Empirical Study of the Effect of Process Invention on Innovation in Manufacturing Industry (*)

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Under today's environment of severer international competition, it is necessary for firms to utilize not only internal but also external knowledge. The use of patents applied for by other organizations seems to be especially important as a source of external knowledge regarding "process inventions," because they are basically carried out only within the factories of each firm. However, whether applied "process inventions" are useful as external knowledge or not is yet to be clarified. Hence, in this study, by empirically analyzing Japanese patents applied by firms in the pharmaceutical, chemical, and food industries, I examined the research question of "whether applied 'process inventions' contribute to innovation across organizational boundaries or not." According to the results of regression analysis, it is revealed that compared with "product inventions," it is difficult for "process inventions" to spill over outside organizations.

I. Introduction

The research question of this study is "whether applied 'process inventions' contribute to innovation across organizational boundaries or not." In order to examine the question, I empirically analyzed Japanese patents applied for by firms in the pharmaceutical, chemical, and food industries.

II. Background and research question

As leaders of innovation, firms traditionally have conducted research & development by utilizing internal resources (Hirai, 2017). However, under today's environment of severer international competition, it is necessary for firms to utilize external resources such as fruits of research, technologies, and ideas outside the organization.

External knowledge is acquired through various means such as technology transfer, reverse engineering, the use of papers published by researchers and patents applied for by other firms or organizations, the transfer of expertise through joint research with academic or research institutions or firms, or relocation of employees (Fujiwara & Watanabe, 2017). Because a "process invention" is basically carried out only within the factories of each firm (Suzuki, 2013), among the means for acquiring external knowledge above, the use of patents seems to be especially important as a source of external knowledge regarding "process inventions."

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However, in Japan, the Intellectual Property Strategy Headquarters (2005) pointed out that a large number of defensive applications by firms existed, and this caused problems such as delays in examination and unintentional technological leakage to overseas. According to Nishikawa (2015), because a “process invention” is often carried out within an infringer’s controlled area, it is impossible to capture the fact of infringement only by the manufactured product itself or circumstances judged from outside, and it may not be possible to exercise the right. Therefore, regarding “process inventions,” there are many cases that are not suitable for protection by patent rights (Nishikawa, 2015).

It is very important for firms to appropriately select whether they will protect a result of research & development as a patent or keep it secret. However, as opportunities for firms to keep newly created technologies confidential increase, opportunities for disclosing new technologies as patents decrease. Conversely, because the patent system is a social means for externalizing and sharing knowledge (Wada, 2008), disclosure of a “process innovation” by patent application has a positive effect from the viewpoint of knowledge spillover (diffusion of technological information) across organizational boundaries.

However, whether an applied "process invention" is useful as external knowledge or not is yet to be clarified. Hence, in this study, I examined the research question of “whether applied ‘process inventions’ contribute to innovation across organizational boundaries or not.”

III. Previous studies

There are many studies that focused on patents as a source of external knowledge and empirically analyzed innovation across organizational boundaries. A representative example is Rosenkopf & Nerkar (2001). They paid attention to “beyond local search” which is a means to rely on technologies developed by other organizations, and they revealed that exploration across both organizational and technological boundaries had the greatest impact on subsequent technological development by using patent data in optical disk technology.

On the other hand, there are few empirical studies on “process inventions,” and very few studies have analyzed the influence of “process inventions” on innovation by using patent data.

IV. Method

1. Analyzed industries

In order to select industries to be analyzed, I used data from the Japan Patent Office's "Survey of intellectual property-related activities[1]." Because "process inventions" are related to trade secrets and know-how, I extracted the number of trade secrets and know-how among inventions in each year from fiscal 2008 to fiscal 2016. Then, I summed the numbers from fiscal 2008 to fiscal 2016, and calculated the percentage of the number of trade secrets and know-how in the total of inventions by industry. I selected the pharmaceutical industry whose percentage was the lowest among the manufacturing industries, the chemical industry whose percentage was the closest to that of the total of the manufacturing industries, and the food industry whose percentage was the highest among the manufacturing industries.

2. Analyzed firms

Next, I selected firms to be analyzed in the pharmaceutical, chemical, and food industries. For the selection, I used the operating profit ranking (updated April 12th, 2017) of the website of Nikkei newspaper[2]. Because the present study focused on the spillover of technological information inside and outside organizations, firms that introduced the pure holding company system were hard to handle. This was why those firms were excluded. In addition, NH Foods Ltd. was excluded, since the number of its patents to be analyzed was less than 100, and this was too small to analyze statistically. As a result of extracting the top three firms from each industry in this manner, Astellas Pharma Inc., Takeda Pharmaceutical Company Limited., and DAIICHI SANKYO COMPANY, LIMITED in the pharmaceutical industry, Shin-Etsu Chemical Co., Ltd., Kao Corporation, and Asahi Kasei Corp. in the chemical industry, and Japan Tobacco Inc., Ajinomoto Co., Inc., and Yakult Honsha Co., Ltd. in the food industry were selected.

3. Analyzed patents

Patents of nine firms above to be analyzed were extracted. PatentSQUARE, a patent search system of Panasonic Solution Technologies Co., Ltd., was used to collect patent data. Patents held by the nine firms were collected from the Japan Patent Office. The patent search covered the filing

[1] https://www.jpo.go.jp/shiryou/toukei/tizai_katsudou_list.htm (Date of data acquisition: January 9th, 2018; Last accessed date: March 8th, 2018)

[2] Pharmaceutical industry: https://www.nikkei.com/markets/ranking/page/?bd=eigyo&ba=0&Gcode=09&hm=1 (Date of data acquisition: January 16th, 2018; Last accessed date: March 8th, 2018), Chemical industry: https://www.nikkei.com/markets/ranking/page/?bd=eigyo&ba=0&Gcode=07&hm=1 (Date of data acquisition: January 16th, 2018; Last accessed date: March 8th, 2018), Food industry: https://www.nikkei.com/markets/ranking/page/?bd=eigyo&ba=0&Gcode=01&hm=1 (Date of data acquisition: January 16th, 2018; Last accessed date: March 8th, 2018.) Details of the ranking: https://www.nikkei.com/help/markets/helpindex.html (Last accessed date: March 8th, 2018.)

date period from January 1st, 2000, to December 31st, 2009 (for 10 years).

Then, in order to align the conditions of analyzed patents, those of utility model, those of alteration of application, and those of divisional application were excluded. Also, in this study, as I focused on the spillover of technological information inside and outside the organizations, transferred patents and patents jointly filed with other organizations were excluded. In addition, I eliminated patents with missing data. Finally, 1,155 patents in the pharmaceutical industry, 15,280 patents in the chemical industry, and 1,689 patents in the food industry were extracted. These patents were analyzed by each industry.

4. Variables

(1) Dependent variables

In this study, I used the numbers of forward citations by examiner as dependent variables. In the bibliometric field, citation between documents is frequently used as an index of "importance" or "impact" of documents (Suzuki & Goto, 2007). In a cumulative research & development environment, the use of prior technologies is indispensable (Wada, 2008). If patent A is cited by patent B, there is a probability that inventors of patent B actually utilize the knowledge of patent A, therefore it can be said that citation of patents reflects knowledge flow (Wada, 2008, 2009). Hence, citation of patents represents the cumulative relationship of innovation, and it can be interpreted that patents with many citations spill over more to later research & development (Wada, 2008).

In this study, since attention was paid to the spillover of technological information inside and outside the organizations, the number of forward citations was divided into "the number of forward citations inside the firm" and "the number of forward citations outside the firm." Also, the number of forward citations was divided into "the number of forward citations inside the group firms" and "the number of forward citations outside the group firms." "The number of forward citations inside the firm" was the number of forward citations by the patents filed by the focal firm, including joint applications, among the forward citations by examiner (domestic only). "The number of forward citations outside the firm" was the number obtained by subtracting "the number of forward citations inside the firm" from the forward citations by examiner. Similarly, "the number of forward citations inside the group firms" was the number of forward citations by the patents filed by the focal firm and its group firms, including joint applications, among the forward citations by examiner (domestic only). "The number of forward citations outside the group firms" was the number obtained by subtracting "the number of forward citations inside the group firms" from the forward citations by examiner.

For discrimination of “inside the firm” and “inside the group firms,” “NISTEP dictionary of corporate names (ver.2018.1)[3]” provided by the National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology was utilized.

(2) Independent variables

The method to specify “process invention” from the description of patents is not sufficiently established. According to Shimori et al. (2001, 2004), “product inventions” and “process inventions” in patent claims in Japanese are described as a noun phrase accompanied by a long modifier that indicates its content, and there is a constraint that the content of an invention is described in a sentence. For example, Suzuki & Oda (2012) searches for “method.” (「方法。」 or 「法。」 in Japanese) to specify “process invention.”

With reference to these previous studies, in this study, when a patent claim to be analyzed included “method.,” “method:,” or “method;” (「法。」, 「法：」, or 「法；」 in Japanese), it was identified as a “process invention,” Otherwise, it was identified as “product invention.”

Then, I created three independent variables, “product invention only,” “product invention with process invention,” and “first claim of process invention.”

“Product invention only” was coded as “1” if all claims of a patent did not include “process invention.” Otherwise, it was coded as “0.”

“Product invention with process invention” was coded as “1” if the first claim of a patent did not include “process invention” but “process invention” was included after that. Otherwise, it was coded as “0.”

“First claim of process invention” was coded as “1” if the first claim of a patent included “process invention.” Otherwise, it was coded as “0.”

(3) Control variables

I utilized the firm dummies, the filing date (the number of days from the filing date to January 1st, 2010), the number of inventors, the number of claims, the IPC number (the IPC subgroup number), the dummy of request for examination, the dummy of registration number, the dummy of priority number, the number of family, and the number of inspection requests as control variables.

[3] http://www.nistep.go.jp/research/scisip/rd-and-innovation-on-industry (Date of data acquisition: February 16th, 2018; Last accessed date: March 8th, 2018)

5. Method of regression analysis

I conducted regression analysis by each industry. It is known that the number of forward citations by examiner is distributed close to the negative binomial distribution (Yoshioka (Kobayashi) & Watanabe, 2014). Therefore, I conducted regression analysis by utilizing a negative binominal generalized linear model. However, because "the number of forward citations inside the firm" and "the number of forward citations inside the group firms" as well as "the number of citations outside the firm" and "the number of citations outside the group firms" were the same in the pharmaceutical industry, I analyzed only when the dependent variables were "the number of forward citations inside the firm" and "the number of citations outside the firm" in this industry.

V. Results

1. Simple totaling

First, the percentage of "process invention" was calculated by each industry. The percentage of the patents in which at least one "process invention" was included in all claims was 70.6% in the pharmaceutical industry, 47.2% in the chemical industry, and 56.1% in the food industry. The percentage of patents in which the first claim was "process invention" was 18.2% in the pharmaceutical industry, 22.0% in the chemical industry and 28.8% in the food industry.

Then, for the patents in which the first claim was "product invention," the percentage of request for examination and the percentage of registration were calculated by each industry. The percentage of request for examination was 45.3% in the pharmaceutical industry, 85.6% in the chemical industry, and 63.0% in the food industry. The percentage of registration was 23.3% in the pharmaceutical industry, 65.6% in the chemical industry, and 38.8% in the food industry. Among the three industries subject to analysis, the chemical industry has the highest percentage of request for examination and registration, and the pharmaceutical industry has the lowest percentage of request for examination and registration. Also, for the patents in which the first claim was "process invention," the percentage of request for examination and the percentage of registration were calculated by each industry. The percentage of request for examination was 51.4% in the pharmaceutical industry, 86.5% in the chemical industry, and 60.8% in the food industry. The percentage of registration was 30.5% in the pharmaceutical industry, 68.9% in the chemical industry, and 37.0% in the food industry. As in the case of the patents in which the first claim is "product invention," the chemical industry has the highest percentage of request for examination and registration, and the pharmaceutical industry has the lowest percentage of request for examination and registration.

2. Descriptive statistics

The correlation coefficients of each variable in patents subject to analysis by each industry were calculated. There was no conspicuous correlation between the independent variables and control variables.

3. Regression analysis

(1) Pharmaceutical industry

In this section, I conducted regression analysis of the patents in the pharmaceutical industry by utilizing a negative binominal generalized linear model. In the models where the dependent variables were "the number of forward citations inside the firm" and "the number of forward citations outside the firm," the independent variable "product invention only" was significantly positive at the $p<0.01$ level. Although the independent variable "product invention with process invention" was not significant in the model where the dependent variable was "the number of forward citations inside the firm," it was significantly negative at the $p<0.05$ level in the model where the dependent variable was "the number of forward citations outside the firm." The independent variable "first claim of process invention" was significantly negative at the $p<0.1$ level in the model where the dependent variable was "the number of forward citations inside the firm," and significantly negative at the $p<0.05$ level in the model where the dependent variable was "the number of forward citations outside the firm."

(2) Chemical industry

Here, I conducted regression analysis of the patents in the chemical industry by utilizing a negative binominal generalized linear model. In the models where the dependent variables were "the number of forward citations inside the firm," "the number of forward citations outside the firm," "the number of forward citations inside the group firms," and "the number of forward citations outside the group firms," the independent variable "product invention only" was significantly positive at the $p<0.001$ level. Although the independent variable "product invention with process invention" was not significant in the models where the dependent variables were "the number of forward citations outside the firm" and "the number of forward citations outside the group firms," it was significantly positive at the $p<0.05$ level in the models where the dependent variables were "the number of forward citations inside the firm" and "the number of forward citations inside the group firms." The independent variable "first claim of process invention" was significantly negative at the $p<0.001$ level in the models where the dependent variables were "the number of forward citations inside the firm," "the number of forward citations outside the firm," "the number of forward citations inside the group firms," and "the number of forward citations outside the group firms."

(3) Food industry

In this section, I conducted regression analysis of the patents in the food industry by utilizing a negative binominal generalized linear model. Although the independent variable "product invention only" was not significant in the models where the dependent variables were "the number of forward citations inside the firm" and "the number of forward citations inside the group firms," it was significantly positive at the $p<0.1$ level in the models where the dependent variables were "the number of forward citations outside the firm" and "the number of forward citations outside the group firms." While the independent variable "product invention with process invention" was not significant in the models where the dependent variables were "the number of forward citations outside the firm" and "the number of forward citations outside the group firms," it was significantly positive at the $p<0.05$ level in the models where the dependent variables were "the number of forward citations inside the firm" and "the number of forward citations inside the group firms." The independent variable "first claim of process invention" was significantly negative at the $p<0.1$ level in the models where the dependent variables were "the number of forward citations inside the firm" and "the number of forward citations inside the group firms," and significantly negative at the $p<0.01$ level in the models where the dependent variables were "the number of forward citations outside the firm" and "the number of forward citations outside the group firms."

VI. Discussion

The results of regression analysis above reveal that when "process invention" is included in patent claims, especially when "process invention" is included in the first claim, the number of forward citations by examiner is fewer. This tendency is stronger when the dependent variables are "the number of forward citations outside the firm" and "the number of forward citations outside the group firms," and it indicates that compared with "product inventions," it is difficult for "process inventions" to spill over outside organizations. For this reason, there is a possibility that "process inventions" are more sticky as information than "product inventions." The concept of "stickiness of information" was proposed by von Hippel (1994), and the stickiness of a given unit of information in a given instance is defined as “the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker.” When this cost is high, information stickiness is high. With respect to the impact of the nature of the information to be transferred, tacit information is more sticky than explicit information (von Hippel, 1994; Ogawa, 1997).

In order to carry out the “process invention,” many cases need know-how coded into a person such as skill or technique not shown in the patent description. When such tacit knowledge is necessary, it is difficult to transfer contents of invention described in a patent. Therefore, a “process invention” may be apt not to spill over outside organizations. In addition, there is also a possibility that firms may apply for patents in a manner that makes it difficult to transfer “process inventions” outside the organizations or selectively conceal “process inventions” that are less sticky and easily transferred outside organizations, and the results in this study may reflect such firms’ intellectual property strategies.

Thus, by using patent data, this study reveals the influence of “process inventions” on innovation.

References

Fujiwara, A., & Watanabe, T. (2017). Knowledge management using external knowledge. International Journal of Innovation Management, 21(04), 1750031.

Hirai, Y. (2017). The empirical analysis of meaning observed in the patent documents for effective utilization of patented technology. Fiscal Year 2015 (2015-2017) Report of the Industrial Property Research Promotion Project entrusted by the Japan Patent Office, Foundation for Intellectual Property, Institute of Intellectual Property. [In Japanese].

Intellectual Property Strategy Headquarters. (2005). Promotion program for intellectual property. https://www.kantei.go.jp/jp/singi/titeki2/kettei/050610.html (Last accessed date: March 11th, 2018). [In Japanese].

Nishikawa, Y. (2015). Intellectual property strategies for choosing between acquisition of patent rights and protection of trade secrets. Patent Studies, 59, 56-64. [In Japanese].

Ogawa, S. (1997). イノベーションと情報の粘着性. Organizational Science, 30(4), 60-71. [In Japanese].

Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. Strategic Management Journal, 22(4), 287-306.

Shinmori, A., Saito, S., & Okumura, M. (2001). 特許請求項の可読性向上のための自動言い換えについての考察. In-house workshop of the 7th annual meeting of the Association for Natural Language, 「言い換え/パラフレーズの自動化に向けて」. [In Japanese].

Shinmori, A., Okumura, M., Maruyama, Y., & Iwayama, M. (2004). Structure analysis of Japanese patent claims using cue phrases. （手がかり句を用いた特許請求項の構造解析.） Journal of Information Processing Society of Japan, 45(3), 891-905. [In Japanese].

Suzuki, H. (2013). The patent system for protection of know-how and protection strategy of the process invention - The legal interpretation of prior user rights and proposal of protection strategy matrix of process invention-. Ritsumeikan University, Doctoral thesis. [In Japanese].

Suzuki, H., & Oda, T. (2012). 日本 MOT 学会による査読論文 (2012-3) The framework about the protection strategy of know-how. Technology and Economy, 548, 54-63. [In Japanese].

Suzuki, J., & Goto, A. (2007). Innovation research using JPO patent data (特集 知的財産のダイナミクスを捉える--実証研究の方法論). Journal of Intellectual Property Association of Japan, 3(3), 17-30. [In Japanese].

von Hippel, E. (1994). “Sticky information” and the locus of problem solving: Implications for innovation. Management science, 40(4), 429-439.

Wada, T. (2008). Number of backward patent citations as a quantitative indicator of prior art. RIETI Discussion Paper Series 08-J-038, The Research Institute of Economy, Trade and Industry (RIETI). [In Japanese].

Wada, T. (2009). Backward patent citations and inventors' recognition of differential influences. RIETI Discussion Paper Series 10-J-001, The Research Institute of Economy, Trade and Industry (RIETI). [In Japanese].

Yoshioka-Kobayashi, T., & Watanabe, T. (2014). 研究コンソーシアムの効果: 公的研究開発プログラムにおける成果特許の実証研究. In proceedings of the annual meeting of the Japan Society for Science Policy and Research Management, 29, 905-908. [In Japanese].