2011 International Conference on Economics and Finance Research
IPEDR vol.4 (2011) © (2011) IACSIT Press, Singapore

Impact of public research on industrial innovation

–An empirical analysis focused on pharmaceutical industry and bio-ventures–

Hiromi Saito*
Koichi Sumikura**
National Graduate Institute for Policy Studies
GRIPS
Tokyo, Japan
hiromi_saito@grips.ac.jp *
sumikura@grips.ac.jp **

Abstract—This paper empirically analyzes how firms create innovative products based on research outcomes of universities and public institutes ("public research") using questionnaire data for inventors. In particular, we target inventors belonging to the pharmaceutical industry, which is regarded as a science-based industry. Participants were asked how many products they had not been able to produce without the support of public research resources. The response rate was 48% out of 332 inventors. Results indicate that although they each value public research, differences exist between inventors belonging to large pharmaceutical firms and inventors belonging to bio-ventures regarding product evaluation based on public research outcomes. This paper shows how inventors value the introduction of external scientific knowledge, specifically knowledge from universities and public research institutes; such knowledge is very useful for industrial application.

Keywords-basic science*; *public research*; *innovation*; *pharmaceutical industry*; *bio-venture

I. INTRODUCTION

Even with the ceaseless introduction of recent advanced technology, basic science continues to contribute to industrial technology. However, uncertainty and high costs surround basic science. Thus, only universities and public research institutes are able to conduct basic scientific research. Private firms introduce external research outcomes because it is difficult for them to implement research and develop inventions independently amongst trends of severe global competition, vast diversity of product technologies, and short-term product cycles. This situation is otherwise known as "open innovation" [1][2]. We believe that universities and public research institutes play important roles for science-based industries, including the pharmaceutical industry, as providers of basic scientific knowledge.

However, it is burdensome to decipher to what extent university and private institute-based research outcomes contribute to the industry. Scientific knowledge produced by basic science leads to technological products through various paths. It is difficult for us to trace them individually. On the other hand, evidence is required with regard to knowledge management and policy planning at present. We can not avoid this task even if it is difficult for us to solve it with conventional method.

Therefore, we must consider methods to explain how industries absorb and use knowledge based on basic science and research conducted by universities and public research institutes ("public research"). When quantitatively analyzing such issues, we use either "objective data" (ex. patent data, financial data) or "subjective data" (ex. questionnaire data).

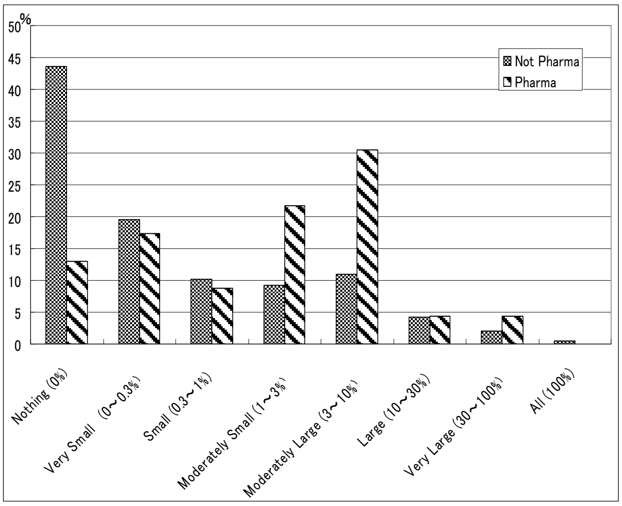
Some previous studies of this issue analyzed coauthorship relations on papers and how the relationships between academic researchers and pharmaceutical researchers affect pharmaceutical firms' performance [3][4][5]. Other study focused on the number of partner firms that jointly apply patents [6]. The study introduced the concept of indexing the amount of scientific knowledge that firms assimilate from universities and public research institutes. This index was used to verify whether absorption of such knowledge influences corporate performance.

Nonetheless, such an index of objective data is not sufficient to fully comprehend the effects of basic science on the industry because it can not capture several alternative available information routes to public research outcomes (ex. conferences, symposiums, personal exchanges with academia). In some cases, subjective data, such as questionnaires, are effective. In one such survey, Mansfield asked United States' firms how many products they could not develop without the outcomes of basic science [7][8]. The results reflected that basic science particularly contributes to advancements in the pharmaceutical industry.

We asked the same type of questions in a large survey for Japanese firms [9]. More specifically, we asked firms how many products they could not produce without the research outcomes conducted by universities and public research institutes. There are eight alternative responses to these questions: all (if the alternative is 100% accurate), very large (more than 30% but less than 100%), large (more than 10% but less than 30%), moderately large (more than 3% but less than 1%), moderately small (more than 1% but less than 3%), small (more than 0.3% but less than 1%), very small (not zero but less than 0.3%), and nothing (0%). Through this survey, we examined how basic science leads to product innovation.

As a result of our survey, Fig.1 indicates that a few pharmaceutical firms (23) answered "moderately large" whereas a majority of pharmaceutical firms (5150) answered "nothing". In addition, the distribution of responses showed a disproportionate weight on low evaluation.

We should note that 50% of respondents are in a zone of management [9]. We can expect differences between managers, who manage companies, and inventors, who actually conduct research and develop products, regarding the evaluation of how public research contributes to commercialization. Managers might not be able to comprehend the process of basic science to practical application of technology, even though they can evaluate commercialization in the final stage. On the other hand, inventors who practice research and apply patents as a result of research and development could understand how basic science contributes to product innovation and fully appreciate the connection between basic science and technology.



Pharmaceutical firms; N = 23, Other firms; N = 5150

Source: The author drew data based on [10]

Figure 1. Evaluation for product innovation based on the public research by managers: Comparison between non-pharmaceutical firms and pharmaceutical firms

Therefore, we empirically analyzed the extent to which the pharmaceutical industry has used outcomes of public research for their commercialization based on the questionnaire data for inventors who apply important patents. In particular, we analyzed on differences among inventors who evaluate the outcomes of public research and its effect on the industry. We also focused on differences between managers and inventors. We analyzed whether there are differences in the evaluation of public research between inventors belonging to large pharmaceutical firms and investors belonging to bio-ventures. We concretely examined differences and similarities between both groups of participants based on information of distribution by kernel estimation. In addition, we analyzed what factors affect investors in their evaluation of public research with the ordered probit model.

II. DATA

Focusing on pharmaceutical firms in Japan, we chose the top 10 firms on sales in 2008 (excluding foreign firms) based on "IMS pharmaceutical market statistics" [11] and 23 firms listed in September 2009 as bio-ventures. Focusing on the patent document applied after 2005, we tried to extract the each firm's inventors whom have applied patents with high degree of importance. However, inventors did not necessarily belong to the said firms. The reason that we put subjects down to important patents is that the random sampling included low-value patents. To avoid mixture of low-value patents with important patents, we focused on important patents only.

We used the "BizCruncher" of Patent Result Co., Ltd index to exact important patents. This index gives each patent a "patent score", which is an aggregated score for each "factor" (action of the applicant or other people) to be positively correlated to the degree of importance of the patent. These factors imply patent application cited by officers on another patent examination, patent application cited in another patent document, patent application on invalidation trial, patent application on early examination request, and patent application registered in the United States. Next, we relatively compared each patent with other patents submitted for approval around the same time to modify the tendency of evaluating older patents as higher. We also compared each patent with other patents in identical technological fields (IPC) to correct differences of patent frequency and differences in the difficulties of patent applications. Each factor is weighted on the basis of statistics of the margin maintenance ratio because important patents tend to be kept for a long time. The patent score is computed as a deviation value. Following this index, we can obtain an inventor's patent score by aggregating the patent score of each patent application in which the inventor is a contributor.

This study chose the top 15 inventors in the patent score out of each subjective firm's patent application applied after 2005. We extracted 15 inventors out of each large pharmaceutical firm. As a result, the number of object inventors was 148, but then we excluded 2 residing abroad. We also extracted bio-venture inventors in the same way. However, some bio-ventures have less than 15 inventors after 2005. In this case we extracted as many inventors as possible. As a result, the number of object bio-venture inventors was 184. The total number of inventors/participants was 332. We sent questionnaire sheets to these 332 inventors. However, some questionnaire sheets were returned because of address unknown (6 sheets in large firms and 23 sheets in bio-ventures). The tentative investigation period was from December 1 to 18, 2009. However, we also collected questionnaire sheets after the deadline by prodding. The final sample was 160 (including non-responders) out of 332 object respondents. The response rate was 48%. The sample size comprising large firms was 74 and the sample size comprising bio-ventures was 85.

TABLE I shows the definitions and descriptive statistics of basic attributes of inventors in our data. As seen in the table1, the sample numbers of the opposing groups—large firm inventors and bio-venture inventors—is nearly identical. The mean of inventors' research years is about 11.5. In education background, most hold a master's degree (M.A.), 42.9%.

TABLE I. DEFINITIONS AND DESCRIPTIVE STATISTICS FOR BASIC ATTRIBUTES

Variable	Definition	Obs	Mean	S.D.	Min	Max
Big firm	1 if a inventor belongs to big pharmacuetical firm, 0 if she belongs to bio-venture.	159	0.465	0.500	0	1
Research year	The number of year which the researcher have researched at current affiliation.	146	11.531	7.087	0	35
Ph.D.	1 if a inventor's educational record is doctoral degree, 0 otherwise	154	0.390	0.489	0	1
M.A.	1 if a inventor's educational record is master's degree,, 0 otherwise	154	0.429	0.496	0	1
B.A.	1 if a inventor's educational record is bachelor's degree, 0 otherwise	154	0.136	0.344	0	1
Junior college	1 if a inventor's educational record is Junior college, 0 otherwise	154	0.013	0.114	0	1
Tertiary college	1 if a inventor's educational record is Tertiary college, 0 otherwise	154	0.019	0.139	0	1
Career college	1 if a inventor's educational record is Carrer college, 0 otherwise	154	0.013	0.114	0	1
High/Junior high	1 if a inventor's educational record is High/ Junior high, 0 otherwise	154	0.006	0.081	0	1

We asked the participants how many of their commodities they could not produce without public research outcomes like [7][8]. In other words, this implies "How does the outcome of public research contribute to product innovation?" We also asked what percentage of their sales relies on public research outcomes. This implies to ask the market value of product innovation. The alternatives are same to Fig.1. Fig. 2 shows those results. The shaded area shows the distribution of evaluation of commercialization based on public research outcomes. The distribution has two peaks: the largest response is "very large" and the next is "moderately large". We found that inventors evaluate product innovation based on the outcomes of public research more than managers' responses in [9].

The dotted area describes the distribution of evaluation for contribution on sales based on the outcomes of public research. The peak of distributions is "some small". Therefore, we find that inventors value contribution on sales by the outcomes of public research less than commercialization.

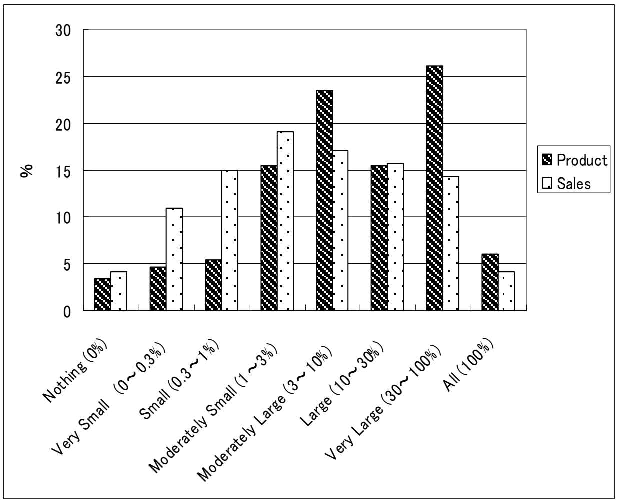
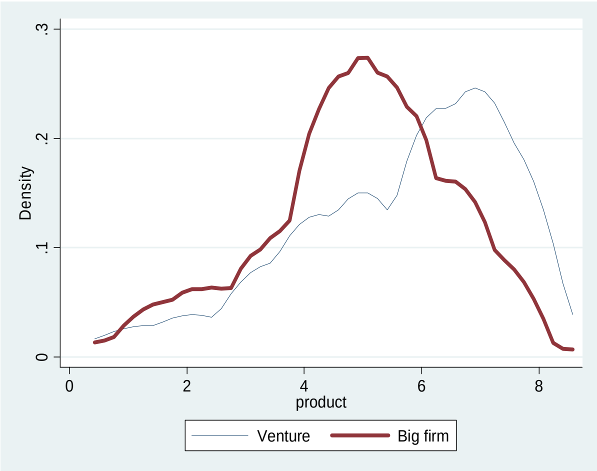


Figure 2. Evaluation for product innovation and the market value based on the public research by inventors.

III. LARGE PHARMACEUTICAL FIRMS VS BIO-VENTURE

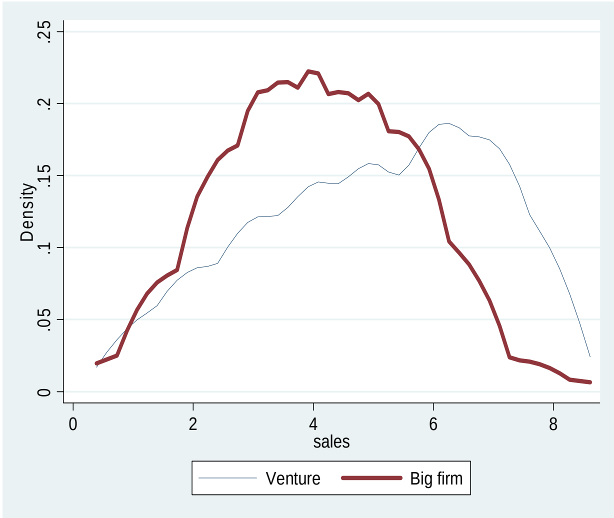
First, we examine how responses vary between inventors belonging to large firms and inventors belonging to bio-ventures. We expect that inventors belonging to bio-ventures evaluate public research contributions for commercialization higher than large firm inventors because some bio-ventures are spun off from public research while large firms can conduct research and develop products independently. However, this is not necessarily clear based on the data. In addition, there are differences in beliefs between firms and individual inventors. Therefore, we explain whether bio-venture inventors evaluate public research contributions for industrial applications higher than large firms by using the kernel estimation of information. Kernel estimation is usually used for metric variables; however, we applied kernel estimation as an approximate treatment because the questionnaire has eight ordered alternative variables.

Fig. 3 describes the distribution of evaluation of commercialization based on the outcomes of public research. The thick line indicates evaluations of inventors belonging to large firms while the thin line indicates evaluation of bio-ventures. The response results (alternatives 1~8) are listed in the order of evaluation from left to right.



N=148

Figure 3. Distribution of evaluation for commercialization based on the outcomes of public research : Large firms' inventors VS bio-venture's inventors



N=146

Figure 4. Distribution of evaluation for sales based on the outcomes of public research : Large firms' inventors VS bio-venture's inventors

We found a difference in the distribution of inventors belonging to large firms and bio-ventures. The distribution of inventors belonging to large firms is a little skew to the right but near normal distribution. On the other hand, the distribution of inventors belonging to bio-ventures is skew to the right more than inventors belonging to large firms. Therefore, we confirm that inventors belonging to bio-ventures highly evaluate the outcomes of public research for commercialization more than inventors of large firms.

Fig. 4 describes the distribution of evaluation for sales based on the outcomes of public research. In this case, we also find that the distribution of inventors belonging to large firms is different from that of bio-ventures. The distribution of inventors belonging to large firms is near normal distribution whereas the distribution of inventors belonging to bio-ventures is skew to the right. This finding is similar to Fig. 3. In fact, bio-venture inventors evaluate public research outcomes higher than large pharmaceutical firm inventors do, whether it is evaluation of commercialization or for sales. However, both dispersions of distribution are large and the peak distribution is more skew to the left than in Fig. 3. This result implies that inventors evaluate public research contributions for commercialization more than for sales.

However, this result does not explain on what factors the evaluation for commercialization or sales are based. The outcomes of public research depend on several factors, but we only focused on whether the investors were affiliated with large firms or bio-ventures. We admit that evaluations of public research depend on background factors other than affiliation; for example, research experience and education background and so on. Therefore, we control these factors with the ordered logit model to analyze how the background of inventors affects evaluation.

Ⅳ. WHICH INVENTORS HIGHLY EVALUATE PUBLIC RESEARCH CONTRIBUTIONS TO INDUSTRY?

We accept eight order alternatives for commercialization and sales as dependent variables to analyze how inventors evaluate public research contributions for commercialization and sales. We also use the ordered logit model to analyze how public research outcomes help firms' performance. We propose eight ordered answers to the question of contribution to commercialization and to sales as ordered variables in using the ordered logit model. The model is

$$y_i^* = X_i a + e_i \quad e_i \sim N(0, s^2)$$
$$y_i = j \quad if \quad \mu_{j-1} \le y_i^* \le \mu_j, \quad j = 1,\ldots,J, \quad \mu_0 = -\infty, \mu_J = +\infty \qquad (1)$$

y_i^* is an unobservable latent variable, while y_i is an observable variable. j corresponds to 8 if a respondent said all, 7 if very large, 6 if large, 5 if moderately large, 4 if moderately small, 3 if small, 2 if very small, and 1 if nothing. a is a parameter. X is a dummy variable describing the background of inventors. Table Ⅰ shows the details. We suppose that the error term e_i exhibits a logistic distribution. We also use the same model for the contribution to sales by such research outcomes.

TABLE Ⅱ shows estimation results. Results for commercialization and sales are similar.

TABLE II. ESTIMATION BY ORDERED LOGIT MODEL

	Product				Sales			
Variable	Coef.	S.E.	Z-value		Coef.	S.E.	Z-value	
Big firm	-0.4533	0.2077	-2.18	**	-0.5025	0.2003	-2.51	**
Research year	-0.0358	0.0144	-2.48	**	-0.0244	0.0123	-1.98	**
Ph.D.	0.9633	0.4478	2.15	**	1.3745	0.2331	5.9	***
M.A.	0.3884	0.4573	0.85		0.8775	0.2485	3.53	***
B.A.	-0.5301	0.5086	-1.04		0.0281	0.3270	0.09	
Junior college	1.1853	0.4670	2.54	**	2.0535	0.2840	7.23	***
Tertiary college	-0.2868	0.6946	-0.41		0.3277	0.4825	0.68	
Career college	1.4963	0.9956	1.5		0.1872	0.2600	0.72	
cut1	-2.4651	0.5740			-1.6588	0.3392		
cut2	-1.8455	0.5154			-0.7891	0.2731		
cut3	-1.4492	0.4920			-0.2065	0.2677		
cut4	-0.7951	0.4747			0.4088	0.2669		
cut5	-0.0526	0.4655			0.9334	0.2805		
cut6	0.4638	0.4563			1.5211	0.2783		
cut7	1.8353	0.5050			2.5371	0.3380		
Observation	140				138			
Psued R2	0.0832				0.066			
Psued log likelihood	-234.3553				-250.8785			

Both wald test were rejected. Baseline of education record is "High/Junior high".

We confirm that large firm inventors tend to give low evaluations for the outcomes of public research on both commercialization and sales because the large firm dummy variable is significantly negative. This is consistent with results of the kernel estimation in section Ⅲ. In addition, we found that inventors with extended research history tend to give low evaluations for public research contributions for commercialization and sales because research years are significantly negative on both commercialization and sales. On the other hand, inventors with a Ph.D. tend to give high evaluation for the outcomes of public research because the Ph.D. variable is significantly positive on both commercialization and sales. This suggests that those with a Ph.D. understand the contents of advanced technology and tend to appreciate the labors of public research. Although junior college graduates also show a significant positive, it does not have significant bearing, because only two participants were junior college graduates.

Ⅴ. CONCLUSION

Using kernel estimation, we found that inventors of bio-ventures give higher evaluations for the outcomes of public research than inventors associated with large firms. This suggests that public research contributes more to commercialization than sales. However, estimation by the ordered logit model suggests that there are not differences between evaluation for commercialization based on basic science and contributions of introducing basic science for sales. Moreover, factors other than association, for example, research experience and education background, affects evaluation.

This paper is a preliminary report and some fact finding still remains. In the future, we will add new analysis and consider more deeply how firms should implement basic science knowledge from universities and public research institutes.

ACKNOWLEDGEMENT

This study was a part of joint research with RIKEN. However, the opinions expressed in this paper do not represent those of RIKEN.

REFERENCES

[1] H.W. Chesbrough, Open Innovation: The new imperative for creating and profiting from technology. Harvard Business School press, Boston Mass, 2003.

[2] H.W. Chesbrough, Open Business Models: How to thrive in the new innovation landscape. Harvard Business School Press, Boston Mass, 2006.

[3] I. Cockburn and R Henderson (1998)."Public-private interaction and the productivity of pharmaceutical research", *NBER Working Paper Series*, working paper 6018.

[4] L.G. Zucker, and M.R. Darby, "Capturing technological opportunity via Japan's star scientists: Evidence from Japanese firm's biotech patents and products," Journal of Technology Transfer, vol. 26, Nos. 1–2, 2001, pp. 37–58.

[5] L.G. Zucker, M.R. Darby, and J.S. Armstrong (2001). "Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology," *NBER Working Paper Series*, working paper 8499.

[6] H. Saito and K. Sumikura, "An Empirical Analysis on Absorptive Capacity Based on Linkage with Academia," International Journal of Innovation Management, vol. 14, No.3, 2010, 491-509.

[7] E. Mansfield, "Academic research and industrial innovation" Research Policy, vol. 20, 1998, pp.1-12.

[8] E. Mansfield, "Academic research and industrial innovation: An update of empirical findings," Research Policy, vol. 26, 1998, pp. 773-776.

[9] H. Saito, and K. Sumikura, "How are fruits of research in universities and public research institutes used?: Brief overview from GRIPS firm survey". GRIPS Discussion Paper Series 10-15, 2010. http://www3.grips.ac.jp/~pinc/data/10-15.pdf (accessible, Nov. 18, 2011)

[10] K. Sumikura and H. Saito, "How scientific knowledge assimilated from academia influences corporate performance—Based on three empirical analyses," Proceedings of Intellectual Property Association of Japan 2010, Intellectual Property Association of Japan, Japan, 2010 (in Japanese).

[11] IMS pharmaceutical market statistics, http://www.ims-japan.co.jp/docs/top_line_08YE.pdf (accessible, 17/11/2010)