001	0.4	
Tech-co scientist	0.00016	0.00017	0.93		0.00002	0.00010	0.19		0.00006	0.00009	0.63	
Pu-Institutes scientist	-0.00009	0.00010	-0.86		0.00001	0.00006	0.11		0.00004	0.00006	0.7	
Paper	-0.00250	0.02099	-0.12		0.01071	0.01204	0.89		-0.00033	0.01358	-0.02	
Observation	4970				4970				4970			
Pseudo R2	0.044				0.011				0.0175			
Log likelihood	-1502.0993				-580.95735				-647.31442			
	Wald chi2(8)	111.56	***		Wald chi2(8)	13.45	*		Wald chi2(8)	24.79	***	

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[i] In this paper, the term 'university-industry-government collaboration' encompasses public research institutes.

[ii] Teikoku Databank. http://www.tdb.co.jp/
For details of the Teikoku Databank 'TDB Survey of Business Trends', refer to the following HP, http://www.tdb-di.com/visitors/keiki_report/pdf/about_keiki.pdf (accessed 4 March 2009.)

[iii] A monetary reward was not given to the respondents. The research company instead sent the companies who registered a white paper on business climate per year; a large scale bankruptcy flash report, and columns about business trend analyses written by a TDB expert, via e-mails. We omitted collabo 9 ('other') and collabo 10 ('nothing') because they are not critical to our research questions.

[iv] Ministry of Internal Affairs and Communications, 'Survey of Research and Development', http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001015772&cycode=0 (in Japanese) (accessed October 2010). An explanation of this survey in English may be found at the following site, http://www.stat.go.jp/english/data/kagaku/index.htm (accessed October 2010).

[v] Of course, it is possible that it is not the central office but the business institution that conducts joint research. If the business institution sits in a prefecture that is not the same as the one where the central office is located, these variables do not correctly reflect the accumulation of knowledge from basic research in the area. However, in our survey, small and medium enterprises constitute about 90%. Therefore, we believe that our area variables wholly reflect the accumulation of knowledge from basic research in the area because we assume that there are not many business institutions situated in a prefecture that differ from that of the central office.

[vi] We assume that technical colleges are included in universities and public research institutes here.

[vii] Ministry of Education, Culture, Sports, Science and Technology (MEXT),'Nationwide list of research institutes in Japan', (in Japanese).

[viii] Ministry of Education, Culture, Sports, Science and Technology (MEXT), 'Basic Survey of Schools' (in Japanese), http://www.e-stat.go.jp/SG1/estat/NewList.do?tid=000001011528

[ix] Ibid., endnote.

[x] Ministry of Internal Affairs and Communications, 'System of Social and Demographic Statistics', http://www.e-stat.go.jp/SG1/estat/List.do?bid=000001025238&cycode=0 (in Japanese)

[xi] We omitted collabo 9 ('other') and collabo 10 ('nothing') because they are not critical to our research questions.

[xii] The unit of our survey is not a business institution but a firm. Therefore, it does not include information about the prefecture where business institutions are located. We cannot capture how collaboration with universities and public institutes in business institutions depends on regional characteristics when a firm has business institutions in prefectures outside the central office location. However, big firms constitute about 10% of our survey. There may be firms that are not big enough to have business institutions other than in the prefecture where their central office is located.