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**Conference Paper**

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28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017

**Provided in Cooperation with:**

International Telecommunications Society (ITS)

*Suggested Citation:* Shigeno, Hidenori; Tsuji, Masatsugu; Matsuzaki, Taisuke; Shinohara, Sobee (2017) : ICT Use, Connectivity, and Innovation Capability in Japanese SMEs, 28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, 30th July - 2nd August, 2017, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/169498>

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# ICT Use, Connectivity, and Innovation Capability in Japanese SMEs

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Key words: External linkages, SEM, causality, open innovation

## 1 Introduction

The emergence of the information economy triggered by information and communication technology (ICT), and furthermore, the transition to the knowledge economy are not unique to Japan; they have realized globally common structural changes. However, some of SMEs in Europe and the U.S. themselves take a role of inducing such changes. Venture companies in the IT and biotech industries are especially representative of these SMEs. They are destroying existing industrial structures and creating new products, services, and business models, a phenomenon aptly called creative destruction. SMEs in Japan, on the other hand, can be said to be victims of this process instead of innovators. In the midst of such rapid and turbulent changes, it goes without saying that sustained innovation is required to regain vitality and, furthermore, grow.

Our main research topic has conducted thus far onsite surveys of SMEs inside and outside Japan, questionnaire surveys, and literature reviews to investigate what are needed to foster innovation by SMEs and, to support answering this question, how innovations are produced (Tsuji et al. 2013a, 2013b, 2016a, 2016b). This paper seeks to construct a new theory on SME innovation by reviewing and comprehending findings and knowledge obtained to date from a unified perspective. Conventional research on innovation in general has focused thematically on individual factors such as absorptive capability, R&D, and open innovation. While this approach has its advantages, it is critical to research innovation as a single process from a broad

perspective and framework. This analyzes how SMEs acquire new information and ideas that are the source of innovation, organize and conduct R&D to integrate these ideas with management resources within the firm, and finally, how they produce the concrete output of these steps that lead to the development of new products. Our research especially seeks to answer what elements are needed in this process, and how they should be combined.

In addition, this paper focuses on internal innovation capability which includes factors such as technologies that the company own, human resources (human factor), managerial organizational form (organization), leadership, and so on. These factors also consist of detailed sub-factors. The examples of the third layer contain as the following factors, for example. The technological factor includes the following factors: (a) ratio of R&D expenditure to sales; (b) the number of intellectual property right owned; and (c) technical and management systems such as R&D. (ii) Managerial organization indicates whether the managerial organization is designed and functioning to encourage exchange and share information among employees or communications inside the firm for innovation. This consists of the following sub-factors: (d) practicing QC circle; (e) cross-functional team; (f) information sharing system using ICT; and (g) the traditional background to stimulate discussions and communications among sections of the firms. Finally, the human resources is an important factor for engaging in innovation activities as well as for design and managing R&D, which consist of the following sub-factors: (h) ability of top management such as degrees or experiences; (i) leadership of top management; (j) degrees and experiences of employees; and (k) the Human Resource Development scheme (HRD) such as OJT (On-the-job training) or OFFJT (Off-the-job training). This paper particularly focuses on factors such as technology, R&D, and ICT use.

The roles of ICT in general for SMEs are summarized as follows: (i) efficiency and rationalization of business works; (ii) supporting decision-making; (iii) communications tools; and (iv) enhancing innovation. It is needless to say that if ICT is introduced to the organization without favorable environments for ICT such as information sharing systems or the learning system for skill formation, it does achieve any objectives. Those systems are not required the existence of ICT, but it is the other way around: Through the information sharing system or the skill formation system,

SMEs tend to construct the capability for better business performance, and the desire to achieve the better performance makes ICT to be introduced in the business process. As a result, the firm achieves their goals, and this continuous and cumulative process over time ends up with the formation of the ICT capability. Thus the role of ICT in the innovation process is required to examine whether ICT is a cause or effect of other innovation capability such as technology or R&D.

With these questions in mind, the paper is structured as follows to shed light on the mechanisms of innovation in SMEs. In the next section innovations obtained through our surveys of SMEs are organized into three types, and their features are described. Section 3 provides hypotheses and models, and in Section 4 these hypotheses are tested. Sections 5 and 6 discuss the estimated results and actual results, and finally offer a conclusion.

## **2. Three types of SME innovation**

### **2.1 Factors determining SME innovation**

SMEs have various limitations with regard to innovation. They seek to innovate and pursue R&D amid these limitations. Accordingly, before analysis is conducted the factors and limitation conditions determining innovation are clarified. This section summarizes these factors and limitations from the results of past onsite surveys and previous research as follows:

#### **(1) Abilities of managers**

Like venture companies in the U.S., in Japan's SMEs, managers with outstanding technical or management abilities lead innovation to a greater or lesser extent. These abilities are not just limited to technology, but also include overseeing R&D and human resource development (HRD) and expanding their networks with other companies through activities such as sales.

#### **(2) Company size**

Company size in terms of capitalization, number of employees, or sales determines innovation in an SME. For example, if an SME seek to have an R&D organization but do not have enough employees, it cannot assign human resources for this purpose. If there are no outstanding personnel, then an SME will tend to focus on improving existing products instead of developing new products.

### **(3) Product type**

The type of innovation is determined by whether the product supplied by the SME is the final product, or a completed part, intermediate part, or simple part. If the final product is sold in the market, the SME can develop new products to meet the needs of mass consumers. If it supplies a simple part or raw material, that is incorporated into a final product by a large company. The extent to which the SME can express originality is then limited and it has no choice but to focus on improvement innovation.

### **(4) Seeds of innovation**

The innovation type is also determined by whether the innovation can be created from original ideas or ideas obtained from the seeds of other firms. As stated in (1) “Abilities of managers” above, innovation through original ideas is autonomous, and innovation through ideas from other companies is non-autonomous. In the latter case, changes in the model of a final product by a large firm, for example, lead to innovation by the part manufacturer as the changes involve development of new parts. Demands from the buyer to respond to complaints and improve quality also lead to improvement in the supplier. In this way non-autonomous innovation generally spread in accordance with the supply chain. In this paper, the flow of such information is called the “transaction channel.” Furthermore, since the latest technologies are often produced in university labs, collaboration between companies and universities and other research institutions, especially in the form of open innovation, is a focus of attention. Included among these firms are SMEs that actively acquire information by partnering with university labs. This paper calls such a route of acquiring information the “intellectual channel.” How SMEs produce innovation through these three sources of ideas is analyzed in this paper.

### **(5) R&D and organizational learning**

The innovation process is also called the learning process (Cohen and Levintal, 1990). The process includes the innovation of the final goal from the ideas, that is, sharing of obtained and absorbed information that is needed for innovation within the firm, combining the information with management resources within the firm, and developing a new product. Incorporated in this process are communication within the firm, the speed of decision-making, the organization and methods of R&D, and HRD. The methods of innovation differ depending on the completeness of this process.

## **2.2 Types of innovation in SMEs**

With the above discussion as the foundation, this paper proposes three types of innovations in SMEs: (1) manager-based, (2) improvement-based, and (3) development-based. These types were extracted from factors above considered to be important. Needless to say, these types are mixed in the actual process of innovation. For manager-based innovation, original products are sent to the market through the use of original technologies developed by the founder-type manager himself or herself. In short, it is a top-down process in which the manager is responsible for innovation. Improvement-based innovation stands on the opposite side of manager-based innovation. SMEs that possess this type of innovation are relatively larger in size, producing parts and raw materials, and have departments dedicated to R&D. However, the special characteristic of this type of innovation is that members of a group or team work together on developing or improving a product at the production site. This team is cross-functional, composed of technology-related departments such as departments for production technology, design, testing, and materials, and in addition, a sales department which deals with the product. Because innovation is often produced from the activities of the onsite production team, this innovation type is called bottom-up (Tsuji et al., 2016b). Development-based innovation can be considered a hybrid of the previous two types. It has a character in between the other two types of innovation in terms of firm size, R&D organization, production method, and HRD. The reason for including this type is that when the percentage of R&D-dedicated employees and R&D investment as a percentage of sales in a firm reach 5 percent or more, the development of new products becomes extremely active. With R&D in its mission statement, such a firm provides research funding and dispatches researchers to university labs, collaborates with universities and related firms and participates in R&D consortiums to develop products and technologies in particular fields, and actively seeks grants and subsidies from the central and local governments.

Table 1, which is the same as in the previous paper, summarizes the characteristics of the above three types of innovation. The purpose of this paper is to analyze the innovation process for each of the three types, so a discussion of their relative merits is not carried out. However, understanding of these characteristics is

beneficial for interpreting the results of empirical analysis as well as for establishing future policy to create innovation.

Table1 Types of innovation

Factor \ Type	Top down	Improvement	Development
Firm Scale	Small	Big	Middle
Type of product	Completed product, Completed parts	Simple parts, Material	Completed parts
Production lot	Small	Big	Small or Middle
Production method	Custom production	Mass production	Custom production, OEM
R&D organization	R&D is nothing	R&D organization	R&D organization
Full-time /R&D employee	0	Small	Big
Engineer HRD method	OJT (Density)	OJT, OFFJT	OJT, Detach to university
New employees	High school graduate	University graduate, Master degree	Industry department High school graduate, College of technology, Mid-career recruitment
Idea	Top manager's experience and study	Customer	R&D team, Customer, University etc.
Collaboration partner	Nothing, or other industries firms	Buyer	Other industries firms, university, etc.
Seeds of innovation	Technology	Claim, Model change	Technology
Type of innovation	Product	Process	Product

### 3. Formulation of hypotheses

#### 3.1 Analytic framework

Here the analytic framework of this paper based on the results of previous research is explained. As new information required for innovation is produced outside the firm (Chesbrough, 2003), how the firm handles the information is critical. Cohen and Levintal (1990) and Zahra and George (2002) consider the innovation process as a learning process, which consists of absorbing new information (1. acquisition), integrating the information with management resources within the company (2. assimilation), converting the information (3. transforming), and delivering new products and services to the market (4. exploitation). They emphasize absorptive capability as being critical for innovation and divide it into potential capability and realized capability. The first two of the four stages of the innovation process above need the former capability whereas the last two stages require the latter. Mariano and

Pilar (2005) expand absorptive capability by including communication with external parties, know-how and experience within the organization, diversity and multiplicity of the knowledge structure, and strategic positioning. For analysis, the cause-and-effect relationships between a variety of factors and capabilities were examined (Lawson & Samson, 2001; Perdomo-Ortiz, Benito & Galende, 2009).

In this paper, since the various concepts mentioned above are abstract, internal innovation is defined in a form that facilitates questionnaire survey responses and their empirical analysis. Specifically, internal innovation capability includes capabilities related to factors such as technologies that the company own, human resources (human factor), organizational form (organization), and leadership

A critical concept today for advancing innovation is R&D. Like innovation, a great amount of diverse research on R&D has been carried out. The reason is that R&D is risky, and its high rate of failure has drawn the interest of management scholars from the start (Booz, Allen, and Hamilton, 1982; Crawford, 1987; Cooper, 2001; Nadia, 2011; Tomita, 2015). Based on such research, many guidebooks and textbooks on R&D have been published, for example by Crawford (1987, 1997), Smith and Reinertsen (1998), Cooper (2001), Kahn (2013). In general, the R&D process is divided into processes such as conception of ideas, selection for commercial application, development, prototyping, and commercialization (Booz, Allen, and Hamilton, 1982).

Previous research has mainly addressed R&D from the perspective of organizational theory. Studies focused on areas such as acquisition of new information through the R&D organization, sharing of the information between members, and the conversion of the information to knowledge, and furthermore, from tacit knowledge to explicit knowledge. Accordingly two roles are considered critical in the R&D process: the gatekeeper, the key person who incorporates new information, and the transformer, who converts the acquired information into knowledge and transmits it to members in the organization (Freeman, 1979; Tsuji et al. 2016a, Tomita, 2015). To smoothly convey information, trustworthiness between R&D members is a prerequisite (Leven and Cross, 2004; Colquitt and Rodell, 2011). Many of these discussions on R&D consider R&D's success or failure as the outcome of their analyses. However, in this



paper the essence of R&D is not the focus. Instead its relationship to the outcome of R&D in the innovation process is analyzed.

### **3.2 Innovation process**

Based on the results of previous research and onsite surveys, this paper divides the process of innovation into the following stages.

#### **(1) Sources of ideas**

The initial stage of innovation is obtaining information and ideas related to new products and services. It is assumed that there are two sources: internal and external to the company. Information related to the latest technologies, markets, etc. is possessed by large companies, universities, and different research institutes. It is absorbed by SMEs using different types of channels. As mentioned above, in this paper transaction channel and intellectual channel are the two channels for external linkages. In addition, this paper hypothesizes a manager-based channel through which managers themselves produce ideas. This channel is the source of information internal to the company.

#### **(2) Internal innovation capability and R&D**

What bring acquired information to fruition as innovation are the company's innovation capability and R&D. The reason for separating the two factors is that the former indicates disparate basic capabilities within the company and the latter is an organizational capability. Also, as our research has focused on internal innovation capability, this paper is interested in its relationship to innovation. What is especially a topic of inquiry is the cause-and-effect relationship between innovation capability and R&D. In short, does internal innovation capability determine the level of R&D, or does internal innovation capability increase due to R&D? The previous research to date has not explicitly taken R&D into account. Therefore, our past studies have argued that information from external linkages improve the internal innovation capability (Tsuji et al, 2013b). In this model, this paper elucidates the causal relationship between internal innovation capability and R&D.

#### **(3) Innovation**

As an outcome variable, we use innovation by integrating both product innovation and process innovation. Although they should be isolated outcomes, integrating them is

necessary due to the limitations of SEM analysis, that is, a latent variable needs more than two observed variables.

The framework of analysis on the innovation process thus described is elucidated by the following Figure 1.

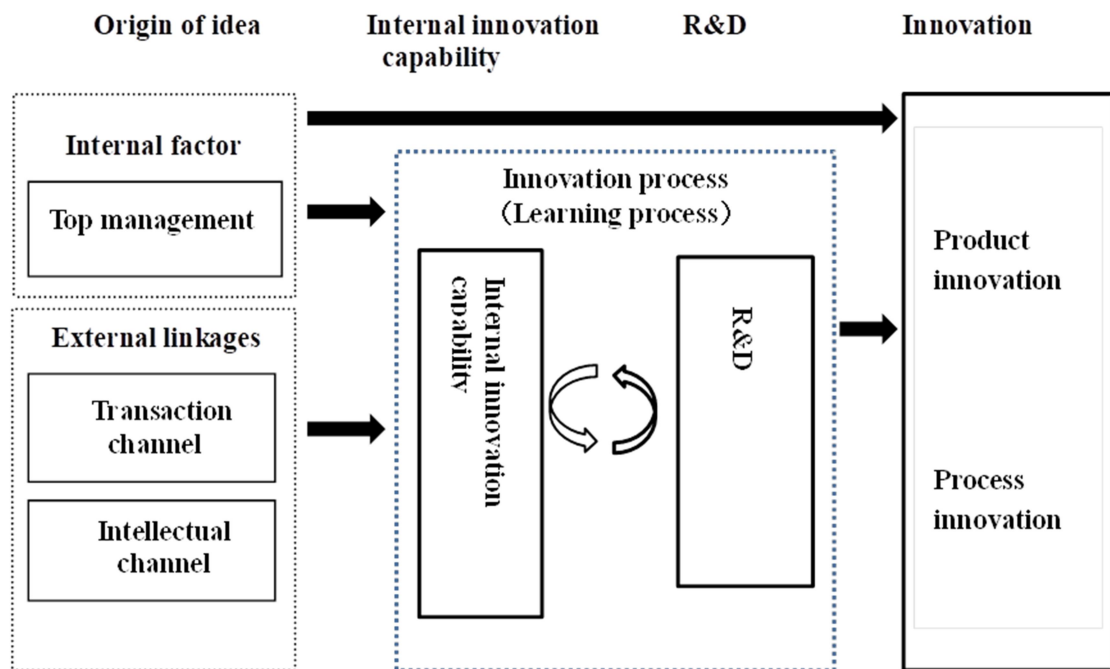


Figure1 Analytical framework of the innovation process

### 3.3 Establishment of hypotheses

From the model diagram shown in Figure 1, the following hypotheses to be tested are set forth. First, for manager-based innovation, it is assumed that in addition to producing direct innovation with technical abilities possessed by the manager himself or herself, the manager demonstrates leadership in the innovation-related organization within the firm. In such case, rather than expressing autocratic power, the manager's leadership has qualities such as nurturing the organization and personnel and coordinating between members and organizations. Such a style of leadership is called "servant leadership" (Greenleaf, 1977). The results of our onsite surveys included several managers who passionately discussed their own management philosophy and human resource development. For these reasons this paper establishes the following hypotheses with regard to managers.

**H1:** Top management creates innovations.

**H2:** Top management leads R&D and influence the organization and implementation of R&D.

This paper assumes two channels, the transaction channel and the intellectual channel, for external linkages, which are the sources of ideas for innovation. The following two hypotheses regarding the channels are posed:

**H3:** The transaction channel increases the internal innovation capability and R&D capability of SMEs.

**H4:** The intellectual channel increases the internal innovation capability and R&D capability of SMEs.

Next, incorporating the results of our research on internal innovation capability and R&D, this paper assumes that information from external linkages increases internal innovation capability, and, as a result, R&D is stimulated. The following hypotheses are set forth:

**H5:** Internal innovation capability stimulates R&D.

**H6:** R&D elevates innovation.

Finally, we integrate the above hypotheses and set forth the following hypothesis.

**H7:** External linkages promote innovation in SMEs.

The next section develops models to test these hypotheses.

## **4. Data and analytical model**

### **4.1 Questionnaire survey**

This model is based on the survey conducted in February 2012. In general, a survey is conducted to verify hypothesis, but the data already obtained was used, since the questionnaire is similar to verify the above hypotheses. The samples were selected as follows: From the lists of *Teikoku Data Bank*, 3,959 firms were selected from the manufacturing, construction, information and communications, and service industries. The criteria of the selection is that sample firms have to satisfy the following conditions: (i) unlisted; (ii) the number of employees is more than 20, (iii) earning positive profits in the recent three terms, that is, one year and half, and (iv) the amount

of sales is increasing. The reason of these limitations is to reduce the number of samples in the appropriate size. The total number of responses is 647, and the response rate is 16.2%. The summary statistics is shown in Table 2.

Table 2 Summary statistics

<b>Outcome Variables</b>					
<b>Innovation</b>	<b>N</b>	<b>Min</b>	<b>Max</b>	<b>Av</b>	<b>S.D.</b>
1. Presence of product innovation	637	0	1	0.67	0.47
2. Presence of process innovation	637	0	1	0.49	0.5
<b>Explanatory Variables</b>					
<b>Top management</b>					
7. The top manager voluntarily shows the idea and decides a new business.	641	1	5	3.71	0.990
8. The top manager takes leading to do new business.	641	1	5	3.89	0.964
5. Propose achievement goal for employees and follow that's outcome to reward.	642	1	5	3.78	0.955
4. Open management outcome to employees	642	1	5	4.10	1.028
3. Employees capability is up by job change.	629	1	5	3.20	1.079
1. Management seeks for short-run profits,	632	1	5	2.84	1.092
2. Management specialized in niche market.	607	1	5	3.21	1.235
6. Management specialized in special technology and product	643	1	5	3.59	1.146
<b>External linkages</b>					
Intellectual channel					
University	647	0	1	0.04	0.2
Public Organization	646	0	1	0.05	0.22
Transaction channel					
Suppliers	647	0	2	0.36	0.624
Customers	647	0	2	0.41	0.656
<b>Technology (Internal capability)</b>					
5. Received technical proposals from the other companies	624	1	5	2.79	1.11
7. Understanding the strong point of the partner, and collaborating in the field of the strong point each other	627	1	5	3.41	1.1
4. Offer own technology for other firms positively.	627	1	5	2.78	1.141
6. Analysis of product and technology data both own and other firms.	624	1	5	2.95	1.085
Owing original technology and development	640	1	5	3.58	0.914
The number of patents (for five years)	523	0	59	1.50	5.207
<b>R&amp;D organizational structure</b>					
1. Decision Making is speedy.	607	1	5	3.58	1.13
2. Give responsibility and authority to R&D department	606	1	5	3.52	1.098
3. Team members' discussion about the agenda each other freely.	606	1	5	3.36	1.066
8. New product and service development is discussed beyond the departments.	606	1	5	3.03	1.210
6. R&D member adopt from internal and external.	604	1	5	2.01	1.100
5. Competitive between R&D members	606	1	5	2.64	0.993
9. Allocate budget based on preference position.	605	1	5	2.77	1.125
10. R&D incentive and awards system	606	1	5	2.57	1.297
<b>R&amp;D implementation</b>					
3. R&D is directly connected to new product and service.	625	1	5	2.86	1.172

2. Basic research and R&D are coordinated.	625	1	5	2.72	1.113
1. The ideas of the new product and service often create in the firm.	627	1	5	3.14	1.136
4. Offer own technology for other firms positively.	627	1	5	2.78	1.141
Analysis of product and technology data both	624	1	5	2.95	1.085
Accept other firm's technological proposal.	626	1	5	3.40	1.142
7. Collaboration with alliance firms in common strong domain each other	627	1	5	3.41	1.100
9. Target market	624	1	5	2.79	1.110
8. Concentrated on main business, others are outsourcing.	625	1	5	2.93	1.125
10. Many idea is obtained by customers.	628	1	5	3.04	1.073
<b>Individual characteristics</b>					
Year of establishment	626	185	201	196	23.3
Capital (Log)		4	1	9	
The number of employees	638	2.3	11.1	7.85	1.02
The number of Patents (past five years)	621	1	600	50.6	51.4
The ratio of R&D to Sales	523	0	59	1.5	5.207
	478	0	70	2.6	5.2

## 4.2 Construction of variable

### (1) Outcome variable

We take the number of achieved innovation in the questionnaire as an outcome variable, namely respondents were asked whether they achieved innovation during 2006-2010. Particularly, QII.(1) asked whether they supplied new product or service to the market, while QII.(3) asked whether they introduced new production method or new method of marketing. The former is related to product innovation, and the latter is to process innovation. Firms were asked to reply "yes" or "no." The number of positive replies is taken as a variable. More than two-thirds replied "yes" for product innovation, while the more than half replied so for process innovation.

### (2) Top management

The ability of top management is not observable, and we asked questions related the nature of this ability, which consists of eight items. Each question requires replying the five-Likert scale from 5 to 1 point. Those are as follows:

QI.1. Management seeks for short-run profits

QI.2. Management specialized in niche market

QI.3. Employees capability is up by job change

QI.4. Open management outcome to employees

QI.5. Propose achievement goal for employees and follow that's outcome to reward

QI.6. Management specialized in special technology and product

QI.7. Top management voluntarily shows the idea and decides a new business

QI.8. Top management takes leading to do new business

By using all these questions, factor analysis of the Likelihood method is conducted. After the Varimax rotation, the result is shown in Table 4.3. Two questions such as “QI.7. Top management voluntarily shows the idea and decides a new business” and “QI.8. Top management takes leading to do new business” are extracted as significant. The latent variable regarding these is termed by “Top management.” These two observed variables coincide with what we learned from the in-depth interview. The average values of replies to questions 7 and 8 are 3.71 and 3.89, respectively, implying that they are greater than the average.

Table 3 Factor analysis for top management

Observation variables	factor 1	factor 2	factor 3	factor 4	communality
7. The top manager voluntarily shows the idea and decides a new business.	<b>0.897</b>	0.064	-0.006	0.137	0.828
8. The top manager takes leading to do new business.	<b>0.796</b>	0.097	0.012	0.162	0.669
5. Propose achievement goal for employees and follow that's outcome to reward.	0.111	0.993	-0.012	0.010	0.999
4. Open management outcome to employees	0.004	0.445	-0.035	0.177	0.230
3. Employees capability is raised by job rotation.	0.070	0.333	0.035	0.179	0.149
1. Management seeks for short-run profits,	0.003	-0.010	0.999	0.014	0.999
2. Management specialized in niche market.	0.087	0.137	0.034	0.688	0.502
6. Management specialized in special technology and product	0.256	0.252	-0.012	0.573	0.459
Variance	1.529	1.391	1.004	0.911	
Proportion	19.115	17.386	12.549	11.385	
Cumulative	19.115	36.501	49.050	60.435	

### (3) External linkages

QIV.(1) asked the sources of information related to innovation such as transaction partners, organizations, universities, and respondents are required to reply “yes” or “no.” If they replied “yes” to either buyer or seller, they are considered to obtain information from transaction partners, while if they relied positively to university or public research institutions, they obtained from the intellectual channel. In either case, the number of the positive replies is taken as a value of the variable.

### (4) Internal innovation capability (technology)

Internal innovation capability consists of various factors, but the numbers of replies of the questions related to those factors are small and significant variables were not extracted. Then we focus on questions related to technology, since it is closely related to innovation. Then QIII.(1), asking whether the following questions hold true to your firm, contains questions related to the technological level of firms, which are as follows:

QIII.1.4. Offer own technology for other firms positively

QIII.1.5. Received technical proposals from the other companies

QIII.1.6. Analysis of product and technology data both own and other firms.

QIII.1.7. Understanding the strong point of the partner, and collaborating in the field of the strong point each other

We also find other following questions related to technology:

Owing original technology and development

The number of patents (for five years)

We apply factor analysis to these questions by using the same method as before, and the result of factor analysis is shown in Table 4.

Table 4 Factor analysis for internal innovation capability (Technology)

Objective variables	factor 1	factor 2	Communality
5. Received technical proposals from the other firms	<b>0.849</b>	-0.258	0.598
7. Understanding the strong point of the partner, and collaborating in the field of the strong point each other	<b>0.545</b>	0.185	0.418
4. Offer own technology for other firms positively.	<b>0.488</b>	0.179	0.346
6. Analysis of product and technology data both own and other firms.	0.188	0.553	0.431
Owing original technology and development	-0.044	0.446	0.316
The number of patents (for five years)	-0.084	0.375	0.121
Variance	1.616	0.613	
Proportion	26.938	10.220	
Cumulative	26.938	37.158	

According to the result of factor analysis, one latent variable is extracted, which consists of “QIII.1.5 Received technical proposals from the other firms” and “QIII.1.7 Understanding the strong point of the partner, and collaborating in the field of the strong point each other.” The latent variable from these questions is referred to as

“Technology,” In particular; QIII.5 implies the possibility that SMEs with the high technical level may be engaged in collaboration with larger firms to which SMEs supply parts and components. This may correspond to SMEs of improvement type.

#### **(5) R&D characteristics**

R&D has two characteristics such as R&D organizational structure and R&D implementation, and let us discuss the former. R&D organizational structure was asked in question QIII.(2) to what extent the following items are true for your firm.

Questions are as follows:

QIII.2.1: Decision Making is speedy

QIII.2.2: Give responsibility and authority to R&D department

QIII.2.3: Team members' discussion about the agenda each other freely.

QIII.2.4: Competitive between R&D members

QIII.2.5: R&D member adopt from internal and external sections

QIII.2.6: New product and service development is discussed beyond the departments

QIII.2.7: Allocate budget based on preference position.

QIII.2.8: R&D incentive and awards system

To eight related questions, factor analysis is similarly applied, and the results are shown in Table 5. The first factor extracted contains QIII.2.1: Decision Making is speedy, QIII.2.2: Give responsibility and authority to R&D department, and QIII.2.3: Team members' discussion about the agenda each other freely. Particularly, question 2.2 is related to decentralization and autonomy of R&D units. From our field research, it is observed that the speed of decision making is a merit of SMEs. From these, it follows that the latent variable from these observation is referred to as “R&D structure”

Previous papers also discussed about autonomy and found autonomy as a variable to elevate innovation from Japanese data, whereas Argyres and Silverman (2004) and Lerner and Wulf (2007) claim that centralization in R&D organizations is better to pursuit innovation in terms of efficient allocation of resources and coping with shifts of technologies, markets, and other environments over R&D. This study supports the autonomy as a factor promoting innovation.

“QIII.2.3: Team members' discussion about the agenda each other freely” is related to another important nature of R&D, which is mutual understanding and



confidence among members in the process of the diffusion of information and knowledge, which is emphasized by Szulanski, Cappetta, and Jensen (2000), Leven and Cross (2004), and Colquitt and Rodell (2011).

Table 5 Factor analysis for R&D organizational structure

Objective Variables	Factor 1	Factor 2	communality
1. Decision Making is speedy	<b>0.968</b>	-0.194	0.680
2. Give responsibility and authority to R&D department	<b>0.956</b>	-0.056	0.832
3. Team members' discussion about the agenda each other freely.	<b>0.633</b>	0.330	0.838
8. New product and service development is discussed beyond the departments.	0.141	0.626	0.550
6. R&D member adopt from internal and external.	-0.154	0.544	0.187
5. Competitive between R&D members	0.026	0.653	0.453
9. Allocate budget based on preference position.	0.101	0.654	0.654
10. R&D incentive and awards system	-0.042	0.577	0.297
Variance	4.663	0.502	
Proportion	51.816	5.574	
Cumulative	51.816	57.391	

To identify another factor related to R&D, QIII.(1) is employed, which consists to the following ten questions on R&D performances and arrangements:

QIII.1.1: The ideas of the new product and service are often create inside the firm

QIII.1.2: Basic research and R&D are coordinated

QIII.1.3. R&D is directly connected to new product and service

QIII.1.4: Offer own technology for other firms positively

QIII.1.5: Accept other firm's technological proposals

QIII.1.6: Analysis of product and technology data both own and others firms

QIII.1.7: Collaboration with alliance firms in common strong domain each other

QIII.1.8: Concentrated on main business, others are outsourcing.

QIII.1.9: Target market

QIII.1.10: Many ideas are obtained by customers

Factor analysis is also applied for these questions, and results are summarized in Table 6. The first factor consists of "QIII.1.3. R&D is directly connected to new product and service," "QIII.1.2: Basic research and R&D are coordinated" and "QIII.1.1: The ideas of the new product and service often are create inside the firm." These factors indicate the direction and performance of R&D and accordingly the latent variables based on

these observed variables is referred to as “R&D implementation.” This variable, in other words, indicates whether actual R&D leads to achieve innovation, which is an essential question to R&D and various previous papers also analyzed (Leonard-Barton, 1988 ; Iansiti, 1998.). The organizational arrangement or environment to achieve “QIII.1.1: The ideas of the new product and service often are create inside the firm” has been analyzed widely (Sundgren et al., 2005).

Table 6 Factor analysis for R&D implementation

Objective Variables	Fact- or 1	Fact- or 2	Fact- or 3	Fact- or 4	Fact- or 5	Commu- nality
3. R&D is directly connected to new product and service.	<b>0.878</b>	0.163	0.209	0.052	0.092	0.1224
2. Basic research and R&D are coordinated.	<b>0.840</b>	0.138	0.245	0.103	0.044	0.1764
1. The ideas of the new product and service often create in the firm.	<b>0.571</b>	0.114	0.218	0.088	0.162	0.5652
4. Offer own technology for other firms positively.	0.173	0.970	0.125	0.104	0.027	0
6. Analysis of product and technology data both	0.302	0.135	0.936	0.084	0.079	0
5. Accept other firm’s technological proposal.	0.100	0.345	0.085	<b>0.537</b>	0.046	0.5695
7. Collaboration with alliance firms in common strong domain each other	0.111	0.249	0.299	<b>0.553</b>	0.158	0.504
9.Target market	0.154	0.024	0.152	0.087	0.674	0.4894
8. Concentrated on main business, others are outsourcing.	0.181	0.157	0.117	0.355	0.339	0.6709
10. Many idea is obtained by customers.	0.178	0.122	0.133	0.168	0.358	0.7601
Variance	2.037	1.241	1.107	0.797	0.770	
Proportion	0.331	0.202	0.194	0.128	0.125	
Cumulative	0.331	0.533	0.728	0.858	0.983	

## 5. Estimation of R&D model

### 5.1 R&D model

The model with additional internal innovation capability is termed by the R&D model. By this addition, the mode contains two sub-process related to internal innovation capabilities as well R&D, which leads to more detailed analysis of SMEs’ innovation process. The path diagram is expressed in Figure 3 and the estimation results of the direct effect are summarized in Table 7. The fitness of the model is shown in Table 8.

#### (1) Path diagram and standardized direct effect

R&D model adds one variable to the R&D model, which is the latent variable of “Technology,” which indicates firm’s technological ability to collaborate with external

linkages. As already explained, mother companies may not accept SMEs as subcontractors, if they do not own sufficient technological capability. Since all definition and contents of the latent variables are already explained, the remaining issues are an analytical interests related to the following: (i) the cause-and-effect relationship among the latent variables, namely it must be identified which variables are causes and which are results; and (ii) which latent variable initiates the while process, “Autonomy” is located first in the process, which shows it is the most important in the process. The path diagram and the estimation results of standardized direct effect are shown in Figure 2 and Table 11, respectively.

At first, the path diagram of the R&D model seems not to be different much, even if a new latent variable of technology is added. Interesting observations are as follows:

(i) Top management

Three paths from top management to two R&D latent variables and innovation are positively significant, implying that top management plays an essential role in the R&D model. This shows that these paths are reflected from the innovation of top management-type. The season why the path to “Technology” is not significant is clear. In this type of innovation, owner is also an engineer and he/she directly contributes innovation.

(ii) Transaction channel

The path from transaction partner is positively significant to “R&D structure,” but not so to “R&D implementation.” This implies that trough the transaction channel which is based on the supply chain, information related to constructing R&D units or the framework of R&D units in a concrete way is transferred to SMEs. This implies that this path seems to correspond to innovation of improvement-type.

(iii) Intellectual channel

The paths from University/research institutions which are positively significant are found to “Technology” as well as to “R&D implementation,” which are positively significant. This is a bit different from the transaction channel, implying that trough the intellectual channel, information related to cutting-edge technology affect directly not only to the level technology of SME but also to the orientation or direction of “R&D implementation.” The former is reasonable since SMEs can learn the latest technology from university laboratories, which elevate the technological ability and then change

the direction of R&D. Moreover, the path from University/research institutions provides indirect effect to “R&D structure” through technology indicating the level of technology determines the R&D organizational structure, namely higher the level of technology requires more sophisticated R&D units or the framework of R&D units correspondingly.

(iv) Causal relationship

The latent variable of technology is found to be the first among all latent variables due to the results of SEM. It is technology that SEMs have to elevate to connect with external linkages. This indicates that the level of technology is the most important, which leads to R&D. The causal relationship is not vice versa. This is the same results as our previous studies (Tsuji et al, 2013). This is also consistent with observations from our field research.

**(2) Fitness of model**

The fitness of the SEM model is shown in Table 10 which is determined by GFI (goodness-of-fit index) and AGFI (adjusted goodness-of-fit index) which take the value between 0 and 1 indicating criteria of the explanatory power of the model. If  $GFI \geq AGFI$  and both indices are 0.9 or more, the model can be judged as proper. CFI (comparative fit index) evaluates the model in terms of goodness-of-fit showing how much the model is improved in comparison with the independent model estimated under the assumption that there is no correlation among the observed variables. It takes the value from 0 to 1, and the model is judged as being good fit if CFI is 0.9 or more. Moreover, RMSEA (root mean square error of approximation) is an index that expresses the divergence between the estimated and actual distribution of the model expressed in terms of the amount of degrees of freedom. The model can be judged as good fitness, if it is 0.10 or less. The results show that GFI (0.946), AGFI (0.922), CFI (0.943), and RMSEA (0.058) satisfy all above conditions.

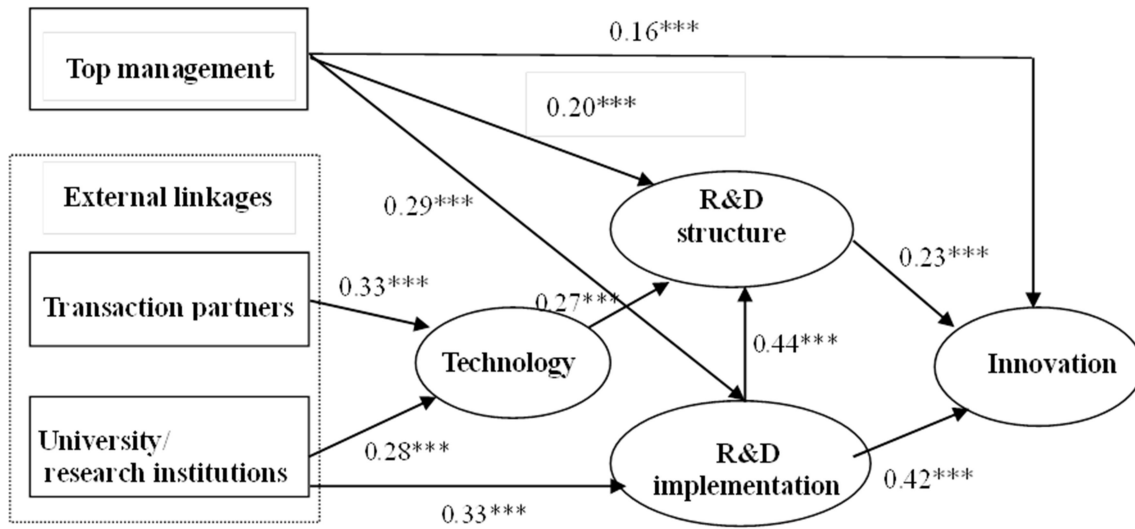


Figure 2 Path diagram of the R&D model

Table 7 Standardized direct effect (R&D model)

From	To	Standardizing Coefficient	SE	<i>t</i> -value	<i>p</i> -value
Top management	R&D structure	0.204***	0.047	4.951	0.001
Top management	R&D implementation	0.285***	0.040	6.074	0.001
Top management	innovation	0.158***	0.021	3.060	0.002
Transaction partner	technology	0.334***	0.288	2.735	0.006
University/ public research institution	technology	0.278***	0.744	3.170	0.002
University/ public research institution	R&D implementation	0.331***	0.618	3.583	0.001
Technology	R&D structure	0.270***	0.059	4.766	0.001
R&D structure	Innovation	0.228***	0.020	3.896	0.001
R&D implementation	R&D structure	0.442***	0.060	9.773	0.001
R&D implementation	innovation	0.418***	0.029	6.751	0.001

Table 8 Fitness of model (R&D model)

$\chi^2$ value	Degree of freedom	p value	GFI	AGFI	CFI	RMSEA	AIC
300.912	94	0	0.946	0.922	0.943	0.058	384.912

### (3) Total effect and verification of hypotheses

Table 9 and 10 show standardized indirect and total effects, which show all related paths are positively significant.

Regarding hypotheses stated earlier, all effects from top management and external linkages are positively significant, which demonstrate **H3** and **H4**. As explained earlier, technology activates two categories of R&D, implying **H5** is verified. Finally since two categories of R&D enhance innovation, this demonstrates **H6**. Accordingly, external linkages are verified to promote innovation, which **H7** is demonstrated.

Table 9 Standardized indirect effect of the (R&D model

To	From	Transaction partner	University/ public research institution	Top management	technology	R&D implimentation
R&D structure		0.090***	0.076***	0.204***	--	--
Innovation		0.21***	0.189***	0.352***	0.062***	0.519***

Table 10 Standardized total effect of the R&D model

To	From	Transaction partner	University/ public research institution	Top management	technology	R&D implementa- tion	R&D structure
technology		0.334***	0.278***	--	--	--	--
R&D implementation		--	0.331***	0.285***	--	--	--
R&D structure		0.090***	0.221***	0.330***	0.270***	0.442***	--
Innovation		0.21***	0.189***	0.352***	0.062***	0.519***	0.228***

## 6. Estimation of ICT model

### 6.1 ICT model

The purpose of the section is to examine the role of ICT in the innovation process, and ICT is one factor of internal innovation capability. In so doing, one more latent variable named ICT is introduced in the previous mode R&D model, which is referred to as the ICT model.

The questionnaire contains questions on ICT use related to innovation which were asked in QV.4. The questions used in this analysis are summarized as follows:

QV.4.2: ICT assists the advertisement of products

QV.4.3: ICT makes the speed of decision making faster

QV.4.4: ICT shortens the development period of new product

QV.4.5: ICT increases the number of new product and services development

QV.4.6: ICT makes it easy to obtain consumers' need

These questions required replying the five-Likert scale from 5 to 1 point and the data is summarized in Table 2. The method of constructing the latent variable related to ICT, instead of factor analysis, the SEM model can calculate it automatically in case the questions to use are already determined. The latent variable is termed by "ICT." Thus the ICT model expands the previous R&D model by adding one more latent variable. Accordingly, the purpose of the ICT model is to examine whether ICT contributes to SMEs' innovation and how ICT relates to other latent variables of the internal innovation capability, that is, the causality among the latent variables.

Since In this model, the roles of ICT with respect to the external linkages is emphasized, top management is not analyzed. Then the hypotheses to be verified are as follows:

**HICT1:** The transaction channel increases the internal innovation capability such as ICT and technology and R&D capability of SMEs.

**HICT2:** The intellectual channel increases the internal innovation capability such as ICT and technology and R&D capability of SMEs.

**HICT3:** Internal innovation capability such as ICT and technology stimulates R&D.

**HICT4:** R&D elevates innovation.

**HICT5:** External linkages promote innovation in SMEs

## **6.2 Estimation results**

Since the framework of the ICT model is basically the same as the previous model, and estimation results are summarized in Figure 3 and Table 11; the former shows the path diagram, while the latter the estimation results of the direct effect. The fitness of the model is shown in Table 12. Regarding the sources of ideas, top management is erased,

which are because of (i) emphasizing the roles of ICT in terms of connecting the external linkages through transaction and intellectual channels, (ii) comparing the results of the R&D model, and (iii) maintaining the simplicity of analysis.

Form the results, the following characteristics of the roles of ICT in the innovation process are observed.

### **(1) Roles of ICT use**

Basic results are similar to as the previous model regarding the latent variables used in the previous model. Great changes are found paths from ICT to all other latent variables such as Technology, R&D structure, R&D implementation, and Innovation, implying that ICT plays important roles in the innovation process. It should be noted that ICT directly promotes innovation. Though ICT, SMEs obtain information on innovation from the external linkages. Particularly, ICT is located first in the innovation process, which indicates it is an origin affecting to other factor of innovation. In this sense, ICT is the most important in the internal innovation capability.

### **(2) Connectivity**

There are two paths from external linkages to ICT which affect other latent variables, which is already mentioned. This indicates that in addition to the paths from the external linkages identified in the R&D model, SMEs own other routs which connect to external linkages. It is reasonable for ICT to create new tools for the external linkages. However, there is one difference in the paths of the R&D model; the path from University/research institution to Technology cannot be found. On the other hand, a new path from Technology to R&D implementation appears. That is, ICT takes over the direct channel from University/research institution to Technology but it creates a new path indirectly connect from University/research institution to R&D implementation.



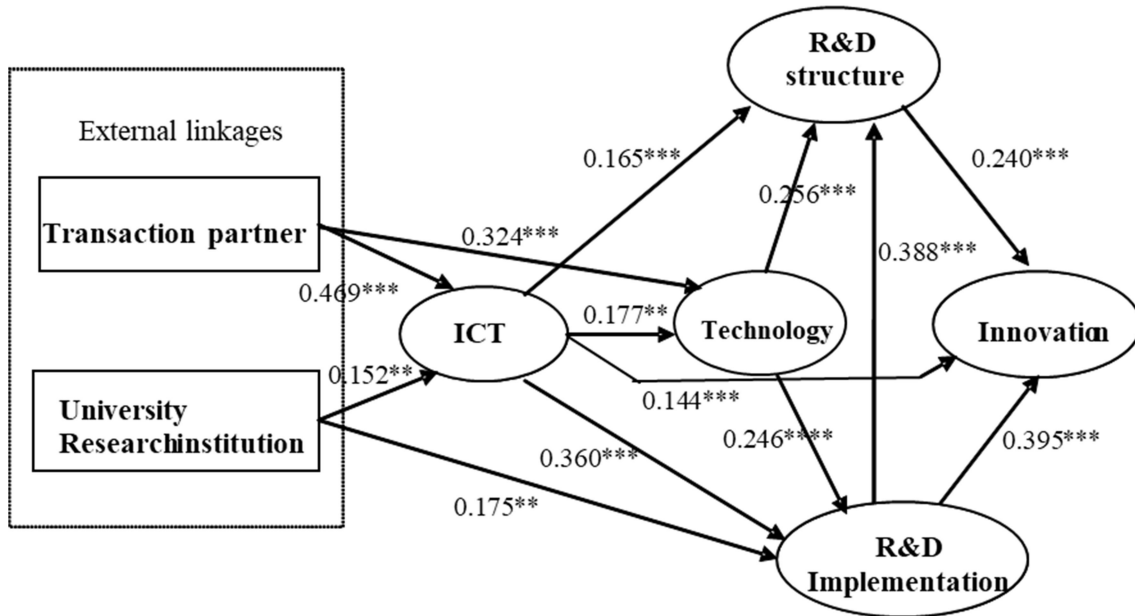


Figure 3 Path diagram of the ICT model

Table 11 Standardized direct effect (ICT model)

From	To	Standardizing Coefficient	SE	t-value	p-value
Transaction partner	ICT	0.469***	0.225	4.468	0.000
Transaction partner	Technology	0.324***	0.296	2.882	0.004
University/research institution	ICT	0.152**	0.416	2.085	0.037
University/research institution	Technology	0.130	0.564	1.613	0.107
University/research institution	R&D implementation	0.175**	0.446	2.377	0.017
ICT	Technology	0.177**	0.092	2.343	0.019
ICT	R&D implementation	0.360***	0.056	6.848	0.000
ICT	R&D structure	0.165***	0.065	3.651	0.000
ICT	Innovation	0.144***	0.027	2.577	0.010
Technology	R&D implementation	0.246***	0.051	4.200	0.000
Technology	R&D structure	0.256***	0.068	4.458	0.000
R&D implementation	R&D structure	0.388***	0.068	7.823	0.000
R&D implementation	Innovation	0.395***	0.030	5.966	0.000
R&D structure	Innovation	0.240***	0.020	3.938	0.000

Note: \*\*\*, \*\*, and \* indicate the significance level of 1, 5, 10%, respectively.

### 6.3 Fitness of the ICT model

The test statistics of the fitness of the model is shown in Table 12 implying all tests are satisfied as well.

Table 12 Fitness of the ICT model

$\chi^2$ value	Degree of freedom	p value	GFI	AGFI	CFI	RMSEA	AIC
382.522	137	0.000	0.945	0.925	0.947	0.052	484.522

### 6.4 Total effect and verification of hypothesis

Again the standardizing indirect effect and total effects are shown in Table 13 and 14, respectively. All latent variables are positively significant to innovation in which ICT has the second largest coefficient next to R&D implementation.

Table 13 Standardizing indirect effect

to	From	Transaction partner	University/research institute	ICT	Technology	R&D implementation
Technology		0.083***	0.027***	--	--	--
R&D implementation		0.269***	0.093***	0.044***	--	--
R&D structure		0.286***	0.169***	0.202***	0.095***	--
Innovation		0.242***	0.168***	0.247***	0.186***	0.093***

Standardizing total effect

to	From	Transaction partner	University/research institute	ICT	Technology	R&D implementation	R&D structure
ICT		0.469***	0.152**	--	--	--	--
Technology		0.407***	0.157***	0.177***	--	--	--
R&D implementation		0.269***	0.268***	0.404***	0.246***	--	--
R&D structure		0.286***	0.169***	0.366***	0.352***	0.388***	--
Innovation		0.242***	0.168***	0.391***	0.182***	0.488***	0.240***

Regarding hypothesis, since the transaction and intellectual channels have positively significant paths to ICT and R&D, this demonstrates **HICT1** and **HICT2**. The paths from ICT and technology have positively significant to two R&D latent variables, implying **HICT3** is verified. Two latent variables related to R&D are

positively significant to Innovation, which indicated that R&D elevates innovation and then satisfies **HICT4**. Finally, from these it follows that external linkage enhances innovation, which demonstrates **HICT5**.

## **7. Discussion**

This paper studies thus far using two models how SMEs obtain information outside the firm, integrate it with domestic resources they own, and achieve innovation. In two models, the hypotheses proposed are verified. Here in this section, by comparing the conclusions obtained in this paper with those of previous papers, we clarify characteristics of the models. First, regarding top management-type of innovation, the conclusions we obtained are similar to those of our previous studies and other literature. Since Schumpeter, innovators who are full of venture spirit take risks and challenge to innovation are prerequisite for the theory of innovation. This study, on the other hand, does not assume these managers, but we attempt to extract from data the role of top management in the innovation process as innovators. Second, this study demonstrates that, in two channels such as transaction and intellectual, R&D's contents and effects to innovation are different. In particular, from the transaction channel, the autonomy of R&D organizations and mutual understanding and confidence among related engineers in SMEs are found important, whereas in the intellectual channel, the level of technology and R&D orientation or implementation are essential. The connectivity to external linkages is similar to results obtained by other studies (Dyer and Nobeoka, 2000; Todo, Matous, and Inoue, 2016; Tsuji et al, 2016a). However, this study is a bit different from others in the context organization and structure to achieve better performances. Some of the variables listed in the questions shown in Table 4.5 are not significant, which are summarized as follows:

QIII.2.4: Competition among R&D members

QIII.2.5; R&D members are selected from internal and external sections

QIII.2.6: New product and service development is discussed beyond the departments

QIII.2.7: Allocate budget based on preferences

QIII.2.8: R&D incentive and awards system

Other studies emphasized cross-functional teams as well as QC (Tsuji et al., 2013a, 2016a, 2016b), Award scheme to provide incentives (Lerner and Wulf, 2007), employment scheme such as job rotations, promotion, and wages and salaries (Haneda and Ito, 2016). These differences are considered due to the framework of this study such that R&D is examined in the whole process of innovation from the origins of ideas to the final outcome of innovation. On the other hand, others focused and emphasized particular or individual issues. It is required for us to enhance questionnaire or analytical tools.

In the R&D model, it is technology that absorbs new information owned by external linkages, and technology in the context is one of internal innovation capability. In this sense, innovation is achieved by absorbing new information and transforming it to knowledge by R&D and sharing among members. R&D does not necessarily enhance technology. Thus this study demonstrates that our fundamental causality in the innovation process such as external linkages  $\rightarrow$  internal innovation capability  $\rightarrow$  R&D  $\rightarrow$  innovation is still valid. In two channels, the level of technology as an internal innovation capability is essential and with absorptive capability SMEs can obtain new information (Cohen and Levinthal, 1990; Tsuji et al. 2013a, 2016a; Tomita, 2015).

## **7. Conclusion**

The characteristics of this paper lie in the facts that based on our field research, the models are constructed to verify how actual innovation and R&D are conducted in SMEs and what essential factors for achieving them are. This study classifies innovation models into three types such as top management, improvement, and development and discusses how these three types are different in one model. As a result, we obtain some different results from those of previous papers.

This study, however, owns some limitations which are solved by future analysis. Those are as follows: (i) this paper cannot identify gate keepers or transformers which previous papers aimed to identify; (ii) further studies have to focus on the transforming information to knowledge, bridging the technology and market, combining basic and applied R&D, and nurturing human resources to contribute to these.

Another requirement for further study should be focused on policy, which is not discussed here in detail. Our in-depth interviews found that instead of large amount of subsidies, SMEs want small subsidies to support for investment in new fields or for exhibitions in the trade shows. SMEs of development-type tend to own specific technologies, but due to human power and financial capability they cannot advertise their technologies to other firms, nor expand their technologies. To exhibit their products and technologies in trade shows or exhibitions are good opportunities for them. There must be some policy measures to cope with this and the accumulation of basic research would solve the issues.

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