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Universities' Role as Knowledge Sources for Product Innovations

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Abstract

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Universities' Role as Knowledge Sources for Product Innovations

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[Abstract]

This study verified innovation objectives for Japanese SMEs' access to university knowledge the effects of university knowledge on innovation outcomes. The analysis found the following three points. First, Japanese SMEs do not access university knowledge strategically according to innovation objectives but decide whether to use university knowledge in consideration of such factors as proactive R&D spending, financial constraints on innovations and the effectiveness of legal means to secure profit from innovations. Next, product innovations for "improving product or service quality," "expanding product or service lineups," "replacing existing products or services" and "exploring new markets" can lead to financial successes without university knowledge, rather than with such knowledge. Finally, the utilization of university knowledge does not necessarily lead to greater technological capabilities. In Japan, science, technology and innovation policy has strongly encouraged university-industry collaboration from later 1990's aiming to support innovation activities for SMEs. The results of this study do not confirm the total effects of the policy.

Keywords: product innovation, knowledge source, university, innovation objective, SME

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1. Introduction

Enterprises face various problems in the process of developing products and services required in the market and methods for their production. Solving these problems is the core of the innovation process. The innovation process must take advantage of knowledge distributed widely in society to produce new knowledge. Enterprises must learn and use knowledge held by engineers, researchers, other enterprises, universities, public research institutes and other parties. As technologies become more and more advanced and complicated, the speed of technological advancement increases in various areas of knowledge required by enterprises, making it difficult for any enterprise alone to respond to such advancement. In such case, enterprises may have to cooperate with other organizations and pursue total optimization while learning from the cooperation.

Knowledge includes advanced technological knowledge that is particularly significant for innovations. It has become very difficult for any enterprise to produce such knowledge on its own. Particularly, small enterprises have a limited capacity to produce new knowledge on their own. An enterprise may acquire effective knowledge from other organizations including suppliers, vendors, universities, competitors and companies in other industries. There are various channels for acquiring effective knowledge, ranging from daily business talks, academic societies and open exhibitions to such literature as journals, academic papers and patent documents. Enterprises are thus required to make efforts to effectively obtain, accumulate and use external knowledge.

Amid such situation, this study pays attention to interactions between enterprises and universities that have rapidly grown closer as one of the knowledge transfer channels for organizations over recent years. Generally, technology transfers from universities to enterprises have been conceived as the key of the interactions. Researchers have thus tended to pay attention to the fact that scientific knowledge, product ideas, patents and other established technological knowledge have flowed from universities to enterprises.

However, the interactions between universities and enterprises are not limited to such narrowly defined knowledge transfers. Universities' services for enterprises in industry-academia cooperation take the form of universities' consulting for enterprises in many cases. In this way, knowledge transfers between universities and enterprises are understood not only as the provision of innovation opportunities through knowledge and idea transfers between these parties but also as the transfer between them of capabilities to benefit from innovations (Breschi and Lissoni, 2001). In this way, researchers who give priority to dynamic knowledge creation must pay attention to various forms of capability transfers between universities and enterprises (Florida, 1999; Salter et al, 2000; Pavitt, 2001).

Innovations have various objectives. Enterprises engage in innovations to achieve objectives such as expanding existing markets, increasing their market shares, exploring new markets, introducing new products and responding to regulations. We can easily conceive that channels and sources for the effective obtainment of external knowledge differ depending on the innovation objectives.

Under the assumption that enterprises produce knowledge on their own and make efforts to strategically obtain and make effective use of knowledge at other organizations in order to achieve various innovation objectives, this study uses a questionnaire poll on small and medium-sized enterprises in Japan to empirically analyze objectives for which they access university knowledge. This study also verifies how differences between objectives and the utilization or non-utilization of university knowledge would influence their innovation outcomes. The reason this study subjects SMEs to analysis is that SMEs are growing more important as Japan's innovation system shifts from enterprises' respective closed innovations to external cooperation network-based innovations. SMEs, which have less business resources than large enterprises, tackle external cooperation more proactively as found by various surveys (RIETI, 2004; Motohashi, 2010).

This study is organized as follows: The next section overviews the preceding relevant studies and proposes hypotheses. The third section introduces data for analysis and the fourth section describes statistical models to verify the hypotheses. The fifth section describes the estimated results and the sixth section gives a conclusion.

2. Preceding studies and creation of hypotheses

Generally, knowledge is widely recognized as important for social development (Goto and Odagiri, 2003). Attracting attention at enterprises is a dynamic knowledge creation process where they absorb information on existing technologies and add new knowledge to such information (Nelson and Winter, 1982).

As the effective utilization of external knowledge has grown more important, the industrial world's ties with universities and other public research organizations have rapidly become closer. This is a common phenomenon seen almost throughout the world (Katz and Martin, 1997; Inzelt, 2001; Agrawal, 2004; Rahm, 1994). In Japan, for example, industry-academia cooperation has been enhanced due to the advancement and complication of technologies for products and services, a relevant increase in the necessity of scientific knowledge, the intensification of international competition amid economic globalization and other factors (Kondo, 2006).

Studies to verify industry-academia cooperation and its effects are roughly divided into two types—one paying attention to institutions and organizations and the other focusing on knowledge media and transfer channels. Studies paying attention to institutions and organizations have frequently attempted to verify organizations and institutions serving as the bridge between the industrial and academic sectors with different cultures and missions, as well as the effects of their functions. For example, interfaces between the industrial and academic domains include technology licensing organizations known as TLOs, liaison offices, regional joint research centers, coordinators, science parks, private technology intermediaries, venture capitals and other organizations that provide specialized services. These organizations' services differ depending on technology maturity, market sizes and distances from the market (Lakhani, et. al., 2007; Woolger, Nagata and Hasegawa, 2008; Watanabe and Jiao, 2008; Kanama, 2010). These intermediaries provide various services between universities and enterprises, allowing knowledge to be transferred smoothly. Organization-oriented studies have also analyzed industry-academia cooperation outcomes broken down by the location of and distance between the universities and enterprises (Ponds, Oort and Frenken, 2010; Tijssen, 2012) and by enterprise or university size (R).

As for institutions, studies on the effects of the U.S. Bayh-Dole Act launched in 1980 have been the most advanced (Mowery and Ziedonis, 2002; Mowery and Sampat, 2005). In Japan, a study analyzed Article 73 of the Patent Act of Japan which provides for the rules for joint ownership of patents between multiple organizations (Kanama, 2012).

Regarding knowledge media and transfer channels, some studies have analyzed academic papers from universities, patents, human resources, product prototypes, production methods, rating technologies and relevant knowhow transfers. Others have studied academic societies, personnel exchanges, joint studies, contract studies, researcher exchanges, consortiums and other knowledge transfer channels.

Empirical studies have been done robustly to comprehensively assess these effects. Thursby and others conducted surveys on knowledge transfers through industry-academia cooperation in the United States and Canada (Thursby and Thursby, 2001). They cited informal meetings and other interactions between researchers at enterprises and universities as the most important activity in the process where research outcomes at universities are transferred.

Cohen and others requested research divisions engaging in research and development operations mainly at manufacturing enterprises to rate knowledge sources at universities and other public research organizations for business research activities on a four-point scale (Cohen, et al. 2002). The rating results indicated that enterprises use academic papers, informal interactions, academic societies and research panels, and consulting as university knowledge sources.

As indicated by the above discussions, enterprises in general use academic papers, informal interactions and academic societies most frequently as media or channels for obtaining knowledge from universities. But these studies have never touched on innovation objectives. As noted earlier, enterprises have various objectives for their innovations. Channels and sources they access for obtaining external knowledge are expected to differ depending on the innovation objectives. Therefore, we should assume that university knowledge sources and channels for knowledge utilization may differ depending on the innovation objectives.

From this viewpoint, Leiponen and Helfat (2010) took advantage of a large-scale questionnaire poll conducted in Finland in 1997 to verify the following three hypotheses: (1) Enterprises with more diverse innovation objectives are more successful in innovation. (2) Enterprises that access more diverse knowledge sources make greater innovation outcomes. (3) Enterprises with more diverse innovation objectives and knowledge sources make greater innovation outcomes. In the poll, questionnaires were sent to all manufacturing enterprises with 100 or more employees and randomly sampled smaller manufacturers with less than 100 employees in Finland. The study analyzed responses sent back from a total of 1,030 enterprises. Questionnaires asked enterprises to cite the 10 biggest innovation objectives and the 12 most important knowledge sources conceivable at the enterprise level based on activities between 1994 and 1996. The analysis brought about significant results supporting all three abovementioned hypotheses.

Leiponen and Helfat (2010) concluded that innovation objectives and knowledge sources should be diversified more and more to make greater outcomes. But their study fell short of rating individual objectives and knowledge sources. Particularly, it lacked any empirical analysis on the presence or absence of university knowledge that is expected to greatly influence enterprise research and development activities, as well as on outcomes for cases where such knowledge is utilized. So, this study sets the following hypotheses for quantitative verification based on the above discussion.

Hypothesis 1: Whether enterprises utilize university knowledge depends on their innovation objectives.

Furthermore, it can be assumed that if the knowledge sources or knowledge obtainment channels they access are different, the degrees of objective outcomes may differ. Then, the following two hypotheses are set to observe university knowledge utilization by objective and analyze degrees of innovation outcomes by innovation objective and by whether university knowledge is utilized.

Hypothesis 2: Innovations realized through university knowledge utilization bring about greater earnings.

Hypothesis 3: Innovations realized through university knowledge utilization feature higher technological levels than those for competitors.

3. Data descriptions

In verifying the hypotheses proposed in Section 2, this study uses individual data (at the enterprise level) from the Japanese National Innovation Survey 2009 (hereinafter referred to as the "J-NIS2009") conducted by the National Institute of Science and Technology Policy at the Ministry of Education, Culture, Sports, Science and Technology. The J-NIS2009 was conducted in 2009 to survey private enterprises' innovative activities between FY 2006 and 2008. Survey targets were private enterprises with 10 or more employees, including those in the agriculture-forestry-fisheries and tertiary industries. Questionnaires were sent to 15,789 enterprises and valid responses came from 4,579 enterprises[2].

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[2] For details of the J-NIS2009, see National Institute of Science and Technology Policy,

The J-NIS2009 defined innovation in line with the Oslo Manual (3rd Edition), known as an international manual for measuring innovations, and designed the questionnaire based on the Community Innovation Survey implemented in European and other foreign countries. Therefore, it covers a wide range of items involving enterprise innovative activities, including research and development activities and obstacles, as well as product innovation objectives, the utilization or non-utilization of universities as knowledge sources, and product innovation outcomes that are required for verifying the hypotheses in this study[3]. These items are given in forms available for international comparison.

As noted in Section 1, SMEs are growing more important as Japan's innovation system shifts from enterprises' respective closed innovations to external cooperation network-based innovations. Nevertheless, however, no light has been shed on the realities of innovative activities including Japanese SMEs' external cooperation. So, this study conducts an analysis focusing on manufacturing SMEs. While SMEs in Japan are defined as companies with 300 million yen or less in capital or investment, or as companies and individuals with 300 or less employees, the individual data from the J-NIS2009 do not include capital or employment sizes. When designing the questionnaire, the survey divided enterprises into three groups – small enterprises with 10 to 49 employees, medium-sized enterprises with 50 to 249 employees and large enterprises with 250 or more employees – and selected samples in each group. Then, this study uses the employment size data and treats enterprises with 10 to 249

Ministry of Education, Culture, Sports, Science and Technology (2010), "Report on Japanese National Innovation Survey 2009," NISTEP REPORT;144

[3] International comparison results using the J-NIS2009 are compiled by Nishikawa and Ohashi (2010), "Current Aspects of Innovations in Japan: Evidence from Cross-Country Comparison," NISTEP DISCUSSION PAPER. 68.

employees as SMEs for descriptive purposes for an analysis.

Manufacturing SMEs accounted for 951 of enterprises that made valid responses in the J-NIS2009. Of these manufacturing SMEs, 292 enterprises or 30.7% said they realized product innovations. What were the objectives for their product innovations? The survey gave 12 alternative product innovation objectives (see Figure 1).

Figure 1 indicates that nearly 90% of enterprises introduced new products or services into the market for the objective of expanding operating profit. More than 80% cited improving product or service quality (87.3%), expanding product or service lineups (84.6%) and exploring new markets (81.8%). In contrast, percentage shares for environment-friendly objectives were lower than for other objectives, including 39.0% for reducing energy consumption, 32.5% for reducing soil, water and air pollution, and 33.6 percent for improving recycling rates. Thus, enterprises realizing product innovations for environment-friendly objectives slipped below 40% of the total.

For this study, the 12 alternative objectives in the questionnaire are divided into two groups—a. to c. and d. to l. The division is based on the following assumed enterprise behaviors. When introducing new products or services into the market, enterprises first pursue expanding operating profit and market shares as indicated by Objectives a. to c. As specific methods to achieve these objectives, they set Objectives d. to l. For example, an enterprise citing a., d. and e. as its product innovation objectives might have pursued "a. expanding operating profit" as a grand objective and chosen "d. improving product or service quality" and "e. expanding product or service lineups" as specific methods to achieve the grand objective.

One of this study's objectives is to verify whether the utilization or non-utilization of university knowledge depends on product innovation objectives or whether enterprises strategically utilize university knowledge according to their objectives. Objectives such as expanding operating profit and expanding market shares can be interpreted as slogans. None of the enterprises responding in the J-NIS2009 shied away from selecting these objectives. Therefore, focusing on specific objectives is expected to be suitable for analyzing strategic objectives of enterprises. The following thus analyzes Objectives d. to l.

(Figure 1)

4. Methods for verifying hypotheses

First, the probit analysis in which the utilization or non-utilization of universities as knowledge sources is given as a dependent variable is conducted to verify Hypothesis 1. Next, the ordered probit analysis treating innovation outcomes as a dependent variable is implemented to verify Hypotheses 2 and 3.

The dependent variable for an estimated equation to verify Hypothesis 1 is the utilization or non-utilization of universities as knowledge sources (university), as explained above. Product innovation objectives (Objectives 1 to 5) are used as an independent variable for verifying Hypothesis 1. Since enterprises use various means to expand operating profit and market shares as noted in the previous section, the probit analysis is conducted for each objective. A positive coefficient for the variable means that enterprises tend to utilize university knowledge for achieving specific objectives.

(Table 1)

However, many factors other than innovation objectives can be expected to influence decisions on whether to utilize universities as knowledge sources. In order to control these factors, this study built on Veugelers and Cassiman (2005) to use enterprise size (turnover), the ratio of research and development costs to sales (rd_intensity), the presence or absence of expansion into overseas markets (overseas), the presence or absence of cost and technological difficulties in innovation (cost, tech), and the presence or absence of effective legal and strategic protection in securing profit from innovations (protect_legal, protect_strategy) as independent variables. While Veugelers and Cassiman (2005) use industry dummies based on two-digit divisions of the International Standard Industrial Classification with a view to controlling industry heterogeneity, the same treatment of data in the J-NIS2009 has resulted in very small numbers of samples for some industries. Therefore, this study uses the product innovation rate in the same industry (product_industry) as a variable to control industry heterogeneity. As for the share for enterprises realizing innovations in the same industry, a positive coefficient can be expected because more frequent innovations in an industry intensify market competition and prompt enterprises to access newer knowledge.

Leiponen and Constance (2010) point out that there is a positive correlation between the diversity of product innovation objectives and the number of knowledge sources. Therefore, this study adopted the number of product innovation objectives other than those in question (number) as an independent variable to indicate the diversity of objectives. Variables are described and defined in Table 1.

In this study, environment-related objectives j. to l. are counted into the total number of innovation objectives. But no probit analysis is conducted for each of them. Given that interests in environmental problems have grown over the past years, an analysis of these objectives is of great interest. However, environment-related innovations are expected to feature societal demand, growing interests and other aspects that are different from those for other innovation objectives. Eventually, independent variables for environment-related objectives may differ far from those for other objectives. Therefore, it is difficult to build any estimated model for these objectives in the context of this study. So, this study excluded these objectives from the analysis.

Next are descriptions about dependent variables used for the models to verify Hypotheses 2 and 3. The ratio of realized product innovations to total sales (sales) is used as a variable to indicate the financial impact of product innovations. As the ratio of realized product innovations to total sales is surveyed through the orderly alternatives 1 to 6 in the J-NIS2009 as indicated by Table 2, this analysis treats the dependent variable as an ordered discrete value. As indicated by Table 2, a higher value for the variable means a greater financial impact on a relevant enterprise.

(Table 2)

The period of time required by competitors for developing products or services meeting a realized product innovation (advance) is used as a variable indicating the technological impact of the realized innovation. As higher-technology products or services are more difficult for competitors to imitate, a higher value for the variable is interpreted as indicating a greater technological impact. As is the case with the financial impact, the J-NIS2009 gave questions regarding this variable as indicated in Table 3. Therefore, this analysis treats the variable as an ordered discrete value, as is the case with the variable indicating the financial impact.

(Table 3)

Following are the variables used for the models to verify Hypotheses 2 and 3: The key variable is the utilization or non-utilization of universities as knowledge sources (university). A positive coefficient for the variable means that the utilization of university knowledge has led to a great financial or technological impact. In considering other factors to influence innovation outcomes, this study referred to Cohen (2010). Cohen (2010) cited industry heterogeneity (inter-industry variation), technological opportunities and appropriability as factors influencing innovation outcomes. Preceding studies used an industrial dummy as a proxy variable for industrial heterogeneity, the ratio of research and development costs to sales as that for technological opportunities, and the effectiveness of means to secure profit from innovations as that for appropriability. This study follows those preceding studies. As variables indicating the industrial heterogeneity, however, this study uses the share for enterprises realizing product innovations in the same industry (product_industry), the presence or absence of FY 2006-2008 market expansion (market) and the presence or absence of an acceleration in the dissemination of product or service information from FY 2006 to 2008 (information). This is because the adoption of industrial dummies results in very small numbers of samples for some industries, making the estimation difficult, as is the case with the verification of Hypothesis 1. As for the "product_industry" variable, a negative coefficient can be expected because more frequent innovations in an industry intensify market competition, making it difficult for enterprises to acquire profit from technologically advanced innovations.

In order to control enterprise attributes and give considerations to sales, the presence or absence of expansion into overseas markets and the diversity of product innovation objectives, this study adds the number of product innovation objectives, excluding those in question, to the estimated equation. Details and definitions of these variables are given in Table 1.

While this study uses the abovementioned dependent and independent variables to verify Hypotheses 1, 2 and 3, considerations must be given to the endogeneity problem for independent variables for the estimation. Although product innovation objectives are the key independent variable for the verification of Hypothesis 1, these objectives may correlate with factors that are observable for enterprises but unobservable for analysts. For example, consumers' ratings of existing products or services in an industry can influence enterprises' replacement of existing products or their expansion of product lineups but cannot be grasped as data by analysts. The same problem emerges with the verification of Hypotheses 2 and 3. While the utilization of universities as knowledge sources is the key variable for Hypotheses 2 and 3, the utilization may correlate with factors as error terms that are unobservable for analysts.

It has been pointed out that when the endogeneity problem exists for such independent variables, coefficients may be overestimated[4]. In order to address the endogeneity problem, this study uses instrumental variables for the estimation. As instrumental variables for product innovation objectives in Hypothesis 1, this study

[4] Griliches and Mairesse (1995) and some other studies provide details of the endogeneity problem for estimation models.

prepared the following three: (1) an industry-level average number of enterprises realizing product innovations for the same objective, (2) an industry-level average number of enterprises answering that legal protection is effective for securing profit from innovations, and (3) an industry-level average number of enterprises answering that strategic protection is effective for doing so. The abovementioned exogenous variables as independent variables are added to these three variables and innovation objectives are treated as dependent variables.

For models to verify Hypotheses 2 and 3, this study prepared the following three: (1) an industry-level average number of enterprises utilizing universities as knowledge sources, (2) an industry-level average number of enterprises answering that legal protection is effective for securing profit from innovations, and (3) an industry-level average number of enterprises answering that strategic protection is effective for doing so. Exogenous variables as independent variables are added to these three variables and the utilization or non-utilization of universities as knowledge source is treated as dependent variables.

As noted by Wooldridge (2002), and Miranda and Hasketh (2006), however, a two-stage estimation using instrumental variables cannot bring about a consistent estimator when dependent variables are discrete and allegedly endogenous variables are binary. Taking this point into account for Hypothesis 1, this study used the FIML (Full Information Maximum Likelihood) method to simultaneously estimate the equations for determining whether universities are utilized as knowledge sources and determining specific objectives for product innovations[5]. As for Hypotheses 2 and 3, the FIML method was also used to simultaneously estimate the equations for determining

[5] The stata smm command was used for the estimation.

the impacts of product innovations and determining whether universities are utilized as knowledge sources.

5. Estimated results

Table 4 indicates descriptive statistics for variables used for verifying Hypotheses 1, 2 and 3. Because product innovation objectives were confirmed in the previous section, this section reviews other independent variables. The “number” variable averages 5.257 indicating that enterprises introduce products or services into the market for diverse objectives. Among difficulties facing SMEs in innovation, 20.2% of these enterprises cited cost problems (cost) against 54.8% citing technological problems (tech), confirming that technological aspects rather than costs exert constraints on SMEs’ innovations. Among means to secure profit from innovations, 29.8% of these enterprises cited legal protection as effective, against 57.2% viewing strategic protection as effective. A majority of them thus recognized that the preemptive commercialization of innovations before competitors’ actions, the complication of designs and concealment are more effective than legal protection. The “market” variable stands at 27.0%, meaning that more than 70% of enterprises saw the domestic market shrinking or leveling off between 2006 and 2008. On the other hand, the “information” variable came to 58.7%, indicating that some 60% of enterprises recognize the dissemination of technological information as having accelerated over the three years from FY 2006.

(Table 4)

First, let us review estimates for the model to verify Hypothesis 1 (Table 5). The (I) model excluding product innovation objectives from the estimated equation is first used for confirming the general trend. Statistically significant values are given for the "rd_intensity," "cost" and "protect_legal" variables. The positive coefficient for the "rd_intensity" variable indicates a trend where enterprises with larger ratios of research and development costs to sales utilize university knowledge more frequently for innovation. In order to utilize university knowledge, enterprises must have high technological levels to absorb such knowledge. Since enterprises design research and development operations to raise their technological levels, a larger ratio of research and development costs to sales can be interpreted as indicating a higher technological level and an environment where university knowledge can be utilized more easily.

Next, the coefficient for the "cost" variable is positive, indicating that enterprises plagued with greater financial difficulties in innovation utilize university knowledge more frequently. While the hollowing-out of Japan's manufacturing industry on the rise of emerging countries such as China and India has remained at issue over a long time, the estimate apparently reflects that enterprises under financial constraints utilize university knowledge for efficiently implementing research and development.

The coefficient for the "protect_legal" variable is also positive, meaning that enterprises viewing legal protection as more effective for securing profit from realized innovations utilize university knowledge more frequently. Legal protection allows enterprises to exclusively provide protected products or services to the market over a certain period of time. While university knowledge's effects on innovation outcomes are verified in Hypotheses 2 and 3, the positive coefficient for the "protect_legal" variable indicates that an environment where enterprises can provide products or services exclusively will encourage them to utilize university knowledge.

(Table 5)

Next, let us review estimates through Models (II) to (VI) where innovation objectives are added as independent variables. Coefficients for these objectives are negative in the estimated equations other than the Model (VI) equation for the objective of adapting to regulations or standardization. However, a statistically significant value is gained only for Model (V) where the innovation objective is exploring new markets.

This means that enterprises realizing product innovations for the objective of exploring new markets utilize university knowledge less frequently than those with other innovation objectives, endorsing a special trend for such enterprises. As long as statistically significant values have not been gained in most of the models, however, the hypothesis that enterprises utilize university knowledge according to product innovation objectives has failed to be supported. This indicates that Japanese enterprises do not strategically access university knowledge in accordance with their objectives but depend on other exogenous factors in deciding whether to utilize university knowledge. The analysis results in this study indicate these exogenous factors amount to the “rd_intensity,” “cost” and “protect_legal” variables.

While Japanese SMEs do not necessarily utilize university knowledge for strategic purposes, there is a question of whether innovations utilizing university knowledge for such specific objectives as improving quality and replacing existing products or services are different from those utilizing no such knowledge.

First, estimates are given for the models to estimate Hypothesis 2 focusing on financial outcomes of product innovations (Table 6). Coefficients for the "university" independent variable subject to verification are negative in Models (I) to (IV) and the coefficient is positive in Model (V). In all these models, the coefficients are statistically significant.

Model (I), which analyses enterprises realizing product innovation for the objective of improving quality, indicates that enterprises utilizing university knowledge for product innovations for an objective receive less financial impact from innovations than those realizing innovations for the same objective without utilizing university knowledge. This means that enterprises realizing innovations without utilizing university knowledge are more financially successful. The same indication is seen for such other objectives as "expanding product or service lineups," "replacing existing products for services," and "exploring new markets."

The reason for this indication may be that knowledge at universities is far away from the market. As generally noted, research at universities is positioned as the upstream portion (close to basic research) of the innovation process and possesses difficulties in leading to commercial products or services. In order to allow product innovations realized with university knowledge to be accepted by and diffuse in the market, relevant products or services may have to be updated further. In the J-NIS2009 used for this study, enterprises were asked to specify the ratios of product innovations realized between FY 2006 and 2008 to sales in FY 2008. Therefore, the survey cannot be used for grasping any long-term impact of product innovations. In order to verify this point, we may have to use databases focusing on specific innovations, such as the SPRU.

On the other hand, Model (V) analyzing product innovations for the objective of adapting to regulations and standardization progress produced a positive coefficient.

This indicates that enterprises, when being forced by exogenous factors including regulations and standardization to introduce new products or services into the market, can receive a greater financial impact by utilizing university knowledge. The following reason is conceivable for this model's results that are different from those of other models. As noted above, tougher regulations and standardization progress are exogenously given irrespective of enterprises' intentions. While enterprises are required to introduce products or services meeting regulations and standardization into the market in order to maintain their sales, it may be difficult for them to have inside knowledge or technologies for addressing such situation. In this case, solving technological problems by utilizing universities with advanced knowledge or technologies may be an easier way to realize products or services favored by consumers.

(Table 6)

Among other variables, the "number" and "rd_intensity" have statistically significant coefficients that are positive in all these models. As for the "number" variable, product innovations for a larger number of objectives can exert greater financial impacts on enterprises. This is the same conclusion as given by such preceding studies as Leiponen and Constance (2010). In respect to the "rd_intensity" variable, this study found that product innovations realized by enterprises with more research and development investment can receive greater financial impacts. In all models other than Model (IV), both or either of the "protect_legal" and "protect_strategy" variables have positive coefficients that are statistically significant. This indicates that enterprises with effective means to secure profit from product innovations realize greater sales.

Next, let us review the relationship between the utilization or non-utilization of university knowledge and technological impacts of product innovations regarding Hypothesis 3 (Table 7). The "university" independent variable for verification has a statistically significant positive coefficient only in Model (III). This means that enterprises seeking to replace existing products or services utilized university knowledge to realize products or services with higher technological levels. Coefficients in all the other models are negative and statistically insignificant. Therefore, university knowledge does not necessarily exert any influence on technological advancement for such product innovation objectives as "improving quality," "expanding product lineups," "exploring new markets" and "adapting to regulations and standardization."

As far as the above estimated results indicate, Hypothesis 3 that product innovations realized through university knowledge utilization for specific objectives feature higher technological levels fails to be endorsed, except for some specific objectives. The following is a conceivable reason for such results. This study's analysis target is manufacturing SMEs defined as having 10 to 249 employees. The technological advancement of new products or services at enterprises of this size group might have stemmed not from university knowledge or their own technological capabilities but from other exogenous factors peculiar to the market.

Among variables indicating other exogenous factors, both or either of the "protect_legal" and "protect_strategy" variables have statistically significant positive coefficients in all the models. This indicates that enterprises having means to secure profit from product innovations produce products or services having higher technological levels.

As indicated by descriptive statistics in Table 4, 58.7% of the enterprises recognized the dissemination of technological information as having accelerated over the three years from 2006. This means that even if enterprises realize innovations with high technological levels, the relevant technological information would disseminate among their competitors promptly, resulting in reducing their profit from these innovations. Under such situation, enterprises may get an incentive to imitate technologies realized by others in a catching-up approach rather than pioneering the development of new products or services with high technological levels. This study's estimated results indicate that the presence of effective means to secure profit at enterprises may provide an incentive for them to pioneer higher technological capabilities.

(Table 7)

6. Conclusion

This study verified innovation objectives for Japanese SMEs' access to university knowledge and analyzed the effects of university knowledge on innovation outcomes. Estimated results provided the following four findings:

- Japanese SMEs do not access university knowledge strategically according to innovation objectives but decide whether to use university knowledge in consideration of such factors as proactive research and development spending, financial constraints on innovations and the effectiveness of legal means to secure profit from innovations.

- A comparison of product innovations for specific objectives indicates that product innovations for "improving product or service quality," "expanding product or service lineups," "replacing existing products or services" and "exploring new markets" can lead to financial successes without university knowledge, rather than with such knowledge.

- The utilization of university knowledge can bring about greater financial impacts in cases where exogenous factors such as tougher regulations and standardization progress force SMEs to introduce new products or services.

- A comparison of product innovations for specific objectives suggests that the utilization of university knowledge does not necessarily lead to greater technological capabilities.

Under the Act on Special Measures concerning Industrial Revitalization that took effect in 1999, universities have been expected to promote their knowledge and technology transfers to the industrial world. But this study's analysis results indicate that the utilization of university knowledge does not necessarily lead to the creation of high-quality innovations. An apparent reason for the results may be that enterprises do not necessarily access university knowledge in a strategic manner, as indicated by this study's analysis results. This means that Japanese SMEs may not access or utilize knowledge required for their innovations but utilize only knowledge they can access. Therefore, knowledge from universities might have failed to accurately match knowledge required by enterprises.

The J-NIS2009 used for this study represents single-year data, failing to provide data for dynamic impacts that innovations exert on enterprises. Therefore, data for financial impacts of product innovations are limited to three years from FY 2006. Furthermore, the survey fails to specify the times when product innovations were realized, treating equally innovations realized in the first half of FY 2006 and those in the second half of FY 2008. These problems might have caused biases in estimated financial impacts of product innovations. In order to address these problems, we will have to use databases focusing on individual products and services to indicate long-term trends, such as the SPRU conducted in the U.K. But no such database has been created in Japan. A future challenge is an analysis that takes into account dynamic impacts of innovations on enterprises.

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Figure 1 Product innovation objectives

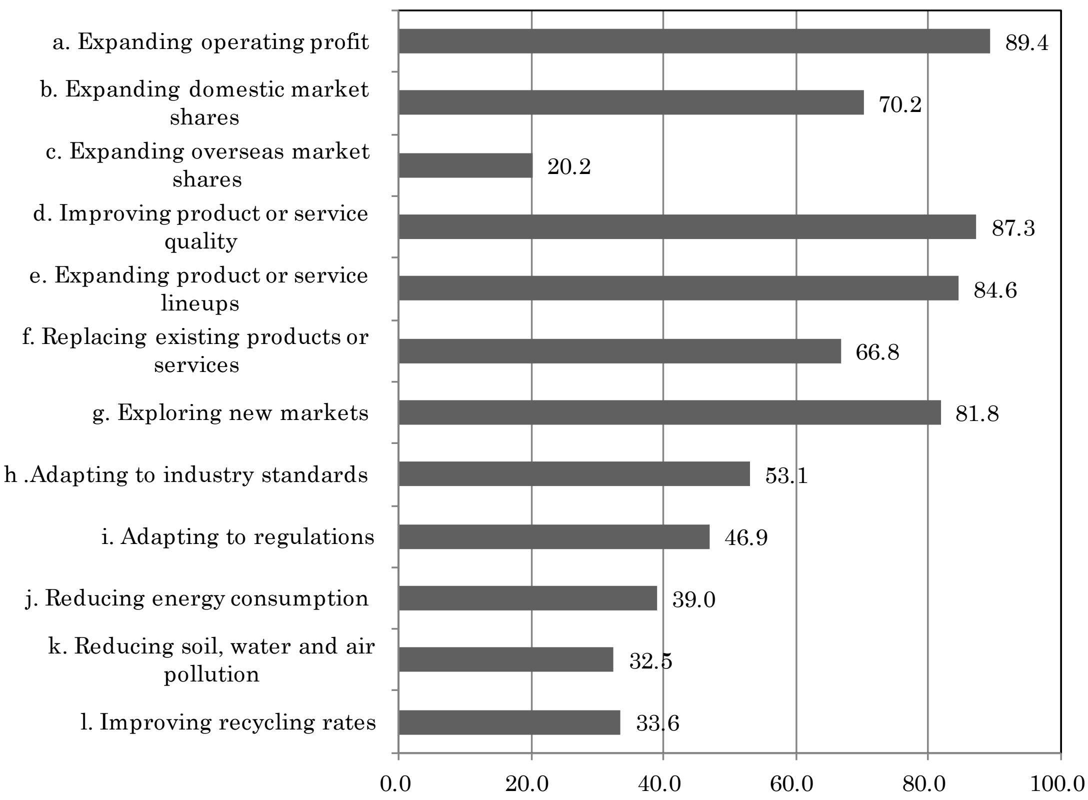

Table 1 Descriptions and definitions of variables

	Variable	Definition
sales	Ratio of realized product innovations to total sales in FY 2008	discrete(1-6)
advanced	Period of time before competitors develop products or services with technologies similar to those for realized product innovations	discrete(1-6)
university	Have enterprises used universities as knowledge sources?	dummy: 0=no; 1=Yes
objective_1	Have enterprises set improving product or service quality as a product innovation objective?	dummy: 0=no; 1=Yes
objective_2	Have enterprises set expanding product or service lineups as a product innovation objective?	dummy: 0=no; 1=Yes
objective_3	Have enterprises set replacing existing products or services as a product innovation objective?	dummy: 0=no; 1=Yes
objective_4	Have enterprises set exploring new markets as a product innovation objective?	dummy: 0=no; 1=Yes
objective_5	Have enterprises set adapting to regulations and standardization as a product generation objective?	dummy: 0=no; 1=Yes
number	Number of product innovation objectives	discrete(1-9)
turnover	Logarithmic value of sales in FY 2006	continuous
rd_intensity	R&D costs' ratio to sales in FY 2006-2008	continuous(0-1)
overseas	Have enterprises provided products or services in overseas markets?	dummy: 0=no; 1=Yes
cost	Have enterprises faced cost shortages in innovation?	dummy: 0=no; 1=Yes
tech	Have enterprises faced technology shortages in innovation?	dummy: 0=no; 1=Yes
protect_legal	Has legal protection been effective for protecting profit from innovation?	dummy: 0=no; 1=Yes
protect_strategy	Have the introduction of new products into the market and the complication or non-disclosure of designs been effective for protecting profit from innovation?	dummy: 0=no; 1=Yes
product_industry	Share for enterprises realizing product innovations at industry levels	continuous(0-1)
market	Has the market size expanded between 2006 and 2008?	dummy: 0=no; 1=Yes
information	Has the speed accelerated for the dissemination of product or service information from 2006 to 2008?	dummy: 0=no; 1=Yes

Table 2 J-NIS2009 questions (financial impact)

				0-1%	1-5%	5-10%	10-20%	25-50%	50-%
a.	Ratio of product innovations to FY 2008 sales			1	2	3	4	5	6
b.	Presence or absence of new product innovations for market	1. Absent	2. Present						
	- Ratio of new product innovations for market to FY 2008 sales			1	2	3	4	5	6

Table 3 J-NIS2009 questions (technological impact)

a.	Less than 6 months	d.	3 to less than 5 years
b.	6 to less than12 months	e.	5 to less than 10 years
c.	1 to less than 3 years	f.	10 or more years

Table 4 Descriptive statistics for variables

	Average	standard deviation	Min	Max
sales	2.560	1.365	1	6
advanced	2.813	1.154	1	6
university	0.237	0.426	0	1
objective_1	0.873	0.333	0	1
objective_2	0.846	0.362	0	1
objective_3	0.668	0.472	0	1
objective_4	0.818	0.386	0	1
objective_5	0.603	0.490	0	1
number	5.257	2.477	1	9
turnover	7.188	1.260	4.905	13.755
rd_intensity	0.011	0.022	0	0.188
overseas	0.476	0.500	0	1
cost	0.202	0.402	0	1
tech	0.548	0.499	0	1
protect_legal	0.298	0.458	0	1
protect_strategy	0.572	0.496	0	1
product_industry	0.463	0.121	0.184	0.630
market	0.270	0.445	0	1
information	0.587	0.493	0	1

Table 5 Estimated results for hypotheses 1

	(Ⅰ)			(Ⅱ)			(Ⅲ)		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|
number	0.015	0.028	0.580	0.096	0.071	0.177	0.042	0.085	0.623
turnover	0.085	0.071	0.226	0.089	0.071	0.210	0.085	0.071	0.234
rd_intensity	3.683	2.057 *	0.073	3.812	2.046 *	0.062	3.773	2.080 *	0.070
overseas	0.121	0.170	0.478	0.113	0.172	0.512	0.122	0.171	0.476
cost	0.469	0.207 **	0.023	0.532	0.215 **	0.013	0.478	0.211 **	0.023
tech	0.274	0.181	0.130	0.296	0.185	0.109	0.284	0.187	0.127
protect_legal	0.518	0.186 ***	0.005	0.545	0.189 ***	0.004	0.533	0.196 ***	0.007
protect_strategy	-0.059	0.186	0.752	-0.073	0.188	0.700	-0.060	0.189	0.750
product_industry	0.152	0.640	0.813	0.319	0.663	0.631	0.241	0.747	0.747
object_1				-0.551	0.501	0.272			
object_2							-0.160	0.701	0.819
constant	-1.944	0.606 ***	0.001	-1.986	0.611 ***	0.001	-1.980	0.633 ***	0.002
Log likelihood		-159.087			-225.441			-254.503	
Sample		305				340			

	(Ⅳ)			(Ⅴ)			(Ⅵ)		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|
number	0.073	0.104	0.483	0.164	0.041 ***	0.000	-0.072	0.065	0.272
turnover	0.104	0.077	0.179	0.094	0.075	0.210	0.088	0.070	0.204
rd_intensity	3.609	2.068 *	0.081	3.429	0.921 ***	0.000	3.254	2.051	0.113
overseas	0.120	0.170	0.479	0.094	0.147	0.520	0.107	0.169	0.527
cost	0.515	0.218 **	0.018	0.489	0.155 ***	0.002	0.467	0.205	0.023
tech	0.286	0.182	0.117	0.295	0.136 **	0.030	0.254	0.180	0.159
protect_legal	0.497	0.191 ***	0.009	0.352	0.177 **	0.047	0.515	0.185	0.005
protect_strategy	-0.037	0.191	0.848	-0.017	0.168	0.921	-0.031	0.186	0.869
product_industry	0.185	0.640	0.773	0.280	0.458	0.541	0.328	0.655	0.617
object_3	-0.451	0.828	0.586						
object_4				-1.048	0.267 ***	0.000			
object_5							0.789	0.605	0.192
constant	-2.078	0.641 ***	0.001	-1.839	0.592 ***	0.002	-1.959	0.597 ***	0.001
Log likelihood		-260.638			-252.382			-234.540	
Sample					340				

***:1%, **:5%, *:10%

Table 6 Estimated results for hypotheses 2 (financial impact)

	(Ⅰ)			(Ⅱ)			(Ⅲ)		
	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|
university	-1.248	0.092 ***	0.000	-1.290	0.091 ***	0.000	-1.175	0.083 ***	0.000
number	0.085	0.022 ***	0.000	0.137	0.019 ***	0.000	0.056	0.020 ***	0.004
turnover	-0.128	0.036 ***	0.000	0.015	0.027	0.568	-0.121	0.024 ***	0.000
overseas	0.124	0.088	0.157	-0.105	0.080	0.189	0.046	0.068	0.504
rd_intensity	10.952	1.530 ***	0.000	12.282	1.564 ***	0.000	12.870	1.340 ***	0.000
protect_legal	0.188	0.106 *	0.077	0.048	0.091	0.599	0.357	0.075 ***	0.000
protect_strategy	0.287	0.102 ***	0.005	0.398	0.089 ***	0.000	0.417	0.088 ***	0.000
product_industry	0.632	0.373 *	0.090	0.120	0.312	0.700	0.840	0.296 ***	0.004
market	0.175	0.093 *	0.060	0.268	0.085 ***	0.002	0.018	0.080	0.826
Log likelihood		-344.968			-323.471			-254.129	
Sample		248			240			190	
Subgroup	Improving product or service quality			Expanding product or service lineups			Replacing existing products or services		

	(Ⅳ)			(Ⅴ)		
	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|
university	-1.308	0.163 ***	0.000	1.037	0.127 ***	0.000
number	0.130	0.049 ***	0.009	0.057	0.031 *	0.063
turnover	-0.122	0.053 **	0.022	-0.025	0.026	0.345
overseas	0.086	0.149	0.562	-0.072	0.107	0.499
rd_intensity	11.573	1.924 ***	0.000	3.940	1.561 **	0.012
protect_legal	0.101	0.141	0.471	-0.374	0.133 ***	0.005
protect_strategy	0.200	0.163	0.222	0.264	0.119 **	0.026
product_industry	0.157	0.855	0.854	-0.436	0.344	0.205
market	0.170	0.143	0.232	-0.108	0.120	0.366
Log likelihood		-326.935			-245.289	
Sample		232			172	
Subgroup	Exploring new markets			Adapting to industry standards and regulations		

***:1%, **:5%, *:10%

Table 7 Estimated results for hypotheses 3 (technological impact)

	(Ⅰ)			(Ⅱ)			(Ⅲ)		
	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|
university	-0.365	0.533	0.494	-0.579	0.488	0.236	1.228	0.092 ***	0.000
number	-0.053	0.043	0.216	-0.001	0.041	0.978	0.052	0.022 **	0.016
turnover	0.093	0.062	0.136	0.107	0.065 *	0.100	0.071	0.033 **	0.033
overseas	0.070	0.164	0.671	0.135	0.165	0.415	0.017	0.081	0.838
rd_intensity	3.990	3.415	0.243	5.187	3.476	0.136	-2.246	1.422	0.114
protect_legal	0.395	0.187 **	0.035	0.455	0.188 **	0.015	-0.082	0.091	0.367
protect_strategy	0.462	0.184 **	0.012	0.365	0.185 **	0.048	0.381	0.109 ***	0.000
product_industry	-0.667	0.643	0.299	-0.755	0.669	0.260	-0.353	0.378	0.351
information	-0.164	0.161	0.309	-0.172	0.161	0.286	-0.181	0.087 **	0.037
Log likelihood		-350.412			-337.604			-266.959	
Sample		253			244			193	
Subgroup		Improving product or service quality			Expanding product or service lineups			Replacing existing products or services	

	(Ⅳ)			(Ⅴ)		
	Coefficient	Standard deviation	P>|z|	Coefficient	Standard deviation	P>|z|
university	-0.419	0.559	0.454	-0.796	0.544	0.143
number	-0.055	0.042	0.191	0.045	0.069	0.516
turnover	0.100	0.062	0.108	0.154	0.073 *	0.035
overseas	-0.019	0.170	0.912	0.065	0.199	0.744
rd_intensity	4.188	3.505	0.232	5.792	3.699	0.117
protect_legal	0.376	0.186 **	0.043	0.299	0.243	0.218
protect_strategy	0.389	0.188 **	0.039	0.398	0.245	0.105
product_industry	-1.001	0.681	0.142	-1.485	0.798 **	0.063
information	-0.204	0.164	0.214	-0.192	0.194	0.323
Log likelihood		-342.646			-235.616	
Sample		236			176	
Subgroup		Exploring new markets			Adapting to industry standards and regulations	

***:1%, **:5%, *:10%