Technology that Produces Sustainable Competitiveness: A Comparison of Innovative Technologies and Accumulated-knowledge Technologies

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Summary

Approaches that serve as a source of technology that produces sustainable competitiveness can be classified into two types: the acquisition of patents based on innovative technology (innovative technologies), and accumulation of knowledge over many years in specific technical fields (accumulated-knowledge technologies). This paper compares the influence these two sources of technological advantage have on corporate competitiveness. As a conclusion, accumulated-knowledge technologies are demonstrated to be more important for sustainable competitiveness than innovative technologies. This tendency is especially notable when technological change is rapid.

Keywords

Sustainable competitiveness, Innovative technologies, Accumulated-knowledge technologies, Organizational capabilities

I. Introduction: Objectives of the Study

For manufacturers, creating added value and improving financial performances through technological development is critical. Recently, however, it has become difficult to link technological development capabilities to corporate performance. In order to continue creating added value sustainably, companies must maintain their advantage over competitors. Because of the two developments identified below, however, in recent years competition has grown exceedingly fierce, and even when firms possess proprietary technology they have developed, such technology is immediately imitated. First, the technological level worldwide has improved as a whole and the number of highly competitive firms has increased, centered on regions such as East Asia. Korean and Taiwanese firms in particular are now highly competitive, even in state-of-the-art technologies. Second, advances in design technology have promoted modularization and standardization, resulting in vigorous transactions in intermediate goods such as components and devices (Baldwin and Clark, 2000). As a result, it has become possible for even a new Chinese firm with low technological capabilities, for example, to develop and manufacture products that are equivalent to those of leading companies, by purchasing the necessary components and devices.

In such an environment, even if a firm possesses technology it has developed internally that technology can be imitated easily by competitors. Consequently firms find it increasingly difficult to create added value and generate profits. Yet firms must maintain technological distinctiveness and advantage in order to create added value and profits.

The principal objective of this paper is to consider the conditions that enable a firm to maintain its competitiveness through technological advantage without being easily imitated. Theoretically, the paper uses RBV (Resource Based View of the Firm) and organizational capabilities as a base. Of these, I will particularly emphasize the importance of building organizational capabilities through the accumulation of knowledge, and problem-solving abilities through continuous learning.

Specifically, the research in this paper examines the following two features as characteristics of technologies that support sustainable competitiveness. The first is achieving advantage through the development of groundbreaking technologies that previously did not exist. Because firms can obtain patents on innovative technologies, such technologies in particular can be protected from imitation by competitors and linked to sustainable competitiveness. This paper calls this type of technological strength “innovative technologies.” The second is technical knowledge and experience or design capabilities and problem-solving abilities in a specific technical field that have been accumulated through long-term learning. These are referred to as “accumulated-knowledge technologies.” The experience and knowledge learned continuously by engineers cannot be imitated easily and is related to sustainable competitiveness. In fact, much of technological advantage is supported by accumulated-knowledge technologies (Nobeoka, 2007).

To what extent do these two types of technologies contribute to a firm’s sustainable advantage and competitiveness, and to the resulting sales and profit performance? Furthermore, does the degree of importance of each type of technology vary based on differences among technological areas or the competitive environment? This paper seeks to clarify these questions. Others have discussed the importance of both innovative technologies (and patents) and accumulated-knowledge technologies as well (Fujimoto, 2003). There has been little research, however, on how differently innovative technologies (patents) and organizational capabilities contribute to corporate performance.

In many papers, patents have been used as the dependent variable in research on business administration, as seen in empirical analyses of organizational capabilities represented by Henderson & Cockburn (1994) or Somaya, Williamson and Zhang (2007). Moreover, research analyzing the contribution of organizational capabilities to corporate financial performance is scant and has many problems. First, in much of the research concerning organizational capabilities, organizational capability is the dependent variable. In addition, in many papers, both the dependent variable and independent variable are variables of organizational capabilities. In Clark & Fujimoto (1991) or Eisenhardt & Tabrizi (1995), for example, organizational structure and processes are used as the independent variable, and development speed (lead time) and efficiency are used as dependent variables, but both might be variables concerning organizational capabilities. Moreover, in research where corporate performance is the dependent variable, in many cases an item such as the number of defects or development efficiency is used as the explanatory variable (see, for example, Ethiraj, Kale and Krishnan, 2005). There also is a high probability such variables are mere outcomes from differences in operations management methods and cannot necessarily be called organizational capabilities.

Concerning the accumulation of organizational capabilities, there also is research analyzing the extent to which the use of internal resources and outsourcing affects corporate performance, such as Rothaermel, Hitt & Jobe (2006); this is an extension of research concerning make-or-buy, however, and cannot be said to deal with organizational capabilities themselves. This paper will directly clarify how accumulated organizational capabilities have contributed to sales and profit performances through products.

The unit of analysis for this study is "technology." Development of technology is normally carried out continuously over many years, and organizational capabilities accumulated through this process. Moreover, during this period the technology is usually utilized for numerous products in multiple business units and contributes to their sales and earnings. In other words, when technology is the unit of analysis, because the technology is developed continuously, it is necessary to dynamically analyze the entire period during which the technology is used for multiple products, rather than perform a static analysis at a certain point in time. In this paper we will use this definition of "technology," including the technology development process over a long period of time rather than simply at a specific point in time.

There is no research that assumes technology as the unit of analysis in this manner and analyzes, for such technology, the relationship between organizational capabilities accumulated over many years and the extent to which the technology has contributed to sales and profit performance through products. When discussing technology in the context of organizational capabilities, however, this type of analysis is indispensable. Such analysis is difficult because it is nearly impossible to measure the contribution of the technology to sales and profit performance through products over many years. Technology is applied in numerous products, but there are no data by product. It also is impossible to separate and tease out a specific technology's contribution from among the operating results (net sales and earnings) achieved through product sales. This is the reason such research has not been conducted previously.

For this paper, however, managers who were involved with technology over many years and able to evaluate the contribution of the technology to sales and profit performance for a long period of time provided such evaluations subjectively. Subjective evaluation may not be perfect, but this research therefore places greater priority on importance and relevance, rather than on the robustness of the research method.

In this paper, as a conclusion of empirical analyses we argue that to sustainably achieve strong operating results, accumulated-knowledge technologies are of greater importance than innovative technologies and patents, and that this tendency is especially remarkable in areas where technological change is rapid.

II. Theoretical Framework and Hypotheses

As described above, we believe the technology used by firms to maintain their competitiveness can be classified into two types: innovative technologies and accumulated-knowledge technologies. Both types of technology can be expected to contribute to firms' sustainable operating results.

In the following section we will lay out a hypothesis of the influences of innovative technologies and accumulated-knowledge technologies on sales and profit performance.

The first type of innovative technology is state-of-the-art technology. In this paper we use the patent-protected technologies that firms have successively developed as state-of-the-art technologies, for which they have obtained patents, as the definition of "innovative technologies." More specifically for this paper, because "technology" covers a long-term period, innovative technologies usually mean technologies that create many small patents over the period. Products that use such innovative technologies can generate first-mover advantages (Lieberman and Montgomery, 1988). Furthermore, by obtaining a patent, firms can avoid imitation by competing firms, which is tied to sustainable competitiveness (Rumelt, 1984).

Numerous firms mainly implement this first pattern, pursuing innovative technology development and obtaining patents with the goal of maintaining a technological competitive advantage. Patent acquisition through technical innovation also is superior from the standpoint that clear goals can be set qualitatively and quantitatively as technology and product development objectives as part of corporate strategy. In reality, however, when comprehensively evaluating a firm's technological capabilities, the role played by "technology innovation (and patents)" is considerably limited. The role of "accumulated-knowledge technologies," noted here as the second type of technology innovation, is actually much larger.

"Accumulated-knowledge technologies" are those for which the core knowledge is the technical expertise and problem-solving abilities engineers and an organization have accumulated over many years, even if such technology lacks innovative characteristics that enable the firm to acquire a patent. The specific elements accumulated include the engineering and problem-solving capabilities learned over time through the experience of organizational and individual trial and error, the manufacturing facilities and testing equipment created through successive improvements and the test data acquired for a long time. Of these, one element that is especially important as a component of accumulated-knowledge technologies over many years is the problem-solving capabilities learned and amassed by engineers over the years. In fact, a substantial portion of a firm's technology is comprised of the problem-solving capabilities of individual engineers. When a certain automotive firm "possesses superb high-performance engine technology," for example, to a large extent this means "the firm has many excellent engine engineers with years of development and design experience in high-performance engines."

The problem-solving abilities of engineers are learned and accumulated through trial and error experience. As a consequence such abilities cannot be imitated. The problem-solving abilities a certain engineer has learned through experience with various technologies and product developments over ten years in a specific technical field, for example, cannot be condensed and learned by other engineers in one or two years. Even when viewed as having been learned to the same degree, there is a fundamental difference between capabilities learned in a year or two and capabilities learned over a span of ten years (Lado and Wilson, 1994). A large portion of technological capability as an organization is concentrated in such engineers problem-solving abilities. Because they are accumulated through longtime learning, many aspects of accumulated-knowledge technologies cannot be imitated by competitors in a short period of time (Hatch and Dyer, 2004).

In addition, conditions that make it difficult for competitors to imitate, discussed mainly within the theoretical framework of RBV (Resource-based view), include the extent of complexity and tacitness (McEvily and Chakravarthy, 2002, causal ambiguity (Lippman and Rumelt, 1982), path dependency (Dierickx and Cool, 1989), organization-specific assets (Peteraf, 1993) and invisible assets (Itami, 1987). These are in fact typical characteristics of technologies for which long-term knowledge accumulation requires time. Problem-solving capabilities as the result of accumulated learning are naturally path dependent, exhibit a high degree of tacitness and are organization-specific capabilities unique to an individual organization. In other words, the term "accumulated-knowledge technologies" as considered in this paper are a concept that encompasses all of these.

Such innovative technologies and accumulated-knowledge technologies can both be expected to contribute to the sustainable competitiveness of manufacturing firms. In the first place, there are strictly speaking just two types of technology related to each of these as sources of technology that cannot be easily imitated. One, which is represented by the patent system, is technologies that are protected legally. While there are in fact many cases where a patent can be circumvented, making substantive imitation possible, by definition these technologies cannot be imitated because they are legally protected. The other is technologies that cannot be imitated unless a long period of time is invested, even if the details of the technology are understood. For example, the substance of BMW's technology for developing engines that demonstrate smooth, high performance can all be broken down and viewed. Other firms are unable to develop similar technology in a short time span, however. The time needed to accumulate and learn the required trial and error cannot be shortened significantly (Dierickx and Cool, 1989).

While factors other than these two that make it difficult to imitate technology can be enumerated, such as complexity and tacitness, with the exceptions of legal protection and learning that takes a long term, firms cannot necessarily eliminate the possibility competitors will be able to imitate the technology even within a short time. The innovative technologies and accumulated-knowledge technologies considered in this paper represent the source of these two types of technologies that can never be imitated.

Next, even if both innovative technologies and accumulated-knowledge technologies are important, the point that must be pursued further is which technology is more important. Speaking from the conclusion, we believe accumulated-knowledge technologies are of greater importance. This paper emphasizes the sustainability of competitiveness. Depending on the innovative technology, even when a firm has obtained a patent there is a strong probability competitors will gradually catch up through the use of various approaches. Accumulated-knowledge technologies, on the other hand, by definition contain a mechanism to continually improve the technology more effectively than competitors. In contrast to innovative technologies, for which there is no guarantee innovation will continue, accumulated-knowledge technologies by definition include strengths from a dynamic aspect.

Moreover, compared with innovative technologies, for which a large portion has been converted into explicit knowledge as symbolized by its protection under a written patent, for accumulated-knowledge technologies the amassed know-how and problem-solving ability hold the key and there are numerous components possessing tacit knowledge characteristics. In this respect as well, accumulated-knowledge technologies are believed to contribute more sustainably to strong competitiveness. From these discussions we shall first set out the following two hypotheses.

Hypothesis 1a Both innovative technologies and accumulated-knowledge technologies contribute to the long-term performance of firms.

Hypothesis 1b Accumulated-knowledge technologies make a greater contribution than innovative technologies to sustainable competitiveness.

The importance of the respective technologies may differ depending on the characteristics and area of the technology. This study adopts as technologies characteristics, “technologies that undergo rapid technological change,” “technologies with integral architecture, as opposed to modular architecture, that require coordination with other technologies” and “technologies that are production technologies, not product technologies,” and then considers whether innovative technologies, or accumulated-knowledge technologies, are more important under each condition.

Let’s begin by considering technologies that undergo rapid technological change as a technology characteristic. In areas where technological change is rapid, are innovative technologies or accumulated-knowledge technologies more important? There are two conflicting approaches to this hypothesis. One might think that innovative technologies are more important because companies respond directly to technological change in the market by developing innovative technologies. Accumulated-knowledge technologies, on the other hand, cannot respond directly in the short term to new technologies, because by definition they require a long term to accumulate.

Next, as an opposing view it is possible to believe that even if a patent is acquired based on innovative technologies, the effectiveness will be limited because technology changes. Viewed from this standpoint, accumulated-knowledge technologies can be considered more effective in response to technological change because of the greater possibility they can be adapted across a broad range. While innovative technologies are limited solely to a specific technology, accumulated-knowledge technologies possess greater generality, together with the aspect of responding easily to technological change, because they are supported primarily by problem-solving capabilities. For accumulated-knowledge technologies, generality can be increased by strategically establishing the technological scope, and the possibility that the contribution to firm performance can be sustained is thought to be comparatively high. In this paper we adopt the latter logic to set out Hypothesis 2a below.

Next let us consider technologies with integral architecture as a characteristic of technology. In other words, how does the degree of contribution of innovative technologies and accumulated-knowledge technologies differ depending on whether they are technologies that are used independently or technologies that are used together with other technologies (i.e., depending on whether the technologies are modular or integral)? To use technologies skillfully in combination with other technologies through coordination within integral architecture, an organization must have coordination capabilities. To foster such coordination capabilities, organizational routine, which can be established only by experiencing coordination activities repeatedly, is critical. Therefore accumulated-knowledge technologies can be expected to be especially important for technologies within integral architecture. Consequently we set up Hypothesis 2b below.

Finally, with regard to the technology realm, let's consider a comparison of product technology with production technology. If innovative technology can be developed within a product technology, it will lead directly to the success of the product in the market. In other words, innovative technology is thought to be especially important for product technology. For production technology, on the other hand, the accumulation of long-term expertise is important. Other research has also pointed out that proprietary manufacturing facilities that represent the accumulation of improvements contribute to corporate competitiveness (Hatch and Mowery, 1998). Therefore we have formulated Hypothesis 2c, which states that for production technology, accumulated-knowledge technologies are more important than innovative technologies, and vice versa.

Hypothesis 2a In fields where technological change is rapid, accumulated-knowledge technologies contribute more strongly to the sustainable performance of a firm than innovative technologies.

Hypothesis 2b In technical fields where coordination with other technologies are required, accumulated-knowledge technologies contribute more strongly to the sustainable performance of a firm than innovative technologies.

Hypothesis 2c For production technologies, accumulated-knowledge technologies contribute more strongly to the sustainable performance of a firm than innovative technologies.

III. Empirical Analysis

To test the hypotheses discussed in the previous section, we have implemented a questionnaire survey at four manufacturing firms in Japan. The methodology and result of the survey are described below.

1. Research methodology and analytical model

For the purpose of the present study we conducted questionnaire surveys at four Japanese manufacturing firms from 2007 through 2008. Three of the four firms are large-scale manufacturers with annual sales in excess of one trillion yen, while the remaining company has annual sales of approximately 100 billion yen. The industries ranged from electrical appliances, telecommunications and automobile components to precision instruments. We asked executives (referred to below as "mediators") at each firm who were in positions that gave them a bird's-eye view of all of their company's technologies to assist with the survey, and obtained responses from a total of 119 key engineers (managers) (breakdown for the four companies: 49 individuals, 37 individuals, 23 individuals and 10 individuals). The mean age of the respondents was 41.8 years. When selecting the engineers we wanted to choose individuals from as many different technical fields as possible. We also asked the mediators to select engineers who had thorough familiarity, from the past to the present, with the application of technology in products in the technical fields for which they are responsible and with the product's market performances. The mean number of years in which the individuals had worked at their firms was about 18 years. In addition, for eight individuals among the respondents who gave answers concerning technologies that had achieved especially strong performances, we also asked the mediators to gather qualitative information regarding reasons for their strong performances.

In the questionnaire survey, the respondents selected, from among technologies related to their own activities, those technologies that had maintained advantage vis-à-vis competitors and that had succeeded as core technologies. The definition and breadth of "technology" was left to the discretion of the respondents. However, respondents were requested to answer all questions consistently, using the same definition. Although respondents could not disclose details of the technologies because of confidentiality, they identified the technologies as "image-recognition technology for ***," for example, or "semiconductor fabrication technology for ***" ("for ***" indicating one technical field, not one product). The respondents answered the mechanism by which the technology contributes to sustainable competitiveness and firm performance using a five-point Likert scale. The constructs and variables as well as question items are shown in Table 1. Each variable was measured based on the mean for two question items.

First, we measured the contribution to sustainable performance, which was the dependent variable, by asking two questions: to what extent has the technology contributed to an increase in sales, and to what extent has it contributed to an improvement in profit margins, over time until now. Next, as the independent variable we looked at two items each for the characteristics of "accumulated-knowledge technologies" and "innovative technologies," as shown in Table 1. Specifically, respondents were requested to "Evaluate the extent to which the following items have contributed at the reason or source that this technology was not imitated by competitors over many years and enabled your firm to maintain its performance." The answers they provided for the four items are listed in Table 1.

As mentioned in the first section of this paper as well, because these variables were being evaluated over a long term the only measurement method that could be considered was to have engineers who are well informed about these technologies, the products in which the technologies are used and the extent of the contribution to sales and profit performance provide a subjective assessment. Although bias in subjective responses is undeniable, we believe this problem is comparatively small. The influence of such subjectivity is limited because the study analyzes the relationship between the characteristics of the technologies and organizational capabilities and the degree of contribution of the technologies to sales and profit performances, not the performances of the respondents themselves. In addition, rather than change the objectives of the analysis because they cannot be measured, we believe conducting the research using the best research methodology, without changing the objectives, is the correct approach.

Table 1 Question items in the survey

	Construct and variable	Question item	Correlation coefficient
Dependent variable	Contribution to sustainable performance	Has contributed substantially to increasing sales of the company's products over-time until now	0.72
		Has contributed substantially to improvement of the profit margins of the company's products over-time until now	
Independent variable	Accumulated-knowledge technologies	Expertise and capabilities accumulated over many years as an organization	0.74
		Experience and knowledge obtained through long-term trial and error	
	Innovative technologies	State-of-the-art technology in the industry	0.52
		Company holds the patent	
Control variable	Investment of resources	A sufficient number of engineers had been assigned	0.63
		Sufficient investment was made in facilities etc.	
	Period from start of development	Number of years since the start of development of the technology	NA

Let's take a look at the internal consistency (reliability) of the question items that constitute these variables. First, the correlation coefficient for the responses to the two question items concerning the contribution to performance is high at 0.72. Next, the two questions that constitute accumulated-knowledge technologies have a high correlation as well (correlation coefficient =0.74). Finally, the variables for innovative technologies are constituted from two question items concerning state-of-the-art technology and patents, and the correlation coefficient between these also is high

(0.52).

We established three control variables. The first is the volume of resources invested in the technology. Specifically this is the resources investment concerning engineers and facilities. Because this variable is thought to have a large influence directly on the success of technology and product development, it must be controlled. The second is the amount of time since the start of development of the technology that was given as a response. Generally when the period since the start of development is short, the extent of the technology's contribution to sales and profit performances is thought to be small. The third, which is not shown in Table 1, was the introduction of four company dummies. This was necessary to control for the high probability the contribution to performances differ depending on factors such as differences in the industries in which each firm operates. We also examined a control using a dummy variable by industry, but because this resulted in a variable that was similar to the firm dummy, we selected the firm dummy.

Furthermore, to test Hypothesis 2 (a, b, c) we analyzed the results by dividing the sample according to the characteristics of the technologies. For technologies that experience rapid technological change, we extracted samples that received 4.0 or more points on the 5-point Likert scale for the response "This technological field has been experiencing rapid technological change." Similarly, we analyzed only those samples that received 4.0 or more points for the responses "This technological field often requires adjustment and coordination with other technologies within the company" for Hypothesis 2b and "In this technological field, production technology are more important than product technology" for Hypothesis 2c. Of all 119 samples, the number of samples of technologies that met these three conditions was 61, 79 and 69, respectively.

2. Results of the data analysis

Table 2 shows the mean, standard deviation and correlation coefficient of each variable, while Table 3 shows the multiple regression analysis results. From these tables we can see that both accumulated-knowledge technologies and innovative technologies contribute to sustainable competitiveness. Both innovative technologies and accumulated-knowledge technologies are significant. In the multiple regression analysis in Table 3, compared with the base model (model 1) including only control variables, the adjusted coefficient of determination (adjusted R-squared) of model 2 rises sharply from 0.03 to 0.26. From this we can understand that accumulated-knowledge technologies and innovative technologies have a substantial influence on sustainable competitiveness.

Next, let's try to determine whether innovative technologies or accumulated-knowledge technologies have a stronger influence. First, when we examine the standardized coefficient, accumulated-knowledge technologies are significant at the 1% level and innovative technologies are significant at the 5% level. Moreover, although not shown here we also verified the models in which all of the control variables were introduced together with only accumulated-knowledge technologies, or with only innovative technologies, respectively. As a result, the adjusted coefficient of determination was 0.23 when all of the control variables and only accumulated-knowledge technologies were introduced, and was 0.08 when all of the control variables and only innovative technologies were introduced. These results support Hypothesis 1, which states that while both accumulated-knowledge technologies and innovative technologies make a contribution to sustainable competitiveness, accumulated-knowledge technologies are more important.

Table 2 Average, standard deviation and correlation coefficient

		Mean	S.D.	1	2	3	4	5
1	Contribution to performance	4.18	0.85	1.00				
2	Accumulated-knowledge technologies	3.63	0.88	***0.46***	1.00			
3	Innovative technologies	2.52	0.97	***0.28***	0.17	1.00		
4	Investment of resources	3.14	0.90	0.15	-0.01	*0.20*	1.00	
5	Period from start of development	23.4	19.6	***0.25***	0.13	0.11	*0.19*	1.00

Italicized figures in bold type are statistically significant at 1%; italicized figures in plain type are statistically significant at 5%.

Table 3　Results of multiple regression analysis (Hypothesis 1)

	Model 1 (n=119)			Model 2 (n=119)		
	Correlation	t	Significance	Correlation	t	Significance
Constant		11.7			4.7	
Accumulated-knowledge technologies				0.43	5.20	***
Innovative technologies				0.18	2.23	**
Investment of resources	0.09	1.10		0.07	0.76	
Period from start of development	0.01	2.50	***	0.18	2.13	**
Firm dummy (four companies)	-	-		-	-	
R-squared	0.07			0.30		
Adjusted R-squared	0.03			0.26		

**5% significance　***1% significance　(Coefficient is the standardized coefficient)

Next let's turn to results concerning Hypothesis 2. For Model 3 in Table 4, the analysis was limited to sectors with rapid technological change. Here we can see that only accumulated-knowledge technologies are important and that innovative technologies do not contribute to sustainable competitiveness. This result supports Hypothesis 2a. For the technologies in Model 4 that require coordination, only accumulated-knowledge technologies are significant, and innovative technologies are not effective. Thus Hypothesis 2b was supported as well. On the other hand, for manufacturing technologies, although we set up a hypothesis that, like Hypothesis 2a and 2c, the influence of accumulated-knowledge technologies is stronger, in reality the contribution of innovative technologies is also significant. The result is not different from the result when all technologies were introduced (n=119). In other words Hypothesis 2c was not supported.

Among the models, the contribution of accumulated-knowledge technologies is remarkably high in Model 3 (when technological change is rapid), and the result that the coefficient of determination is the highest of all the models is also important. It was thought that when technological change is rapid, the contribution of innovative technologies in direct response to change would logically be high as well. However, we have found that accumulated-knowledge technologies are important for responding to technological changes as hypothesized. The results of the analysis, including this aspect, are discussed in the following section.

Table 4　Results of multiple regression analysis (Hypothesis 2)

	Model 3 (n=61)			Model 4 (n=79)			Model 5 (n=69)		
	Rapid technological change			Coordination required			Production technology		
	Cor.	t	Sig.	Cor.	t	Sig.	Cor.	t	Sig.
Constant		3.45			4.75			2.54	
Accumulated-knowledge technologies	0.49	4.30	***	0.32	2.96	***	0.46	4.24	***
Innovative technologies	0.12	1.05		0.17	1.58		0.26	2.34	**
Investment of resources	-0.02	-0.16		0.15	1.27		0.03	0.22	
Period from start of development	0.17	1.51		0.20	1.66	**	0.14	1.20	
Firm dummy (4 firms)	-	-		-	-		-	-	
R-squared	0.40			0.25			0.33		
Adjusted R-squared	0.32			0.18			0.25		

**5% significance　***1% significance　(Coefficient is the standardized coefficient)

IV. Discussion

1. Accumulated-knowledge technologies and innovative technologies

From the study it was understood that both accumulated-knowledge technologies and innovative technologies are important for sustainable competitiveness. The fact that accumulated-knowledge technologies supported by engineers' capabilities and learning have a greater impact than innovative technologies supported by patents was also clarified. Although there is a propensity in both scholarly research and management activities to emphasize the development of innovative technologies and acquisition of patents, this view probably needs to be revised.

Why have innovative technologies been valued more in the past than accumulated-knowledge technologies? Perhaps this is because innovative technologies are easier to administer, both when doing research and when managing the technologies, than accumulated-knowledge technologies. Because of the wealth of available patent data in particular, for scholarly studies researchers have tended to pursue research that utilizes this data. To the extent researchers are unable to work on-site at firms in order to understand the essence of accumulated-knowledge technologies and gather data, on the other hand, research on such technologies is much more difficult.

At firms as well, patents and innovative technologies are easy to manage as targets of technology management. Conversely, the measurement and evaluation of accumulated-knowledge technologies is extremely difficult, and strict management and control are nearly impossible. The importance of accumulated-knowledge technologies is supported empirically, however, and many business people concurred with this importance in the interview survey conducted for the present study. Both academic researchers and businessmen and women should address accumulated-knowledge technologies more extensively, including the development of measurement and management methodologies for such technologies.

Moreover, as evident in Table 2, accumulated-knowledge technologies and innovative technologies have a weak correlation. That is, the relationship between the two types of technologies – such that a firm will be able to create innovative technologies and obtain many patents because it possesses accumulated-knowledge technologies, for example, or oppositely be able to create accumulated-knowledge technologies based on having developed innovative technologies – is weak. Therefore when the importance of accumulated-knowledge technologies is considered, researchers and business people should work harder in the search for management of accumulated-knowledge technologies than on the management of innovative technologies or patents. According to Nobeoka (2007), the contents of accumulated-knowledge technologies offer benefits such as advanced problem-solving abilities based on engineers' learning and the improvement of test equipment and manufacturing technology, and the strengthening of organizational capabilities to coordinate among different functions and business units. To a certain extent these benefits will accumulate naturally, even if not sought intentionally by management, simply through the process of implementing technology and product development. When the importance of accumulated-knowledge technologies is considered, however, the accumulation of such benefits probably should be managed more explicitly and strategically.

2. The importance of innovative technologies and accumulated-knowledge technologies

As a point demonstrated by the present study, the clarification that the importance of accumulated-knowledge technologies varies according to technological characteristics is a major contribution. The pace of technological change, the need for coordination with other technologies and production technology were examined as technological characteristics. Among these, the fact accumulated-knowledge technologies are especially important when coordination is required is an easy point to comprehend. Implementing coordination smoothly within an organization demands the accumulation of trial and error or problem-solving experience among engineers in different functions and technological areas. Technologies that contradicted the hypothesis are production technologies. While the contribution to sustainable competitiveness produced by accumulated-knowledge technologies was thought to be especially large because the accumulation of continuous improvement is especially important with production technologies, innovative technologies were also similarly important. The reason is probably that situations in which not only improvements but also technological innovations are required are increasing for production technologies such as semiconductor-related technology and materials technology as well. Innovative technology development is being demanded not just for product technologies, but also for production technologies.

Lastly, the empirical results concerning the relationship between the speed of technological change and the importance of accumulated-knowledge technologies is the most interesting. There is a propensity to believe that innovative technologies in new technological fields are necessary for technologies that undergo rapid technological change. Responding to frequent technological change with repeated innovative technology hits of first-base singles is pretty useless, however. As shown in Table 2, the correlation between innovative technologies and investment of resources (engineers and capital investment) is significant, which means large investments are necessary. Notwithstanding this fact, even if a firm can develop innovative technologies it will be unable to maintain its advantage for long, and linking its innovations to large positive operating results will be difficult, because the technological change is so fast. In addition, if a firm is simply playing a game of "whack-a-mole" and merely responding to new technologies that result from such technological change, building its strengths (core capabilities) in order to sustainably position the firm in an advantageous position vis-à-vis competitors will be difficult. This may be the reason all of the firms that have joined the competitive fray, if they just pursue innovative technological development in the midst of rapid technological change, in many cases slip into conditions that prevent them from achieving strong performances.

Accumulated-knowledge technologies, on the other hand, are an amassing of problem-solving capabilities, and there is a greater possibility the range of applications will be wider than with innovative technologies (patents) that are limited to a specific technology. One component of accumulated-knowledge technologies is the top, highly-learned engineers themselves. In cases where a firm "has" a certain specific "technology," this frequently means it employs engineers who have extensive experience in a technical field and possess excellent design capabilities and problem-solving skills. Even more than specific innovative technologies, the presence of engineers with impressive abilities in a technical field makes it easier than patents or other factors for a firm to respond flexibly to technological change.

3. Future research issues

RBV (Resource-based View) has become an important theoretical framework for business administration and already has a long history. Over the years numerous theoretical discussions have taken place, and the volume of empirical research has grown as well. The building processes for the contents of organizational capabilities, resources and capabilities themselves and the sources of competitiveness, however, have not been deeply discussed, and few of the specific mechanisms have been clarified (Newbert, 2007). Simply because of the fact they are accumulated over many years, organizational capabilities are tacit and not easily imitated. For the substance and building processes of organizational capabilities amassed over long years, more discussion of theories that integrate organization learning, the creation of knowledge, evolutionary theory and other approaches is needed. Furthermore, qualitative case studies on the substance of accumulated organizational capabilities must be sufficiently implemented. While accumulated organizational capabilities are complex, and problems are difficult to analyze and quantify both theoretically and practically, further efforts are called for because such capabilities are without a doubt the most important point of view for considering a firm's strong points.

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