15 Environmental Regulation and Firms' Innovation Activities
- An Econometric Study Using Patent Data -(*)

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It is generally said that Japanese environmental technology is superior to that of other countries. In this study, we assume that environmental regulation is a factor that may have encouraged Japanese firms to pursue innovation activities in environmental technology, and conduct an empirical analysis to study the relationship between the two. In conducting this analysis, we propose a hypothesis that the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to pursue innovation in environmental technology.

There is a hypothesis which claims that environmental regulation encourages innovation activities by firms (Porter hypothesis). Several empirical studies in support of this hypothesis have been conducted but they left unresolved many issues due to limitations of data etc.

In this study, the relationship between firms' innovation activities in environmental technology and environmental regulation is statistically analyzed, using patent data, financial data, and environmental administration-related data. In performing the study, we assume that the impact which environmental regulation may have on firms varies depending on the firm size and industry type. By controlling these factors, we statistically identify the impact which environmental regulation may have on firms' innovation activities.

From the results of the analysis, we draw a conclusion that the hypothesis of this study cannot be rejected, which suggests that there is a possibility that the Porter hypothesis may be true in Japan.

Ⅰ Introduction

It is said that Japan possesses environmental technology that is superior to that of other countries. Meanwhile, the attention of the international community has been focused on global-scale environmental problems such as global warming and there is a tendency toward a more strict enforcement of environmental regulation. When Japanese firms engage in global economic activities under such international environment, Japan's superior environmental technology can be used as a means of gaining a competitive advantage.

Therefore, it is meaningful to study the factors that facilitated the successful implementation of innovation in environmental technology in Japan in designing industrial policy as well as environmental policy. In this study we assume that Japanese environmental regulation, which is considered to be stricter than in other countries, is a factor that has allowed the successful implementation of innovation in environmental technology in Japan. We analyze whether there is a relationship between the strictness of environmental regulation and firms' innovation activities in environmental technology.

The relationship between environmental regulation and firms' innovation activities was first studied by Porter and van der Linde (1995)(*1). Citing the examples of the Dutch flower-growing industry, the Japanese automobile industry, and the Nordic paper and pulp industry, etc., they argue that environmental regulation will stimulate innovation activities by firms and contribute to the improvement of their international competitiveness. This hypothesis is referred to as the Porter hypothesis.

Based on the Porter hypothesis, we propose in this study a hypothesis that the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to engage in innovation in environmental technology. It is considered that firms' cost structure will change if environmental regulation is enforced and/or strengthened. This is because, due to the enforcement and/or reinforcement of environmental regulation, the

(*) This is an English translation of the summary of the report published under the Industrial Property Research Promotion Project FY2009 entrusted by the Japan Patent Office. IIP is entirely responsible for any errors in expression or description of the translation. When any ambiguity is found in the English translation, the original Japanese text shall be prevailing.

(*1) Porter, M. E. and C. van der Linde (1995) "Toward a New Conception of the Environment-Competitiveness Relationship," Journal of Economic Perspectives 9(4), 97–118.

cost of environmental measures will increase in relative terms. The cost of environmental measures is expected to increase as the degree of the impact of the enforcement and/or strengthening of environmental regulation increases. It is thought that environmental regulation provides an incentive for firms to offset the increased cost of environmental measures due to environmental regulation, and as a result engage in innovation activities in environmental technology.

In order to test the hypothesis, we construct in this study a model that analyzes the influence which the degree of impact of the enforcement and/or strengthening of environmental regulation may have on the decision-making by firms as to whether or not to engage in innovation activities in environmental technology. We construct another analysis model to determine whether or not the degree of impact of the enforcement and/or strengthening of environmental regulation encourages firms' innovation activities in environmental technology. In the analysis of these models, we use patent application data as an indicator of firms' innovation activities. We also use data on the volume of toxic substance release as an indicator that measures the degree of impact of the enforcement and/or strengthening of environmental regulation.

From the results of the analysis, we draw a conclusion that the hypothesis that the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to pursue innovation in environmental technology cannot be statistically rejected. This suggests that there is a possibility that the Porter hypothesis may be true in Japan. It can be said that environmental regulation can be used as an optional technology policy tool for encouraging innovation as well as an environmental policy tool for preserving the environment.

Ⅱ Previous Literature

Concerning the impact of environmental regulation on firms' innovation activities, the traditional theory asserts that environmental regulation stifles firms' innovation activities. It can certainly be argued that environmental regulation will increase firms' costs, and as a result would stifle firms' innovation activities.

It was Porter and van der Linde (1995) who, on the other hand, pointed out the possibility that environmental regulation could encourage firms' innovation activities. Citing examples from the Dutch flower-growing industry, the Japanese automobile industry, and the Nordic paper and pulp industry, they discussed environmental regulation, innovation, and competitiveness. They argued that, when appropriate environmental regulation is put in place, firms accelerate innovation to open up new opportunity for profits. They argue that innovation in response to environmental regulation will lower the cost of manufacturing and product costs (cost offsets), and increase resource productivity, and as a result the international competitiveness of firms will be improved. This statement is called the Porter hypothesis.

In previous empirical studies that have analyzed the relationship between environmental regulation and innovation activities, there are mainly two problems that have not been investigated. They are accumulation of analysis at the level of the firm and accumulation of studies using patent data as an indicator of firms' innovation activities. In light of the previous studies and abovementioned two main problems, we conduct in this study an empirical analysis on environmental regulation and innovation activities in environmental technology.

Ⅲ Hypotheses of This Study

This study is to verify the relationship between environmental regulation and firms' innovation activities. For that purpose, we test the hypothesis that the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to pursue innovation in environmental technology.

If environmental regulation is enforced and/or strengthened, the cost structure of firms is expected to change, and in such a case, the costs of environmental measures will increase in relative terms because firms must respond to the regulation. Also, it is conceivable that the greater the impact of the enforcement and/or strengthening of environmental regulation for firms, the higher the costs of the environmental measures.

It can be thought that, if the cost structure changes, firms will engage in innovation activities to cut down the costs that have increased in relative terms (induced innovation hypothesis). In other words, if the firms' cost structure changes due to environmental regulation and the costs of environmental measures increase in relative terms, they will engage in innovation activities in environmental technology to cut down the increased costs.

Therefore, firms that will be significantly affected by the enforcement and strengthening of environmental regulation have higher incentives to pursue innovation activities in environmental technology than those that will be less affected.

In this study, we use the volume of toxic substance release as an indicator for measuring the impact which enforcement and strengthening of environmental regulation may have on firms. If environmental regulation is enforced and the release of toxic substances is restricted, firms must respond to the environmental regulation to continue their business activities. Therefore, the volume of toxic substance released by firms can serve as an indicator for measuring the potential impact of environmental regulation.

We use patent application data as an indicator of innovation activities in environmental technology. Patent application data can be suitably used as an indicator of innovation activities in environmental technology as we can obtain information on the results, timing, and technical field of firms' innovation activities from the data.

To specifically test the hypothesis (the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to pursue innovation in environmental technology) using the abovementioned two indicators, we propose the following two hypotheses:

Hypothesis 1: Firms file applications for environmental technology-related patents if their volume of toxic substance release increases.

Hypothesis 2: Firms increase applications for environmental technology-related patents if their volume of toxic substance release increases.

Ⅳ Model and Data

In this study, we construct a model for analyzing firms' behavior concerning the application of environmental technology-related patents and a knowledge production function model regarding environmental technology. We use data on environmental technology-related patent applications, data on the volume of toxic substance release, and financial data as input data for the analysis of these models.

In the model for analyzing firms' behavior concerning the application of environmental technology-related patents, we analyze the relationship between the degree of impact which environmental regulation may have on firms and firms' decision-making as to whether or not to file applications for environmental technology-related patents at the level of the firm. This is a model to test Hypothesis 1 (i.e., firms file applications for environmental technology-related patents if their volume of toxic substance release increases).

In the knowledge production function model regarding environmental technology, we analyze the relationship between the degree of impact which environmental regulation may have on firms and the number of applications for environmental technology-related patents at the level of the firm. This is a model to test Hypothesis 2 (i.e., firms increase applications for environmental technology-related patents if their volume of toxic substance release increases). In conducting the analysis, we constructed not only a model in which the explained variable is the total number of patent applications for environmental technology but also a model in which we focused on the numbers of patent applications related to water quality control technology, air pollution control technology, and soil pollution control technology.

We gathered environmental technology-related patent application data by referring to a report published by the Japan Patent Office(*2). The report defines six broad technical fields of environmental technology, such as global environment and regional environment, and 25 sub-technical fields, such as reduction of CFC emissions and environmental monitoring, and lists search queries for searching patents related to respective technologies in these fields. Using this information, we collected patent data with priority dates between 1993 and 2006 from the Industrial Property Digital Library (IPDL).

We classified the number of applications for environmental technology-related patents by priority date and examined their changes over time, and found that the number of applications for environmental technology-related patents was on an upward trend until 2001-2002, and thereafter showed a downward trend. We also found that many of the applicants are firms belonging to the automobile, electrical equipment, or machinery industry and that these firms are leading the innovation activities in environmental technology in Japan.

The number of applications for environmental technology-related patents filed by listed firms increased until 2002 and thereafter showed a downward trend. However, the ratio of the

(*2) Japan Patent Office (2009) "Heisei 20 Nendo Juten 8 Bunya no Tokkyo Shutugan Jokyo Chosa Houkokusho - Kankyo hoka 4 Bunya-" (Research Report on the Situation of Patent Applications in the 8 Priority Fields FY2009).

number of applications for environmental technology-related patents to the total number of patent applications has been on an upward trend since 1993. This indicates that listed firms have been increasing the ratio of patent applications for environmental technology.

By comparing the total number of patent applications per listed firm between the firms that have filed patent applications for environmental technology-related patents and those that haven't, we find that the firms that have filed patent applications for environmental technology-related patents have filed more patent applications overall.

As for data on the volume of toxic substance released by firms, we use data published from the Pollutant Release and Transfer Register (PRTR). From the published PRTR data, we can obtain the release volume data and movement volume data concerning 354 substances by place of business. The toxicity of each of these substances has already been evaluated from the viewpoints of carcinogenicity, mutagenicity, etc.

In order to use the data available from PRTR in the analysis, we must aggregate them at the level of the firm. In doing so, consideration must be given to the toxicity of substances, for it is likely that firms releasing a strongly toxic substance will have more difficulty in treating the substance compared to those releasing the same volume of a weakly toxic substance. In other words, it can be expected that, if environmental regulation is enforced, firms releasing a strongly toxic substance will be affected more. Therefore, in aggregating PRTR data to create an indicator for the degree of impact of environmental regulation at the level of the firm, we must create an indicator that takes into account the degree of toxicity of each substance.

We refer to the method of King and Lenox (2000, 2002) (*3) to aggregate the release volume data and movement volume data by substance and by place of business at the level of the firm. First, we aggregate the volume of toxic substance release by place of business and by toxicity, taking into account the degree of toxicity. We use the inverses of the tolerable daily intake (TDI) and no observed effect concentration (NOEC) described in the PRTR data as values that represent the degree of toxicity.

Next, we normalize weight and aggregated release volumes so that the average is 50 and the standard deviation is 10 for respective toxicity, and perform a principal component analysis using the normalized release volumes and create a composite indicator of the release volume.

Using the indicator of toxic substance release thus calculated, we estimate a model that explains the indicator of toxic substance release by the size of the place of business to calculate an indicator of waste generation and an indicator of waste prevention.

Then, using the indicator of toxic substance release regarding release volume and movement volume, we calculate an indicator of relative waste treatment and an indicator of relative waste transfer for each place of business of the firm.

Other factors that may influence firms' behavior concerning the application of patents are the amount invested in innovation activities, the time trend, and industry characteristics. In this study, we use R&D expense as an indicator of the amount invested in innovation activities. When using R&D expense data in the analysis, we deflate the data by using R&D deflators of Japan (business enterprises, etc.) published by the Ministry of Education, Culture, Sports, Science and Technology (2009) (*4). We also use the year dummy variables and industry dummy variables to account for the time trend and industry characteristics.

Ⅴ Estimation Results and Discussion

In this chapter, we show the results of the regression analysis performed using the models and data described in the previous chapter. The regression analysis covers 1,022 firms for the period between 2001 and 2006 when patent data and PRTR data could be combined. We performed the regression analysis using panel data by year and by firm.

In the regression analysis of the model for analyzing firms' behavior concerning the application of environmental technology-related patents, it was suggested that the more wastes a firm generates, the more likely it will file applications for environmental technology-related patents. In other words, it can be considered that firms that generate a large amount of wastes and thus have a higher potential impact from environmental regulation are more likely to engage in innovation activities in environmental technology to prepare themselves for possible enforcement of environmental

(*3) King, A. and M. Lenox (2000) "Industry Self-Regulation Without Sanctions: The Chemical Industry's Responsible Care Program," *Academy of Management Journal*; King, A. and M. Lenox (2002) "Exploring the Locus of Profitable Pollution Reduction," *Management Science* 48(2).

(*4) MEXT, Ministry of Education, Culture, Sports, Science and Technology ed. "Kagaku Gijutsu Binran Heisei 21 Nendo Ban" (Indicators of Science and Technology FY2009 Edition) (Nikkei Printing, 2009).

regulation in the future.

Further, it was suggested that the more toxic substances a firm releases, the more applications for environmental technology-related patents it will file. In other words, it can be considered that firms that release a large amount of toxic substances and thus have a higher potential impact from environmental regulation are likely to engage in innovation activities in environmental technology more vigorously than firms that do not, in order to prepare themselves for possible enforcement of environmental regulation in the future.

In the regression analysis of the knowledge production function model regarding environmental technology, it was suggested that firms releasing a relatively higher amount of toxic substances in their place of business are filing more applications for environmental technology-related patents. That is, firms releasing a relatively higher amount of toxic substances in their place of business are expected to incur higher costs in responding to environmental regulation on their own, if environmental regulation is enforced in the future, and therefore engage in innovation activities more vigorously than the firms releasing relatively less.

Further, in the regression analysis that focused on the numbers of patent applications related to water quality control technology, air pollution control technology, and soil pollution control technology, it was suggested that firms that release more toxic substances to the respective place of release (waters, atmosphere, soil) file more applications for patents related to the respective environmental technologies (water quality control, air pollution control, and soil pollution control). Therefore, through the analysis of the relationship between the degree of environmental regulation and innovation activities in environmental technology performed from the micro viewpoints of waters, atmosphere and soil, it can be said that firms that release a large amount of toxic substances and thus have a higher potential impact from environmental regulation are more likely to engage in innovation activities in environmental technology to prepare themselves for possible enforcement of environmental regulation in the future.

Ⅵ Conclusion

Through the regression analysis of the model for analyzing firms' behavior concerning the application of environmental technology-related patents, it was shown that the more toxic substance wastes a firm generates, the more likely that it will file applications for environmental technology-related patents. We also found that the more toxic substances a firm releases, the more likely that it will file applications for environmental technology-related patents. From these results it could be said that the more a firm will be affected by environmental regulation, the more likely that it will engage in innovation activities in environmental technology. Therefore, Hypothesis 1 (i.e., firms file applications for environmental technology-related patents if their volume of toxic substance release increases) is statistically supported.

Through the regression analysis of the knowledge production function model regarding environmental technology, it was shown that firms releasing a relatively higher amount of toxic substances in their place of business are filing more applications for environmental technology-related patents compared to those releasing relatively less. Further, through the regression analysis performed from the viewpoints of waters, atmosphere and soil by focusing on the numbers of patent applications related to water quality control technology, air pollution control technology, and soil pollution control technology, it was shown that firms that release more toxic substances will file more applications for environmental technology-related patents. From these results it could be said that the more a firm will be affected by environmental regulation, the more vigorously it will pursue innovation activities in environmental technology. Therefore, Hypothesis 2 (i.e., firms increase applications for environmental technology-related patents if their volume of toxic substance release increases) is statistically supported.

As the two hypotheses of this study are supported statistically, the hypothesis that the greater the impact of the enforcement and/or strengthening of environmental regulation, the higher the incentive for firms to pursue innovation in environmental technology cannot be rejected. This suggests that there is a possibility that the Porter hypothesis may be true in Japan. Environmental regulation is used as an environmental policy tool for preserving the environment, etc., but it could also be used as an optional technology policy tool for promoting innovation. Moreover, if a similar study can be carried out in Europe and America as well as in Japan using data similar to those from PRTR and patent data, it would be possible to clarify the conditions when environmental regulation can function as a technology policy and when it cannot.