18 The Impact of Revisions of the Patent System on Innovation in the Pharmaceutical Industry(*)

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In the pharmaceutical industry, the development of new drugs not only requires a great deal of time and money, but also has a low success rate. At the same time, it does not cost as much to copy a new drug as to develop one. Consequently, the patent system is extremely important in securing incentives for the development of new drugs in the pharmaceutical industry. The objective of this study is to examine in empirical terms the impact that revisions of the patent system have on innovation by companies in the pharmaceutical industry, in which the patent system is so exceedingly important. More specifically, using corporate financial data and patent data, this paper quantitatively evaluates whether the introduction of substance patent system in Japan in 1976 increased research and development expenditure and invention activities leading to the acquisition of substance patents at Japanese pharmaceutical companies. From the investigation of this topic, it emerged that there has been an increase in both research and development expenditure and the number of substance patents at Japanese pharmaceutical companies as a result of the introduction of the substance patent system in Japan in 1976. Accordingly, one can say that the strengthening of patent rights in the form of the introduction of substance patent system has encouraged innovation in the pharmaceutical industry.

Ⅰ Introduction

Since the promotion in the USA in the early 1980s of a policy that strengthened the protection of intellectual property rights, called the pro-patent policy, policies that strengthen intellectual property rights have been implemented in many developed countries. One of the factors behind these policies is said to have been the view that strengthening the protection of intellectual property rights stimulates innovation activities on the part of companies. Thus, intellectual property rights and innovation are closely related and many economic theories have been propounded concerning intellectual property rights and innovation.

In traditional economic arguments, the strengthening of intellectual property rights has been considered to reinforce the appropriability of research and development output, which encourages research and development activities by companies. However, strengthening intellectual property rights leads to the strengthening of exclusive rights in regard to inventions, which brings about a decline in economic welfare. Thus, in arguments based on traditional economics, it was thought that the strengthening of intellectual property rights should be determined with consideration for the trade-off between the promotion of innovation and the decline in economic welfare resulting from the strengthening of exclusive rights. However, in recent economic theory, it has been asserted that intellectual property rights have an impact on innovation through more diverse channels, not only the traditional relationship between intellectual property rights and innovation in this kind of economics. More specifically, Edmund Kitch (1977) argued that granting patent rights in regard to ideas that have not been commercialized leads to the prevention of overlapping investment and free riders, thereby encouraging investment in ideas that have not been commercialized. This theory is called the "prospect theory". Whereas traditional economics emphasizes increasing prior incentives to invention as a result of the strengthening of patent rights strengthening monopoly power, this theory attaches importance to the effect resulting from the granting of patent rights, in terms of increasing incentives to ex post facto investment in inventions that have not been commercialized. For example, in the pharmaceutical industry, even if a new compound that could become a drug candidate is invented, a vast amount of investment, such as

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that associated with clinical trials, is required for its commercialization. Based on prospect theory, it is conceivable that granting patent rights to new compounds that could become drug candidates would have the effect not only of increasing incentives for the invention of new compounds, but also of increasing incentives for investment, such as in ex post facto clinical trials.

What one ascertains from these recent advances in economic theory relating to intellectual property rights and innovation is that the relationship between the two is not a simple one, in which strengthening intellectual property rights encourages innovation; rather, the relationship differs greatly, depending on the nature of innovation in each individual industry. The degree to which the strengthening of patent rights contributes to innovation is not uniform across all industries, but differs considerably between each industry. Accordingly, in empirical studies of economic theory concerning intellectual property rights and innovation, in addition to cross-industry empirical research, it will be important to conduct empirical research focused on individual industries.

It is important to conduct empirical analysis of intellectual property rights and innovation focused on individual industries in this way. The objective of this study is to evaluate in empirical terms the impact on the research and development activities and innovation of the Japanese pharmaceutical industry in particular, which resulted from the substance patent system introduced in Japan in 1976. In addition, it aims to use financial data and patent data at the company level to elucidate whether or not the strengthening of patent rights in the Japanese pharmaceutical industry encouraged research and development activities and innovation.

The main empirical results of this research are as follows. Firstly, the introduction of substance patent system in Japan in 1976 increased research and development expenditure by Japanese pharmaceutical companies. Moreover, the introduction of the substance patent system in Japan in 1976 gave rise to an increase in the number of substance patents amongst the patents registered in the US by Japanese pharmaceutical companies, demonstrating that as a result of the introduction of substance patent system, Japanese pharmaceutical companies increased the number of their inventions of chemical substances.

Ⅱ Patent Rights in the Pharmaceutical Industry and the Introduction of Substance Patent System

In the pharmaceutical industry, research and development is exceedingly important. According to the Japan Pharmaceutical Manufacturers Association Data Book 2011, whereas the proportion of sales accounted for by research expenditure by industry is 4% on average in manufacturing industry as a whole, it is 11.66% in the pharmaceutical manufacturing industry. Thus, compared with other manufacturing industry, the pharmaceutical industry is highly intensive in terms of research and development, and compared with other industries, it is one in which research and development is particularly crucial.

Moreover, in the pharmaceutical industry, it is said that the development of new drugs requires a vast amount of time and money. According to Kuwashima (2006), it has been pointed out that "the development of pharmaceuticals takes from 10 to 20 years, and at least ¥10 billion." However, the invention of a revolutionary new drug generates immense income, which can be in the region of ¥100 billion a year. At the same time, compared with the development of new drugs, copying new drugs does not cost that much money. Thus, due to the nature of the development of new drugs, the pharmaceutical industry is one in which patent rights are very important.

Drug patents can be classified into substance patents, use patents and process patents; of these, substance patents are the patents that are granted to an actual chemical substance with a practical application, such as the active ingredient in a drug. The rights conferred by substance patents are strong and the patent right will be effective as long as it is the same substance, no matter what process is used in its manufacture or the purpose for which it will be used. Accordingly, substance patents can be said to be an extremely important form of drug patent.

However, in Japan, substance patents and drug use patents were not permitted until 1976. Consequently, before 1976, only process patents were permitted for drugs.

However, patents began to be permitted for new chemical compounds and drugs in Japan as well, as a result of the 1975 revision of the Patent Act, which prescribed the adoption of substance patent system from January 1, 1976. More specifically, when the original Patent Act was enacted in 1959, drugs and substances manufactured from chemical substances were

excluded from the granting of patents, but as a result of the 1975 revision, drugs and chemical substances themselves became subject to the granting of patents. In this way, substance patents were introduced in 1976, but if one compares the situation in the pharmaceutical industry that resulted from this with the situation before the introduction of substance patent system, one can point out the possibility that the cost of protecting rights to new drugs has decreased. At the same time, there appears to be hardly any empirical analysis that examines this matter in quantitative terms. Accordingly, one can say that substantiating the impact of the introduction of substance patent system in Japan on innovation in the pharmaceutical industry is an important research project.

Ⅲ Hypotheses

This chapter explains the hypotheses for analyzing the impact that the introduction of substance patentsystem in Japan in 1976 had on innovation and research and development activities in the pharmaceutical industry. More specifically, it firstly examines the following two hypotheses. The first hypothesis is that "the introduction of substance patent system in Japan in 1976 caused Japanese pharmaceutical companies to increase their research and development expenditure." The second hypothesis is that "the introduction of substance patent system in Japan in 1976 caused Japanese pharmaceutical companies to increase the number of their inventions of chemical substances."

Let us firstly examine the first hypothesis. The prospect theory of Edmund Kitch (1977) can be cited as the economic theory behind the hypothesis that "the introduction of substance patent system in Japan in 1976 caused Japanese pharmaceutical companies to increase their research and development expenditure." Prospect theory attaches importance to the effect of encouraging investment in inventions that have not yet been commercialized in the patent system. If this theory is applied to the introduction of substance patent system in Japan, one can anticipate that granting patent rights to chemical substances that could become new drug candidates will promote ex post facto research investment, such as clinical trials of those chemical substances, so one can see that the prospect theory of Edmund Kitch (1977) is behind the first hypothesis.

Details of research and development expenditure in financial data will be used as the proxy variable for research and development expenditure by pharmaceutical companies.

Next, let us examine the second hypothesis. The classical approach to intellectual property rights and innovation in economics can be cited as the economic theory behind the hypothesis that "the introduction of substance patent system in Japan in 1976 caused Japanese pharmaceutical companies to increase the number of their inventions of chemical substances." Classical economic theory concerning intellectual property rights and innovation attaches importance to the effect of patent rights in encouraging invention by strengthening the appropriability of research and development output. If this economic theory is applied to the introduction of substance patents in Japan, appropriability in regard to the invention of chemical substances in Japan will increase as a result of the introduction of substance patent system in Japan, and one can anticipate that if appropriability increases, the invention of chemical substances will be promoted. Furthermore, use patents for drugs were introduced in the pharmaceutical industry at the same time, so it is anticipated that the effect of this will be considerable, even when compared with other chemical industries. Thus, one can see that classical economic theory relating to intellectual property rights and innovation is behind the hypothesis that "the introduction of substance patent system in Japan in 1976 caused Japanese pharmaceutical companies to increase the number of their inventions of chemical substances."

In this study, "the number of substance patents amongst US patents" will be used as the proxy variable for the invention of chemical substances by Japanese pharmaceutical companies. If a chemical substance is invented, it is likely that the pharmaceutical company concerned will acquire a US patent in relation to that chemical substance, so it is appropriate to use the number of substance patents in the US as the proxy variable.

The reason why US patents rather than Japanese patents are used as the proxy variable is that it would be inappropriate to use the number of Japanese patents, because changes in patent acquisition behavior itself by Japanese pharmaceutical companies resulting from a change in the system, namely the introduction of the substance patent system, would be included, rather than the increase in substance patents resulting from the invention of chemical substances by Japanese pharmaceutical companies being promoted by the introduction of substance patent system. More specifically, before 1976, the number

of substance patents in Japan was zero, even if chemical substances were invented, so it is not appropriate to use the number of substance patents as the proxy variable for the invention of chemical substances. Substance patents were introduced in the US since 1790, so if a Japanese pharmaceutical company invented a chemical substance before 1976, it is likely that it would have acquired a substance patent, making this an appropriate proxy variable.

Moreover, in prior research, there are many studies that focus on the number of patents as the proxy variable for innovation. However, this study uses the "number of substance patents" as the proxy variable for innovation. This is because it is inappropriate to use the number of patents as the proxy variable for "inventions of chemical substances". The reason for this is that, as described above, prior to the introduction of substance patent system in Japan in 1976, Japanese pharmaceutical companies acquired multiple process patents with the objective of protecting pharmaceutical substances, and compared with the situation after the introduction of substance patent system, there was an incentive to acquire many process patents. Accordingly, even if the introduction of substance patent system in Japan in 1976 triggered an increase in the invention of chemical substances or drug uses, with the number of substance patents and use patents increasing as a result, this was offset by the decrease in process patents, so one cannot tell whether the number of patents increased. In other words, one can say that it is not necessarily appropriate to use the number of patents as the proxy variable for "inventions of chemical substances".

Ⅳ Verification Techniques and Data

This chapter explains what kind of techniques are used for verification and then specifically explains the data used in the empirical analysis.

1 Verification Techniques

With regard to the impact of the introduction of substance patent system on research and development expenditure, verification is conducted by means of regression analysis (least-squares method), using financial data at the company level. Next, with regard to the impact of the introduction of the substance patent system on the number of substance patents amongst US patents and the number of patents, verification is conducted by means of regression analysis (Tobit model), using financial data and patent data at the company level.

More specifically, a technique called difference-in-differences is used. As can be seen from Sakakibara, M. and Branstetter, L. (2001), one method of analyzing the effects of policies, such as the revision of the patent system, is a method that involves comparing the situations before and after the policy change. However, this method entails the problem that it is not possible to distinguish between the impact of changes in a system and the effect of technology shock, which has an impact on an industry as a whole. On the other hand, difference-in-differences makes the impact of changes in a system distinguishable from the impact of technology shock, to some extent. Accordingly, this study examines the effect of the revision of the patent system, taking Japanese pharmaceutical companies as the treatment group and US pharmaceutical companies as the control group. Japanese pharmaceutical companies, which constitute the treatment group, sustain impacts from both technology shock and the change in the system. On the other hand, US pharmaceutical companies, which constitute the control group, sustain the impact of technology shock, but not the change in the system. By comparing these two, it is possible to measure the impact of the change in the system, whilst excluding the effect of technology shock.

2 Data

The next section explains the data used in the empirical analysis. The data used are financial data and patent data for each pharmaceutical company. Firstly, an explanation will be provided regarding the financial data, followed by an explanation of the patent data.

(1) Financial data

Details of each company's research and development expenditure, tangible fixed assets and sales are used as financial data. With regard to the financial data, information about Japanese pharmaceutical companies was gathered from the Nikkei Economic Electronic Databank System (NEEDS), whilst details for US pharmaceutical companies were gleaned from their annual reports. Moreover, in order to eliminate the impact of fluctuations in prices and exchange rates, these data are expressed in real terms, using the 1965 value of the Japanese yen as the reference.

(2) Patent data

The number of US substance patents is used as patent data. With regard to the number of patents, in the case of Japanese pharmaceutical companies, as a general rule, the number of US patents registered is counted, using as a reference the priority date corresponding to the date of the Japanese application based on which priority is claimed. In the case of US pharmaceutical companies, the number of US patents registered is counted, using as a reference the date of application for the parent application. Continuation applications are not counted.

With regard to the method of identifying substance patents, the claims in US patents were identified visually, and a patent was deemed to be a substance patent if there was at least one claim relating to the invention of a chemical substance. With regard to the databases used for patent data, Ultra Patent was used for identifying substance patents, while Thomson Innovation was used for identifying priority dates and parent applications.

Furthermore, the patents to be analyzed were restricted to patents relating to drugs and classified as Technical Class B under the Derwent World Patents Index (DWPI) in Thomson Innovation.

Ⅴ Empirical Analysis

Firstly, this chapter explains the empirical analysis of the impact on research and development expenditure. The period of analysis covers 19 years, from 1965 to 1983. The reason for restricting the period of analysis to this period is that the number of pharmaceutical companies for which data concerning research and development expenditure can be obtained decreases markedly when one looks for pre-1965 data. Moreover, the period from 1984 onwards was excluded because the term of drug patents became to be extended under the The Drug Price Competition and Patent Term Restoration Act of 1984 (the Hatch-Waxman Act)(Section 156 of US Patent Act), so that there is the possibility that fluctuations in the number of patents could result from the impact of the patent term extension system in the US.

Next, the companies subject to analysis were restricted to a total of 33 companies, consisting of 12 US companies and 21 Japanese companies. The reason for restricting the companies targeted to these 33 companies is that the focus was limited to companies for which research and development expenditure could be obtained for all 19 years from 1965 to 1983. In general, they are major pharmaceutical companies.

In total, it forms panel data covering a total of 33 companies × 19 years = 627 observations, and the sample is balanced panel data, with no entries or withdrawals throughout the period.

The explained variable is the logarithm for research and development expenditure by each company in each year. The explanatory variables are the logarithm for sales by each company in each year and the logarithm for tangible fixed assets for each company in each year. Moreover, with regard to the nature of the research and development expenditure specific to Japanese pharmaceutical companies, a dummy variable that is set at 1 for Japanese pharmaceutical companies and 0 for US pharmaceutical companies is added, multiplied by a trend term. Furthermore, a dummy variable that is set at 0 for US pharmaceutical companies, and for Japanese pharmaceutical companies prior to 1976, and at 1 for Japanese pharmaceutical companies from 1976 onwards is included as the substance patent dummy. If this is significantly positive, one will be able to see that the introduction of substance patent system has had a positive impact on research expenditure by Japanese pharmaceutical companies.

What can be understood from the results of the estimates is as follows. Firstly, the coefficients for sales and tangible fixed assets are 0.58 and 0.09 respectively, which are significantly positive results. These figures demonstrate that if sales and tangible fixed assets increase, research and development expenditure also increases.

The cross term for Japanese pharmaceutical companies and the trend is 0.03, which is significantly positive. From this, one can see that, compared with US pharmaceutical companies, the research and development expenditure of Japanese pharmaceutical companies increases over time.

What is important is the coefficient for the substance patent dummy variable. The coefficient of the substance patent dummy variable is 0.21, which is significantly positive. This suggests that, as stated above, the introduction of substance patent system caused Japanese pharmaceutical companies to increase their research and development expenditure.

Next, this chapter explains the empirical analysis of the impact on the number of substance patents in the US. The period of analysis is the same as that for the analysis of research and development expenditure, i.e. the 19 years from 1965 to 1983. The companies subject to the next analysis were restricted to a total of 20 companies, consisting of 8 US companies and 12 Japanese companies. The reason for restricting the target

companies to these few was that in addition to limiting the focus to pharmaceutical companies for which it was possible to obtain data concerning research and development expenditure for the whole of the 19-year period from 1965 to 1983, in the case of Japanese pharmaceutical companies, the focus was further restricted to the 12 major pharmaceutical companies that concentrate exclusively on pharmaceuticals. Furthermore, with regard to US pharmaceutical companies, the focus was restricted to pharmaceutical companies with no more than double the accumulated number of US patents in the pharmaceutical field that were registered by the biggest Japanese pharmaceutical companies between 1965 and 1983. This was in order to restrict the focus to US pharmaceutical companies where the trends in the number of patents were of a similar nature to those of Japanese pharmaceutical companies, in order to ensure that the US pharmaceutical companies subject to analysis formed an appropriate control group.

In total, this forms panel data covering a total of 20 companies × 19 years = 380 observations.

The explained variable is the number of substance patents. The explanatory variables are the logarithm for research and development expenditure, the logarithm for sales ($\ln(sale_{it})$), and the logarithm for tangible fixed assets (the cross term of the dummy variable for Japanese pharmaceutical companies and the trend term, with the substance patent dummy as a variable set at 0 for US pharmaceutical companies, and for Japanese pharmaceutical companies prior to 1976, and at 1 for Japanese pharmaceutical companies from 1976 onwards) at each company in each year. If this is significantly positive, it will mean that the introduction of the substance patent system has had an impact on the number of patents held by Japanese pharmaceutical companies.

The following can be understood from these estimated values. Firstly, the coefficient of the logarithm for research and development expenditure is 11.6, which is significantly positive. This demonstrates that if research and development expenditure increases, the number of substance patents also increases. Moreover, the coefficient of the cross term for Japanese pharmaceutical companies and the trend is -0.67, which is significantly positive. When compared with US pharmaceutical companies, this demonstrates that the degree to which the number of substance patents held by Japanese pharmaceutical companies increases is small. Furthermore, the coefficient of the substance patent dummy is 11.58, which is significantly positive. This shows that the introduction of the substance patent system caused Japanese pharmaceutical companies to increase the number of substance patents amongst their US patents. This also suggests that the introduction of substance patent system caused Japanese pharmaceutical companies to increase the number of their inventions of chemical substances.

Finally, this section discusses the robustness of the data. In sections 1 and 2, Japanese pharmaceutical companies were taken as the treatment group and US pharmaceutical companies as the control group, and a technique called difference-in-differences was used to examine the impact of the introduction of the substance patent system in Japan on the research and development expenditure and number of patents of Japanese pharmaceutical companies. The objective of using this technique is to distinguish between the impact of the change in the system and the impact of technology shock. However, this technique has the problem that it is not possible to distinguish between changes in research and development expenditure and the number of patents caused by the inherent nature of the US pharmaceutical companies used as the control group, and technology shock. Accordingly, in this section, empirical analysis is carried out focused on Japanese pharmaceutical companies alone, without using US pharmaceutical companies, with the objective of confirming the robustness of the estimate results. In doing so, it is necessary to control for technology shock, so the total number of pharmaceutical patents in the US in each year —with the priority date as the reference— is used as the explanatory variable, as a proxy variable for technology shock. Moreover, an additional analysis was carried out using the trend term as a technology shock.

From the estimate results, one can ascertain from the results of analyzing the impact on research and development expenditure that the substance patent dummy is significantly positive, and that research and development expenditure by Japanese pharmaceutical companies is increasing as a result of the introduction of substance patent system.

In addition, from the results of analyzing the impact on the number of substance patents, one can ascertain that the substance patent dummy is significantly positive, and that the number of substance patents held by Japanese pharmaceutical companies amongst their US patents is increasing

as a result of the introduction of the substance patent system.

The results of the estimates above can be summed up as follows. With regard to the impact of the introduction of the substance patent system in Japan in 1976 on the research and development expenditure of Japanese pharmaceutical companies, in both empirical analysis using difference-in-differences, in which US pharmaceutical companies were added to Japanese pharmaceutical companies as targets of the analysis, and empirical analysis in which the focus was restricted to Japanese pharmaceutical companies, the results showed that the introduction of substance patent system triggers an increase in research and development expenditure. Consequently, one can say that the introduction of substance patent system in Japan in 1976 increased research and development expenditure by Japanese pharmaceutical companies.

Moreover, with regard to the impact of the introduction of the substance patent system in Japan in 1976 on the number of substance patents amongst the US patents registered by Japanese pharmaceutical companies, in both empirical analysis using difference-in-differences, in which US pharmaceutical companies were added to Japanese pharmaceutical companies as targets of the analysis, and empirical analysis in which the focus was restricted to Japanese pharmaceutical companies, the results showed that the introduction of the substance patent system triggers an increase in the number of substance patents. Consequently, one can say that the introduction of the substance patent system in Japan in 1976 increased the number of substance patents amongst the patents registered in the US by Japanese pharmaceutical companies.

Ⅵ Conclusion

This study used financial data and patent data at the company level to examine in quantitative terms whether the introduction of the substance patent system in Japan in 1976 caused an increase in research and development expenditure and innovation activities at Japanese pharmaceutical companies.

Firstly, the prospect theory of Edmund Kitch is behind the hypothesis that research expenditure increases. As a result of empirical analysis using two different methods, it was ascertained that an increase in research and development expenditure at Japanese pharmaceutical companies was triggered by the introduction of substance patent system in Japan in 1976, so the hypothesis based on the prospect theory of Edmund Kitch holds true in the case of the pharmaceutical industry in Japan in relation to the introduction of substance patents in Japan in 1976.

Next, with regard to the analysis of the impact on innovation at Japanese pharmaceutical companies of the introduction of substance patents in Japan in 1976, the hypothesis was formed that the introduction of substance patent system encourages the invention of chemical substances, and this was examined using substance patents amongst patents registered in the US, with the invention of chemical substances as the proxy variable. Classical theory relating to intellectual property rights and innovation lies behind this hypothesis. As a result of empirical analysis using two different methods, it was ascertained that an increase in substance patents amongst the US patents registered by Japanese pharmaceutical companies was triggered by the introduction of substance patent system in Japan in 1976, so the hypothesis based on the classical theory of intellectual property rights and innovation holds true in the case of Japanese pharmaceutical companies in relation to the introduction of substance patent system in Japan in 1976.

The reasons why these hypotheses hold true can be inferred to be the fact that the introduction of substance patent system was a revision of the patent system that had a major impact, and the fact that the timing of their introduction was during a crucial period for the domestic market.

This research has the following two issues. Firstly, difference-in-differences is used as one of the verification techniques. In doing so, US pharmaceutical companies are used as the control group, but conversely, this gives rise to the problem that it is not possible to distinguish between changes in technological opportunities and factors peculiar to US pharmaceutical companies. Consequently, in order to verify the robustness of the findings, empirical analysis restricted to Japanese pharmaceutical companies was carried out, but in order to distinguish between technological opportunities and factors peculiar to the control group, a method could conceivably be used that would involve the addition of pharmaceutical companies in other countries to the control group, as well as those in the US.

Moreover, US patents were confirmed visually amongst the patents registered in the US, but it would seem to be important to carry out this task systematically, en masse. One would like to make this a task for the future.