Universities' role as knowledge sources on product innovations for SMEs

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Ⅰ Introduction

This study focuses on interactions between enterprises and universities that have rapidly grown closer in recent years as a knowledge-transfer channel for organizations. Generally, technology transfers from universities to enterprises have been conceived as the key to these interactions. Thus, researchers have tended to focus on 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 often take the form of universities consulting for enterprises. Thus, 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 of capabilities, which allows them to benefit from (“appropriate”) innovations (Breschi and Lissoni, 2001). Thus, researchers who provide priority to dynamic knowledge creation must focus on 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 of the effective obtainment of external knowledge differ depending on firms’ innovation objectives.

However, there has been very minimal literature examining the relation between innovation objectives and knowledge sources and innovation outcomes. Leiponen and Helfat (2010) investigated the breadth of innovation objectives and knowledge sources with research and development outcomes. However, individual objectives and knowledge sources were not examined in the research.

Under the assumption that enterprises produce knowledge on their own and exert effort to strategically obtain and make effective use of knowledge from other organizations 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 firms access university knowledge. This study also verifies how differences between objectives and the utilization or non-utilization of university knowledge influence firms’ innovation outcomes. The reason this study subjects SMEs to analysis is that SMEs are growing in importance as Japan’s innovation system shifts from enterprises’ respective closed innovations to external cooperation and network-based innovations. Various surveys have found (RIETI, 2004; Motohashi, 2010) that SMEs, which have fewer business resources than large enterprises, tackle external cooperation more proactively.

II　Preceding studies and the creation of hypotheses

Generally, knowledge is widely recognized as important for social development (Goto and Odagiri, 2003). A dynamic knowledge-creation process in which enterprises absorb information on existing technologies and add new knowledge to such information has recently attracted the attention of enterprises (Nelson and Winter, 1982).

As the effective utilization of external knowledge has become more important, the industrial world's ties with universities and other public research organizations have rapidly become closer. This is a common phenomenon observed nearly worldwide (Katz and Martin, 1997; Inzelt, 2001; Agrawal, 2004; Rahm, 1994). In Japan, for example, industry-academia cooperation has been enhanced because of the advancement and complication of technologies for products and services, a relevant increase in the need for 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 focusing on institutions and organizations and the other focusing on knowledge media and transfer channels. Studies focusing on institutions and organizations have frequently attempted to verify the 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 the technology's 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 categorized by the location of and distance between universities and enterprises (Ponds, Oort and Frenken, 2010; Tijssen, 2012) and by enterprise and university size.

Regarding institutions, studies on the effects of the U.S. Bayh-Dole Act launched in 1980 are 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 the joint ownership of patents by multiple organizations (Kanama, 2012).

Regarding knowledge media and transfer channels, certain 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 robustly performed 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). These researchers cited informal meetings and other interactions between researchers at enterprises and universities as the most important activities in the process by which research outcomes are transferred from universities.

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 organizations for business research 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 use academic papers, informal interactions and academic societies most frequently as media or channels for obtaining knowledge from universities. However, these studies have never touched on innovation objectives. As noted earlier, enterprises have various objectives for their innovations. Channels and sources they access to obtain 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 perspective, Leiponen and Helfat (2010) advantageously utilized 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 achieve greater innovation outcomes. (3) Enterprises with more diverse innovation objectives and knowledge sources achieve greater innovation outcomes. Leiponen and Helfat (2010) concluded that innovation objectives and knowledge sources should be increasingly diversified to achieve better outcomes. However, these researchers' study fell short of rating individual objectives and knowledge sources.

As noted above, previous literature has 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 in which such knowledge is utilized. Therefore, this study establishes the following hypotheses for quantitative verification based on the above discussion.

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

Furthermore, if the knowledge sources or knowledge obtainment channels enterprises access are different, the degrees of objective outcomes may differ. Therefore, the following two hypotheses are established to observe university knowledge utilization by objective and to analyze the degrees of innovation outcomes by innovation objective and by whether university knowledge is utilized.

Hypothesis 2: Innovations realized through university knowledge utilization result in greater earnings.

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

Ⅲ　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 (hereafter 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 FY 2008. Survey targets were private enterprises with 10 or more employees, including those in the agriculture-forestry-fishery and tertiary industries. Questionnaires were sent to 15,789 enterprises, and valid responses were received from 4,579 enterprises[1].

The J-NIS2009 defined innovation in accordance with the Oslo Manual (3rd Edition), which is 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, the manual 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[2]. These items are provided in forms available for international comparison.

As noted in Section 1, SMEs are gaining importance as Japan's innovation system shifts from enterprises' respective closed innovations to external cooperation, network-based innovations. Nevertheless, the realities of innovative activities including Japanese SMEs' external cooperation have not been elucidated. Therefore, this study conducts an analysis focusing on manufacturing SMEs. Although 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 fewer 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. The authors then selected samples from each group. Subsequently, this study uses employment size data and treats enterprises with 10 to 249 employees as SMEs for descriptive purposes and analysis.

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

Figure 1 indicates that nearly 90% of enterprises introduced new products or services into the market, with 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 decreased to below 40% of the total.

In this study, the 12 alternative objectives in the questionnaire are divided into two groups: a. to c. and d. to l. This division is based on the following assumed enterprise behaviors. When introducing new products or services into the market, enterprises first pursue an expansion of operating profit and market shares, as indicated by Objectives a. to c. For specific methods to achieve these objectives, enterprises set Objectives d. to l. For example, an enterprise citing a., d. and e. as their product innovation objectives may pursue “a. expanding operating profit” as a grand objective and choose “d. improving product or service quality” and “e. expanding product or service lineups” as specific methods to achieve their larger 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 market shares can be interpreted as slogans. None of the respondent enterprises 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. Thus, this study analyzes Objectives d. to l.

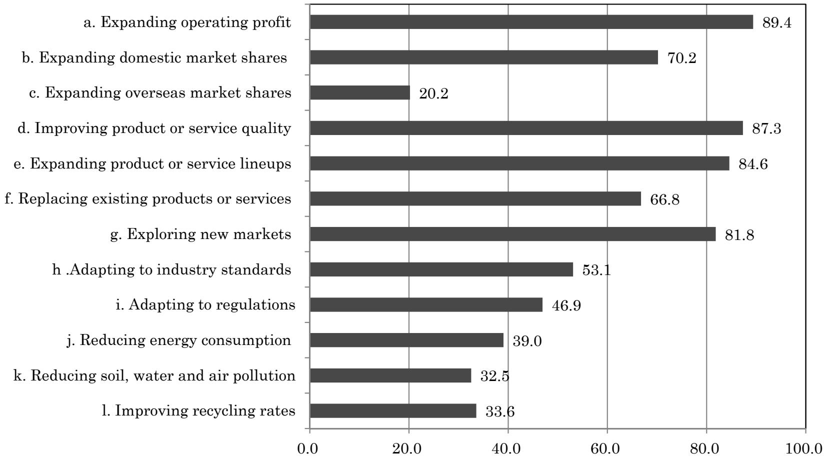

Figure 1 Product innovation objectives

Ⅳ　Methods for verifying the hypotheses

1. Hypothesis 1

First, the probit analysis, in which the utilization or non-utilization of universities as knowledge sources is provided 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.

To verify Hypothesis 1, the utilization or non-utilization of universities as knowledge sources (university) is used as the dependent variable for an estimated equation, as explained above. Product innovation objectives (Objectives 1 to 5) are used as an independent variable to verify Hypothesis 1. Because 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 to achieve specific objectives.

However, many factors other than innovation objectives can be expected to influence decisions on whether to utilize universities as knowledge sources. To control these factors, this study augments research by Veugelers and Cassiman (2005) and uses 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. Although Veugelers and Cassiman (2005) used industry dummies based on two-digit divisions of the International Standard Industrial Classification to control industry heterogeneity, the same treatment of data in the J-NIS2009 resulted in very small samples for certain 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) noted 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.

Descriptions regarding the dependent variables used for the models to verify Hypotheses 2 and 3 follow. We use the ratio of revenue from new products and services in fiscal years 2006 to 2008 to the overall sales in fiscal year 2008 to measure financial impact; the options were “0-1%,” “1-5%,” “5-10%,” “10-20%,”

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

“20-50%,” and “50%-”. Among companies of a similar size, as the revenue new products or services provide increases, the proportion these occupy in overall sales increases. Therefore, it is presumed that a higher ratio is associated with a greater impact on the company’s sales.

To measure technological achievements, the survey asked companies how much time their competitors needed to develop similar new products and services, with the options, “Within six months,” “Six to 12 months,” “One to three years,” “Three to five years,” “Five to 10 years,” and “More than 10 years.” It is presumed that it will take longer for competitors to attain their status as the underlying innovations of a new product or service become more sophisticated. We assume that a longer status attainment time is associated with greater technological achievement.

2. Hypotheses 2 and 3

The variables used in the models to verify Hypotheses 2 and 3 follow; 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 that influence innovation outcomes, this study refers 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 a proxy for technological opportunities, and the effectiveness of means to secure profit from innovations as a proxy for appropriability. This study is in accordance with these preceding studies. As variables indicating industrial heterogeneity, however, this study uses the share of 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 acceleration in the dissemination of product or service information from FY 2006 to FY 2008 (information). We use these variables because the adoption of industrial dummies results in a very small number of samples for certain 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.

To control enterprise attributes and to consider sales in the presence or absence of expansion into overseas markets and in 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 provided in Table 1. Table 2 indicates descriptive statistics for the variables used to verify Hypotheses 1, 2 and 3.

Table 2 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

3. Endogeneity problem

Although this study uses the abovementioned dependent and independent variables to verify Hypotheses 1, 2 and 3, the endogeneity problem for independent variables for the estimation must be taken into account. Although product innovation objectives make up the key independent variable for the verification of Hypothesis 1, these objectives may correlate with factors that are observable by enterprises but unobservable by analysts.

It has been noted that when the endogeneity problem exists for such independent variables, coefficients may be overestimated[3)]. To address the endogeneity problem, this study uses instrumental variables for the estimation. This study used the following instrumental variables for product innovation objectives in Hypothesis 1:

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

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

However, as noted by Wooldridge (2002), and Miranda and Hasketh (2006), a two-stage estimation using instrumental variables cannot result in a consistent estimator when dependent variables are discrete and allegedly endogenous variables are binary. Considering this point in Hypothesis 1, this study used the FIML (Full Information Maximum Likelihood) method to simultaneously estimate the equations to determine whether universities are utilized as knowledge sources and to determine specific objectives for product innovations[4]. As for Hypotheses 2 and 3, the FIML method was also used to simultaneously estimate the equations to determine the impacts of product innovations and to determine whether universities are utilized as knowledge sources.

V Estimated results

1. Objectives and university knowledge

First, we review estimates for the model to verify Hypothesis 1 (Table 3).

Table 3 Estimated results for Hypothesis 1

	(I)			(II)			(III)		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|
object_1	-0.551	0.501	0.272						
object_2				-0.160	0.701	0.819			
object_3							-0.451	0.828	0.586
object_4									
object_5									
number	0.096	0.071	0.177	0.042	0.085	0.623	0.073	0.104	0.483
turnover	0.089	0.071	0.210	0.085	0.071	0.234	0.104	0.077	0.179
rd_intensity	3.812	2.046 *	0.062	3.773	2.080 *	0.070	3.609	2.068 *	0.081
overseas	0.113	0.172	0.512	0.122	0.171	0.476	0.120	0.170	0.479
cost	0.532	0.215 **	0.013	0.478	0.211 **	0.023	0.515	0.218 **	0.018
tech	0.296	0.185	0.109	0.284	0.187	0.127	0.286	0.182	0.117
protect_legal	0.545	0.189 ***	0.004	0.533	0.196 ***	0.007	0.497	0.191 ***	0.009
protect_strategy	-0.073	0.188	0.700	-0.060	0.189	0.750	-0.037	0.191	0.848
product_industry	0.319	0.663	0.631	0.241	0.747	0.747	0.185	0.640	0.773
constant	-1.986	0.611 ***	0.001	-1.980	0.633 ***	0.002	-2.078	0.641 ***	0.001
Log likelihood		-225.441			-254.503		-260.638		
Sample					340				

	(IV)			(V)		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|
object_1						
object_2						
object_3						
object_4	-1.048	0.267 ***	0.000			
object_5				0.789	0.605	0.192
number	0.164	0.041 ***	0.000	-0.072	0.065	0.272
turnover	0.094	0.075	0.210	0.088	0.070	0.204
rd_intensity	3.429	0.921 ***	0.000	3.254	2.051	0.113
overseas	0.094	0.147	0.520	0.107	0.169	0.527
cost	0.489	0.155 ***	0.002	0.467	0.205	0.023
tech	0.295	0.136 **	0.030	0.254	0.180	0.159
protect_legal	0.352	0.177 **	0.047	0.515	0.185	0.005
protect_strategy	-0.017	0.168	0.921	-0.031	0.186	0.869
product_industry	0.280	0.458	0.541	0.328	0.655	0.617
constant	-1.839	0.592 ***	0.002	-1.959	0.597 ***	0.001
Log likelihood		-252.382			-234.540	
Sample			340			

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

Coefficients for the objectives are negative in the estimated equations, other than Model (V)'s equation for the objective of adapting to regulations or standardization. However, a statistically significant value is gained solely for Model (IV), in which the innovation objective explores new markets.

This means that enterprises realizing product innovations with the objective of exploring new markets utilize university knowledge less frequently than those with other innovation objectives. As long as statistically significant values have not been gained in most models, the hypothesis that enterprises utilize university knowledge according to product innovation objectives fails to be supported, which indicates that Japanese SMEs do not strategically access university knowledge in accordance with their objectives but depend on other exogenous factors when deciding whether to utilize university knowledge. The analysis results in this study indicate that these exogenous factors equate to the "rd_intensity," "cost" and "protect_legal" variables.

The positive coefficient for the "rd_intensity" variable indicates a trend in which enterprises with larger ratios of research and development costs to sales utilize university knowledge more frequently for innovation. To utilize and absorb university knowledge, enterprises must have high technological levels. Because enterprises design research and development operations to raise their technological levels, a larger ratio of research and development costs to sales can be interpreted to indicate a higher technological level and an environment in which university knowledge can be utilized more easily.

The coefficient for the "cost" variable is positive, indicating that enterprises plagued with greater financial difficulties in innovation utilize university knowledge more frequently. This estimate reflects that enterprises under financial constraints utilize university knowledge to efficiently implement research and development.

The coefficient for the "protect_legal" variable is also positive, meaning that enterprises that view legal protection as more effective in 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. Although 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 in which enterprises can provide products or services exclusively will encourage them to utilize university knowledge.

2. Financial impact of the utilization of university knowledge

Although 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 provided for the models to estimate Hypothesis 2, focusing on the financial outcomes of product innovations (Table 4). 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 analyzes enterprises realizing product innovation with the objective of improving quality, indicates that enterprises utilizing university knowledge for product innovation receive less financial impact from innovations than those realizing innovations for the same objective without utilizing university

Table 4 Estimated results for Hypothesis 2 (financial impact)

	object_1 Improving product or service quality				object_2 Expanding product or service lineups				object_3 Replacing existing products or services			
	Coef.	Std. Err.		P>|z|	Coef.	Std. Err.		P>|z|	Coef.	Std. Err.		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		

	object_4 Exploring new markets				object_5 Adapting to industry standards and regulations			
	Coef.	Std. Err.		P>|z|	Coef.	Std. Err.		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		

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

knowledge. This means that enterprises realizing innovations without utilizing university knowledge are more financially successful. Similar findings are observed for such other objectives as “expanding product or service lineups,” “replacing existing products for services,” and “exploring new markets.”

The reason for this finding may be that knowledge at universities is distant 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. To allow product innovations realized with university knowledge to be accepted by and diffused in the market, relevant products or services must be updated further. In the J-NIS2009 used for this study, enterprises were requested to specify the ratios of product innovations realized between FY 2006 and FY 2008 to sales in FY 2008. Therefore, the survey cannot be used to grasp any long-term impact of product innovations. To verify this point, we must use databases focusing on specific innovations, such as the SPRU.

Conversely, Model (V) analyzing product innovations for the objective of adapting to regulations and standardization progress produced a positive coefficient, which indicates that enterprises can achieve a greater financial impact by utilizing university knowledge when forced by exogenous factors including regulations and standardization to introduce new products or services into the market. The following reason may explain why this model’s results are different from those of other models. As noted above, tougher regulations and increased standardization are exogenously provided irrespective of enterprises’ intentions. Although enterprises are required to introduce products or services that meet regulations and standards into the market to maintain their sales, it is difficult for SMEs to have inside knowledge or technologies to address such situations. In this case, utilizing universities with advanced knowledge or technologies to solve technological problems is an easier way to realize products or services favored by consumers.

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

3. Technological impact of the utilization of university knowledge

Next, let us review the relation between the utilization or non-utilization of university knowledge and technological impacts of product innovations (Table 5). The “university” independent variable for verification has a statistically significant positive coefficient solely in Model (III), which 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.”

The above estimated results indicate that Hypothesis 3, which states that product innovations realized through university knowledge utilization for specific objectives feature higher technological levels, fails to be endorsed, except for certain specific objectives. The following is a conceivable reason for such results. This study’s analysis target is manufacturing SMEs, which are defined as having 10 to 249 employees. The technological advancement of new products or services at enterprises of this size group stems not from university knowledge or their own technological capabilities but rather from other exogenous factors particular to the market. Among variables indicating other exogenous factors, both or either of the “protect_legal” and “protect_strategy” variables have statistically significant positive

Table 5 Estimated results for Hypothesis 3 (technological impact)

	object_1 Improving product or service quality			object_2 Expanding product or service lineups			object_3 Replacing existing products or services		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	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	

	object_4 Exploring new markets			object_5 Adapting to industry standards and regulations		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	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	

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

coefficients in all the models. This finding indicates that enterprises having means to secure profit from product innovations produce products or services with higher technological levels.

As the reason for the sole positive significance of replacing existing products or services and technological impact, replacing existing products obviously requires the development of new products. For SMEs that have sufficient knowledge to develop a new product for the market, university knowledge may be effective.

Ⅵ 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 rather decide whether to use university knowledge considering 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 success without university knowledge rather than with such knowledge.

・The utilization of university knowledge can cause greater financial impacts in cases where exogenous factors such as tougher regulations and increased standardization 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. However, enterprises seeking to replace existing products or services utilized university knowledge to realize products or services with higher technological levels.

Under the Act on Special Measures concerning Industrial Revitalization that went into effect in 1999, universities are expected to promote their knowledge and technology transfers to the industrial world. However, this study's analysis results indicate that the utilization of university knowledge does not necessarily lead to the creation of high-quality innovations. A potential reason for these results is that enterprises do not necessarily access university knowledge in a strategic manner, as indicated by this study's results. Therefore, Japanese SMEs may not access or utilize knowledge required for their innovations but solely utilize knowledge they can access. Therefore, knowledge from universities may fail to accurately match the knowledge required by enterprises.

The J-NIS2009 used for this study represents single-year data, failing to provide data on the dynamic impacts that innovations exert on enterprises. Therefore, data on the 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 innovations realized in the first half of FY 2006 and those in the second half of FY 2008 equally. These problems may have caused biases in estimated financial impacts of product innovations. To address these problems, we must use databases focusing on individual products and services to indicate long-term trends, such as the SPRU conducted in the U.K. However, no such database has been created for Japanese data. Future studies should analyze the dynamic impacts of innovations on enterprises.

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1) For details of the J-NIS2009, see National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology (2010), “Report on Japanese National Innovation Survey 2009,” NISTEP REPORT;144
2) 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.
3) Griliches and Mairesse (1995) and several other studies provide details on the endogeneity problem for estimation models.
4) The stata smm command was used for the estimation.

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