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Abstract

The innovation by an independence principle is a limit in Japanese firm today. The expectation for the open innovation that positively uses outside resources on business has risen in Japanese firm. In open innovation, the strategy that expands sharing information and using the resource from supplier to customer for the innovation is needed. Therefore, the use of ICT is indispensable for the promotion of the open innovation. In this paper, we discussed how to utilize ICTs for open innovation activities in order to achieve more effective innovation outcomes in Japanese Medium-sized Enterprises. We conducted a mail survey for Japanese Medium-sized Enterprises in industries such as manufacturing, construction, and information and telecommunication in January 2010. Based on their replies, we applied the some logistic regression analyses. As results, the following points are clarified. Firms which achieve open innovation are enhancing the innovation by cooperating and exchanging information with the following entities: (i) affiliate companies which have the excellent technological knowhow; (ii) customers which locate inside or outside of the region; and (iii) firms in the same industry inside of the same region. The firms cultivate mutual trust for a long time and jointly develop frequently the new products and services. And they have frequently exchanged the customer needs, new release information of the rival companies and a high-tech trend with each other. They use CTI and SCM to use information and knowledge for designing and developing a new product and service. Moreover, it can be confirmed that the firm which top management is familiar with ICT and exercises the leadership for ICT use. In addition, the firm not only introduced ICT but also reformed organizational structures, systems, and company's rules at the same time. These analysis results will provide useful suggestions for SMEs to practice open innovation in the future.

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Open Innovation, ICT, Japanese firms
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Open Innovation Success Factors by ICT Use in Japanese Firms

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1. INTRODUCTION

Due to the long recession and the maturation of markets, business environments surrounding Japanese firms become severer and severer. Firms have been struggling in these circumstances by creating innovations such as developing new products and services, finding new markets, and improving the efficiency of business processes. Until now, Japanese firms are successful in the formation of innovation by the "independence principle" by accumulating knowledge and knowhow for innovation within own firm or within group firms. Innovation carried out by the independence principle in Japanese firm now faces the limit. Successful cases of innovation seem to be open innovation by collaborating other firms and organizations, which are initiated by Europe and America firms (Chesbrough, 2003, 2006a, 2006b). Japanese firms now expect further analysis and development of open innovation which use positively managerial and innovation resources outside a firm. In particular, there are some small and medium-sized enterprises (SMEs) that try to find their ways to an open innovation with the firms which they do not have the capital tie-up, since the subcontract system built by large firms has been collapsing.

Chesbrough (2006a, p.1) asserted that open innovation was the purposive use of inflows and outflows of knowledge to accelerate internal innovation and to expand markets for the external use of innovation. That is, it is to enhance new innovation by absorbing outside knowledge and combining it with internal one, and to create new excellent business models by collaborating with entities outside of a firm. In this case, the strategy sharing information and using resources with all firms from suppliers to customers is required. The use of ICT (Information Communication and Technology) is, therefore, indispensable for the promotion of open innovation (Gassmann and von Zedtwitz, 2003; Dogson et al., 2006; Piller and Walcher, 2006; Dittrich and Duysters, 2007).

ICT has been focused on as a tool that improves the productivity of firms (Brynjolfsson and Hitt, 1996; Lehr and Lichtenberg, 1999; Boyton et al., 1994;

Brynjolfsson and Hitt, 1998; Brynjolfsson et al., 2002), and it achieves innovation activities (Thomke, 1998a, 1998b, 2003; Debackere, 1999; Henderson, 1999; Schrage, 1999; von Hippel, 2001; Debackere and Van Looy, 2003; D'Adderio, 2004). ICT is viewed as effective tools for Innovation (Bunno et al., 2009; Lee & Xia, 2006; Dogson et al., 2006). However, it was not clarified what kind of ICT use was useful for open innovation activity and how to use ICT for it. The ICT use of Japanese SMEs is said to be poor compared with large firms (Small and Medium Enterprise Agency, 2008). It seems to be useful to construct indicators of SMEs' ICT use that contribute to practice open innovation.

This paper focuses on ICT use of Japanese SMEs for in open innovation activities and attempts to clarify the effectiveness of their ICT use to open innovation by a quantitative analysis. Due to the number of observation, some estimation do not show good results, and in Appendix in order to identify significant variables, the analysis used stepwise estimation will be presented.

2. SURVEY OF PREVIOUS RESEARCHES OF ICT USE AND INNOVATION

According to a survey analysis of Japanese SMEs (e.g. Bunno et al., 2009) to identify factors affecting the successful implementation of ICT in businesses and to make policy recommendations, there is a clear discrepancy between SMEs with successful ICT use and those without in terms of their performances, obstacles, and desire for policy makers. In particular, SMEs with advanced ICT use recognize their success lied in their capability to make full use of ICT inside a firm, which is referred to as "ICT capability". The survey was, however, based on a assumption that ICT is indispensable for innovation, and accordingly it did not analyze the relevancy between innovation activities and the utilization of ICT. The issue how ICT plays an important role in the innovation process is not fully analyzed yet.

The authors also conducted an extensive mail survey to 5,000 SMEs which were authorized by the Act for Promotion of New Business by SMEs as "innovative" from October to November 2007. As a result, their ICT use was confirmed for process innovation. However, details were not analyzed.

Lee and Xia (2006) analyzed the relationship between organization size and ICT innovation through a meta-analysis of 54 correlations derived from 21 empirical studies. They categorized the following three types of the innovation: (i) innovation of new ICT products and service that was developed or bought based on users' needs; (ii) new process innovation by using ICT; and (iii) mixture of these two achieved at the same

time. The following two points were clarified from their analysis: (i) process innovation and mixture type was more related to firm size than ICT innovation; and (ii) the relationship between organization size and ICT innovation in profit organizations was more significant than that in nonprofit organization. However, this research did not clarify how ICT use was effective to innovation.

As for the relationship between open innovation and ICT use, Dogson et al. (2006) clarified the following points from the case study of the Procter and Gamble Co.: (i) ICTs support communications for open innovation in the community or between communities; and (ii) ICTs such as data mining, simulation, design of prototype and a virtual system are useful for supporting open innovation. Their research, however, is a case study of one leading enterprise, and thus they did not conduct general quantitative analysis.

This paper attempts to examine the effectiveness of ICT use in open innovation activities by identifying success factors in this process.

3. RESEARCH METHOD

3.1. Data-set

This study is based on a mail survey conducted to 2,260 Japanese unlisted companies in industries such as manufacturing, construction, and information and telecommunication in January 2010. This survey targeted unlisted firms which were found in "*Japan Company Handbook (The Kaisha Shikiho) the Unlisted Company in Second Half of 2009*" (Toyokeiza, 2009) published by Toyokeizaishinpo, particularly those listed here were thought as actively engaging innovation activities. The number of valid responses is 152 (6.7%). The analysis covers three years from 2005 to 2008.

Let us summarize results of mail survey shown in Table 1 in what follows. Responding firms has rather long history: firms with over 51 years operation are 67 (44.1%). Approximately two-third of firms (100; 65.8%) has capital less than 300 million yen. The number of employee with less than 300 is 109 (71.8%). The majority of respondents is thus small-sized firms. Regarding to industry, 98 (63.2%) belongs to manufacturing, 25 (16.1%) information and telecommunication companies, 19 (12.3%) construction companies, and 13 (8.4%) others (see Table 1).

Product Innovation is categorized by types such as "original innovation" and "open innovations"; the former is created by its own effort, while the latter by collaborating with other firms. 119 (78.3%) of respondents experienced product innovation, and this percentage seems to be high. But it is reasonable, since respondents firms are thought to

be innovative. Moreover, the percentage of firms achieved original innovation is 88 (73.9%); while open innovation is 71(59.7%) (multiple answers are permitted).

3.2. Analytical method and results of estimations

In order to analyze the relevancy between ICT use and innovation based on the above data, the logistic regression analysis is adopted by taking the number of innovation in 2005-2008 as a dependant variable and by taking firm's characteristics, hardware, software, internet use, success factors of ICT use as explanatory variables. Firm's characteristics consist of "Years of operation," "Capital" and "Industry dummy data: Manufacturing". "Years of operation" and "Capital" are converted into the logarithm. Hardware is used as "Number of PC per employee," while software is categorized as "Sales Management System," "Manufacture Management System," "CTI (Computer Telephony Integration)" and "SCM (Supply Chain Management)". Internet use consists of "Information exchange with customers," "Information exchange with group companies" and "B2C (Business to Consumer)". And "Success factors of ICT use" contain "Executives clarified business policy," "Executives were familiar with ICT," " ICT personnel exercised the leadership for ICT use" and "When ICT was introduced, we reformed organizational structures, systems, and company's rules".

Table 1. Summary statistics

		Freq.	%
Years of operation	51years over	67	44.1
	31-50years	36	23.7
	21-30years	27	17.8
	11-20years	14	9.2
	less than 10years	8	5.3
Capital (million yen)	less than 50	43	28.3
	51- 100	32	21.1
	101-300	25	16.4
	301-500	25	16.4
	501 over	27	17.8
The number of employees	less than 50	38	25.0
	51-100	20	13.2
	101-200	23	15.1
	201-300	28	18.4
	301-500	25	16.4
	501over	18	11.8
Industries (multiple answers)	manufacturing	98	63.2
	construction	19	12.3
	information and telecommunication	25	16.1
	others	13	8.4

Table 2 indicates the results of estimations of ICT utilization and open innovation and shows estimation results of open innovation; “Years of operation,” “CTI,” “SCM” and “Information exchange with group companies” become positively significant. “Number of PC per employee” becomes negatively significant. “Executives clarified business policy,” “Executives were familiar with ICT” and “When ICT was introduced, we reformed organizational structures, systems, and company’s rules” are positively significant, while “ICT personnel exercised the leadership for ICT use” becomes negatively significant.

Table 2. The result of analysis of ICT use and open innovation

		Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
Firm's characteristics	ln (years of operation)	27.846	14.950	1.86	0.063	*	6.949
	ln (capital)	-0.013	0.167	-0.08	0.938		-0.003
	Manufacturing	0.636	0.568	1.12	0.263		0.157
Hardware	Number of PC per employee	-0.862	0.446	-1.93	0.053	*	-0.215
Software	Sales Management System	-0.363	0.499	-0.73	0.467		-0.090
	Manufacture Management System	0.186	0.506	0.37	0.713		0.046
	CTI	2.456	1.239	1.98	0.047	**	0.454
	SCM	1.878	1.060	1.77	0.076	*	0.393
Network	Information exchange with customers	0.473	0.545	0.87	0.385		0.116
	Information exchange with group companies	0.836	0.447	1.87	0.061	*	0.206
	B2C	-0.777	0.697	-1.11	0.265		-0.185
Success factors of ICT use	Executives clarified business policy	0.599	0.294	2.04	0.041	**	0.149
	Executives were familiar with ICT.	0.718	0.310	2.32	0.02	**	0.179
	ICT personnel exercised the leadership for ICT use.	-0.786	0.346	-2.27	0.023	**	-0.196
	When ICT was introduced, we reformed organizational structures, systems, and company’s rules.	0.446	0.248	1.8	0.072	*	0.111
	Constant	-214.308	114.085	-1.88	0.06	*	
	Log likelihood			-73.062			
	Number of obs.			135			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

In case of software use, the marginal effect of “CTI” and “SCM” in the open innovation model is large. From this result, it follows that ICTs are more necessary for the cooperation among other firms for open innovation. Because information exchange with affiliated companies is more effective than with customers, this verifies that information exchange among group firms is more active and a traditional feature of the

Japanese firm system still exists even in the age of the information society. Moreover, it can be confirmed that firms, in which top managers are familiar with ICT and do not leave the leadership to ICT person, achieve more open innovation with ICT use. In addition, it is important that firms not only introduce ICT but also reform organizational structures, business processes and related rules at the same time.

3.3. Results of estimations

In Table 3, the estimation result of the models with management characteristics and business environments added to explanatory variables are presented, being termed by the full model. Management characteristics are classified as “There are other sections in which the development of new products can be examined” and “Basic R&D is important”. And Business environments consist of “Many researchers and engineers enter and leave your company,” “Many venture businesses with good technology and knowhow exist in this area” and “Many group companies have distinguished technologies and knowhow”. The logistic regression analysis is applied to verify the hypotheses mentioned earlier.

In case of open innovation, Table 3 indicates that variables including “Years of operation,” “There are other sections in which the development of new products can be examined,” “Many venture businesses with good technology and knowhow exist in this area,” “CTI,” “Information exchange with group companies” and “Executives were familiar with ICT” become positively significant. “Number of PC per employee” and “ICT personnel exercised the leadership for ICT use” are negatively significant.

Similar to the results obtained in the previous analysis, it can be confirmed that variables such as “The firms with long years in business,” “ICTs are important for the cooperation among other firms” and “Top managers exercise the leadership for ICT use, without leaving the ICT person in charge” contribute to open innovation using ICT.

These results can be interpreted in the following way; firms with successful open innovation have many good group companies and venture companies with specific technology and knowhow. In addition, they are not good at basic R&D, but at application of technology, while “Information exchange with group companies” which is significant in the previous analysis becomes also significant in Table 3.

4. RELATIONSHIP WITH PARTNERS OF OPEN INNOVATION

Here, the following two points are clarified: (i) relationship between middle-sized firms and partners which cooperate to enhance open innovation; and (ii) whether ICTs

are useful tools for communication with partners or not. Similar to the previous analysis, the logistic regression model is also adopted by taking the number of innovation in 2005-2008 as an objective variable and taking type of partners as one of explanatory variables (see Table4, 5, 6, 7).

Table 3. The result of analysis of open Innovation

		Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
Firm's characteristics	ln (years of operation)	43.872	21.005	2.09	0.037	**	10.715
	ln (capital)	0.073	0.204	0.36	0.719		0.018
	Manufacturing	0.830	0.671	1.24	0.216		0.196
Management characteristics	There are other sections in which the development of new products can be examined.	0.833	0.281	2.96	0.003	***	0.203
	Basic R&D is important.	-0.277	0.267	-1.04	0.3		-0.068
Business environment	Many researchers and engineers enter and leave your company.	0.281	0.262	1.07	0.283		0.069
	Many venture businesses with good technology and knowhow exist in this area.	0.542	0.275	1.97	0.049	**	0.132
	Many group companies have distinguished technologies and knowhow.	0.339	0.247	1.37	0.17		0.083
Hardware	Number of PC per employee	-1.344	0.574	-2.34	0.019	**	-0.328
Software	Sales Management System	-0.448	0.634	-0.71	0.48		-0.110
	Manufacture Management System	0.295	0.607	0.49	0.627		0.072
	CTI	2.516	1.365	1.84	0.065	*	0.494
	SCM	1.069	1.228	0.87	0.384		0.259
Network	Information exchange with customers	0.188	0.631	0.3	0.765		0.046
	Information exchange with group companies	1.347	0.592	2.27	0.023	**	0.324
	B2C	-1.098	0.790	-1.39	0.164		-0.238
Success factors of ICT use	Executives clarified business policy	0.426	0.343	1.24	0.213		0.104
	Executives were familiar with ICT.	0.675	0.351	1.92	0.054	*	0.165
	ICT personnel exercised the leadership for ICT use.	-1.069	0.419	-2.55	0.011	**	-0.261
	When ICT was introduced, we reformed organizational structures, systems, and company's rules.	0.521	0.321	1.62	0.105		0.127
	Constant	-340.627	159.994	-2.13	0.033	**	
	Log likelihood			-58.500			
	Number of obs.			132			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

4.1. Partners of Open Innovation

First of all, “Type of partners” is added to an explanatory variable in this logistic regression model. Types of partners are categorized as “Customer inside of a region,” “Customer outside of a region,” “Same trade company in region” and “Mother company or subsidiary company”. Top three items were asked from these; three points were provided to the first item, two points to second place, and one point to the third place. Table 4 indicates the results of estimations.

This estimation reveals that variables such as “Customer in region,” “Customer outside region,” “Same trade company in region” and “Mother company or subsidiary company” become positively significant. From these results, the following three assertions are also confirmed: (i) firms practice innovation which meets customers’ needs; (ii) firms execute the innovation in cooperation with other firms in the region; and (iii) firms execute the innovation in cooperation with mother or subsidiary companies.

Table 4. Partners of open innovation

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln (years of operation)	16.513	11.282	1.46	0.143		4.113
ln (capital)	0.216	0.141	1.54	0.124		0.054
Manufacturing	0.102	0.415	0.24	0.807		0.025
Customer in region	0.557	0.200	2.79	0.005	***	0.139
Customer outside region	0.424	0.175	2.42	0.016	**	0.106
Same trade company in region	0.914	0.518	1.76	0.078	*	0.228
Mother company or subsidiary company	0.371	0.198	1.87	0.061	*	0.092
Constant	-130.172	86.357	-1.51	0.132		
Log likelihood			-88.847			
Number of obs.			151			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

Next, the relationship with partners is analyzed; that is, we attempt to confirm whether they cooperate with each other because they are members of some specific business association, they are transaction partners or they have mutual capital-ties. In so doing, “Strength of connection with partners” is selected as the explanatory variable in the logistic regression model. As for explain variables, we choose the following questions: “Longtime customer,” “Capital tie-up and making to subsidiary company,” “R&D tie-up by contract” and “Consortium member”. As a result of estimation, “Longtime customer” becomes positively significant.

The following assertion is also confirmed as a result. Longtime customer has mutual trust with each other and becomes a partner for an open innovation. It turns out that the customer who has a long-term relationship is preferable as a partner of open innovation.

4.2. Frequency, distance and means of communication with partners

"Frequent development with partners," "Distance (travel time in car)" and "Means of communication" are added to the explanatory variable and analyze the logistic regression analysis again. As for means of communication, firms were asked to select items from "Face-to-face," "Phone," "E-mail," "Tele-conferencing," "Blog and SNS" and "Other". Top three choices were answered from these, and again three points were provided to the first place, two points to the second place, and one point to the third 3rd place. However, because the number of answers was too small, "Tele-conferencing," "Blog and SNS" and "Other" are excluded from the analysis. Table 6 indicates the results of estimation. "Frequent development with partners" becomes positively significant.

The following point becomes clear. Firm which executes open innovation shows a tendency to engage in R&D frequently with partners.

4.3. Information exchange with open innovation partners

Here, what kind of information is exchanged among partners for open innovation is identified. "Type of information" is added to the explanatory variable in the logistic regression model. Types of information contain "Customer needs," "New release information of the rival companies," "High-tech trend" and "Production management information".

Table 7 indicates four types of information become positively significant; namely, "Customer needs," "New release information of the rival companies" and "High-tech trend".

The following points are clarified from the result: (i) in the market, the firm tries to develop a new product and service with the competitive advantage by knowing rivals' information of new products and the customer needs; (ii) firm tries to know the trend of high technology and to attempt to catch up with the trend.

Table 5. Strength of Connection with Partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	14.414	11.487	1.25	0.21		3.404
ln(capital)	0.142	0.179	0.79	0.428		0.034
Manufacturing	0.106	0.498	0.21	0.832		0.025
Longtime customer	0.845	0.492	1.72	0.086	*	0.202
Capital tie-up and making to subsidiary company	1.005	0.742	1.35	0.176		0.209
Consortium member	1.527	1.151	1.33	0.185		0.276
Constant	-112.279	87.850	-1.28	0.201		
Log likelihood			-59.202			
Number of obs.			95			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

Table 6. Frequency, Distance, and Means of Communication with Partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	14.961	10.980	1.36	0.173		3.560
ln(capital)	0.104	0.180	0.58	0.562		0.025
Manufacturing	-0.105	0.527	-0.2	0.842		-0.025
Frequency of development with partners	0.579	0.259	2.24	0.025	**	0.138
Distance (travel time in car)	0.169	0.134	1.26	0.207		0.040
Face-to-face	0.083	0.273	0.3	0.763		0.020
Phone	-0.200	0.268	-0.75	0.455		-0.048
E-mail	0.334	0.263	1.27	0.205		0.079
Constant	-117.264	83.799	-1.4	0.162		
Log likelihood			-59.119			
Number of obs.			97			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

Table 7 Information exchange with partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln (years of operation)	13.231	12.859	1.03	0.304		3.027
ln (capital)	0.246	0.196	1.25	0.21		0.056
Manufacturing	0.202	0.569	0.35	0.723		0.047
Customer needs	1.499	0.547	2.74	0.006	***	0.348
New release information of the rival companies	1.600	0.625	2.56	0.01	**	0.319
High-tech trend	1.228	0.585	2.1	0.036	**	0.253
Production management information	1.001	0.758	1.32	0.187		0.201
Constant	-106.477	98.093	-1.09	0.278		
Log likelihood			-52.126			
Number of obs.			98			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

5. **DISCUSSIONS AND CONCLUSIONS**

It is important to analyze ICT use which is one of factor to enhance open innovation. The following points are clarified from the result of this research. Firms which achieve open innovation are enhancing the innovation by cooperating and exchanging information with the following entities: (i) affiliate companies which have the excellent technological knowhow; (ii) customers which locate inside or outside of the region; and (iii) firms in the same industry inside of the same region. The firms cultivate mutual trust for a long time and jointly develop frequently the new products and services. And they have frequently exchanged the customer needs, new release information of the rival companies and a high-tech trend with each other. They use CTI and SCM to use information and knowledge for designing and developing a new product and service.

Moreover, it can be confirmed that the firm which top management is familiar with ICT and exercises the leadership for ICT use, without leaving the ICT person in charge, practices open innovation with ICT use. In addition, the firm not only introduced ICT but also reformed organizational structures, systems, and company's rules at the same time. These analysis results will provide useful suggestions for SMEs to practice open innovation in the future.

Open innovation has gradually been performing among Japanese firm. However, there are a lot of problems to be solved before it becomes popular, as Itami (2009) mentioned. The problems can be summarized as follows: (i) whether open cooperation can be built; (ii) whether cooperation among organizations can be built; (iii) who bears costs for building cooperation; and (iv) whether mutual trust can be built.

The results obtained in this paper show that Japanese firms find their group firms as partners for open innovation. This is the exactly the same as competitiveness of Japanese firms in the age of manufacturing in the 1980s, which is quite earlier than the age of information society. This implies Japanese firms do not fully exploit benefits of open innovation yet, but this does not reflect that Japanese firms are developing, since open innovation is achieved by collaborating together and combining strength in technology and business system of all firms. This is not the same as Japanese firms have been seeking in such as way to cultivate trust among group firms for the long term. This paper also verifies this importance and shows the direction to transform.

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APPENDIX: Stepwise Estimation

1. Results of estimations

In the first estimation, the stepwise logistic regression analysis is used to select the significant variables. The number of innovation in 2005-2008 is taken a dependant variable, while questions related to firm's characteristics, hardware, software, internet use, success factors of ICT use as explanatory variables, that is, firm's characteristics are "Years of operation," "Capital" and "Industry dummy data: Manufacturing". "Years of operation" and "Capital". Hardware is related to "Number of PC per employee," while software is categorized as "Sales Management System," "Manufacture Management System," "Design Management System," "CRM (Customer Relationship Marketing)," "CTI (Computer Telephony Integration)," and "SCM (Supply Chain Management)". Internet use consists of "PR of company and products," "Information exchange with customers," "Information exchange with group companies," and "B2C (Business to Consumer)". And "Success factors of ICT use" contain "Executives clarified business policy, Executives clarified the ICT introduction target," "Executives were familiar with ICT," " ICT personnel exercised the leadership for ICT use," " We developed the information system in cooperation with the outside advisers such as ICT coordinators and consultants," "We developed the information system in cooperation with mother company and group companies," "We developed the information system in cooperation with customers," "We could introduce ICT in a short time comparatively," "When ICT was introduced, we reformed organizational structures, systems, and company's rules," and "We invested emphatically in ICT".

Table 8 indicates the results of estimations; "Years of operation," "CTI," "SCM," and "Information exchange with group companies" become positively significant. "Number of PC per employee" and "B2C" becomes negatively significant. "Executives clarified business policy," "Executives were familiar with ICT," and "When ICT was introduced, we reformed organizational structures, systems, and company's rules" are positively significant, while "ICT personnel exercised the leadership for ICT use" becomes negatively significant.

Table 8. The result of analysis of ICT use and open innovation

		Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
Firm's characteristics	ln(years of operation)	44.480	16.669	2.67	0.008	***	11.075
	ln(capital)	----------	----------	----------	----------		----------
	Manufacturing	----------	----------	----------	----------		----------
Hardware	Number of PC per employee	-1.190	0.487	-2.44	0.015	**	-0.296
Software	Sales management system	----------	----------	----------	----------		----------
	Manufacture management system	----------	----------	----------	----------		----------
	Design management system	----------	----------	----------	----------		----------
	CRM	----------	----------	----------	----------		----------
	CTI	2.970	1.296	2.29	0.022	**	0.503
	SCM	2.257	1.253	1.8	0.072	*	0.448
Network	PR of company and products	----------	----------	----------	----------		----------
	Information exchange with customers	----------	----------	----------	----------		----------
	Information exchange with group companies	1.053	0.448	2.35	0.019	**	0.257
	B2C	-1.438	0.776	-1.85	0.064	*	-0.313
Success factors of ICT use	Executives clarified business policy	0.852	0.316	2.69	0.007	***	0.212
	Executives clarified the ICT introduction target.	----------	----------	----------	----------		----------
	Executives were familiar with ICT.	0.698	0.304	2.29	0.022	**	0.174
	ICT personnel exercised the leadership for ICT use.	-0.799	0.354	-2.26	0.024	**	-0.199
	We developed the information system in cooperation with the outside advisers such as ICT coordinators and consultants.	----------	----------	----------	----------		----------
	We developed the information system in cooperation with mother company and group companies.	----------	----------	----------	----------		----------
	We developed the information system in cooperation with customers.	----------	----------	----------	----------		----------
	We could introduce ICT in a short time comparatively.	----------	----------	----------	----------		----------
	When ICT was introduced, we reformed organizational structures, systems, and company's rules.	0.427	0.251	1.7	0.089	*	0.106
	We invested emphatically in ICT.	----------	----------	----------	----------		----------
	Constant	-340.529	126.522	-2.69	0.007	***	
	Log likelihood			-67.340			
	Number of obs.			131			

Note: ***, **, and * indicate the significant at the 1, 5, and10% level, respectively.

In case of software use, the marginal effect of “CTI” and “SCM” in the open innovation model is larger than those of other innovation categories. From this result, it follows that ICTs are more necessary for the cooperation among other firms for open innovation. Because information exchange with affiliated companies is more effective than with other suppliers and customers, this verifies that information exchange among group firms is more actively and a traditional feature of the Japanese firms system still exists even in the age of the information society. Moreover, it can be confirmed that firms, in which top managers are familiar with ICT and do not leave the leadership to ICT person, practice more open innovation with ICT use. In addition, it is important that firms not only introduce ICT but also reform organizational structures, business practices and related rules at the same time.

2. Results of estimations: Full model

In Table 9, the estimation result of the models with management characteristics and business environments added to explanatory variables are presented, being termed by the full model. Management characteristics are classified as “The direction of R&D and business strategy coincides with each other,” “The employees' challenges to risks are encouraged,” “To exercise employee's expertise and special skill, practical training and job rotations are practicing,” “There are other sections in which the development of new products can be examined,” “The method of project management has been adopted,” “Basic R&D is important,” “Your company does not rely on technology of other companies have and sticks to your own technology,” and “R&D results in innovation”. And Business environments consist of “Many researchers and engineers enter and leave your company,” “Many venture businesses with good technology and knowhow exist in this area,” “There are universities near to you and you are interested in their at study fields,” “Many group companies have distinguished technologies and knowhow,” “The product market is mature,” and “Influence of Lehman Shock to your company is stronger than other company”. The stepwise logistic regression analysis is applied to verify the hypotheses mentioned earlier.

In case of open innovation, Table 9 indicates that variables including “Years of operation,” “Capital,” “There are other sections in which the development of new products can be examined,” “Many venture businesses with good technology and knowhow exist in this area,” “Many group companies have distinguished technologies and knowhow,” “CTI,” “Information exchange with group companies,” “Executives clarified the ICT introduction target,” and “Executives were familiar with ICT” become positively significant. “Basic R&D is important,” “Number of PC per employee,”

"B2C," and "ICT personnel exercised the leadership for ICT use" are negatively significant.

Table 9. The result of analysis of open Innovation (full model)

		Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
Firm's characteristics	ln(years of operation)	76.513	25.124	3.05	0.002	***	18.301
	ln(capital)	0.370	0.204	1.82	0.069	*	0.089
Management Characteristics	Manufacturing	----------	----------	----------	----------		----------
	The direction of R&D and business strategy coincides with each other	----------	----------	----------	----------		----------
	The employees' challenges to risks are encouraged.	----------	----------	----------	----------		----------
	To exercise employee's expertise and special skill, practical training and job rotations are practicing.	----------	----------	----------	----------		----------
	There are other sections in which the development of new products can be examined.	0.863	0.298	2.89	0.004	***	0.206
	The method of project management has been adopted.	----------	----------	----------	----------		----------
Business Environment	Basic R&D is important.	-0.452	0.283	-1.6	0.11		-0.108
	Your company does not rely on technology of other companies have and sticks to your own technology.	----------	----------	----------	----------		----------
	R&D results in innovation.	----------	----------	----------	----------		----------
	Many researchers and engineers enter and leave your company.	----------	----------	----------	----------		----------
	Many venture businesses with good technology and knowhow exist in this area.	0.617	0.295	2.09	0.037	**	0.148
	There are universities near to you and you are interested in their at study fields.	----------	----------	----------	----------		----------
	Many group companies have distinguished technologies and knowhow.	0.608	0.255	2.38	0.017	**	0.145
	The product market is mature.	----------	----------	----------	----------		----------
	Influence of Lehman Shock to your company is stronger than other company	----------	----------	----------	----------		----------
Hardware	Number of PC per employee	-2.313	0.704	-3.29	0.001	***	-0.553
Software	Sales management system	----------	----------	----------	----------		----------
	Manufacture management system	----------	----------	----------	----------		----------
	Design management system	----------	----------	----------	----------		----------
	CRM	----------	----------	----------	----------		----------
	CTI	3.407	1.402	2.43	0.015	**	0.587
	SCM	----------	----------	----------	----------		----------
Network	PR of company and products	----------	----------	----------	----------		----------
	Information exchange with customers	----------	----------	----------	----------		----------

	Information exchange with group companies	1.555	0.597	2.6	0.009	***	0.368
	B2C	-2.099	0.937	-2.24	0.025	**	-0.365
	Executives clarified business policy	----------	----------	----------	----------		----------
	Executives clarified the ICT introduction target.	0.876	0.437	2.01	0.045	**	0.210
	Executives were familiar with ICT.	0.719	0.352	2.04	0.041	**	0.172
	ICT personnel exercised the leadership for ICT use.	-0.912	0.428	-2.13	0.033	**	-0.218
Success factors of ICT use	We developed the information system in cooperation with the outside advisers such as ICT coordinators and consultants.	----------	----------	----------	----------		----------
	We developed the information system in cooperation with mother company and group companies.	----------	----------	----------	----------		----------
	We developed the information system in cooperation with customers.	----------	----------	----------	----------		----------
	We could introduce ICT in a short time comparatively.	----------	----------	----------	----------		----------
	When ICT was introduced, we reformed organizational structures, systems, and company's rules.	----------	----------	----------	----------		----------
	We invested emphatically in ICT.	----------	----------	----------	----------		----------
	Constant	-592.719	191.882	-3.09	0.002	***	
	Log likelihood			-49.799			
	Number of obs.			123			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

Similar to the results obtained in the previous analysis, it can be confirmed that variables such as "CTI," "Information exchange with group companies" and "Top managers exercise the leadership for ICT use, without leaving the ICT person in charge" contribute to open innovation using ICT.

These results can be interpreted in the following way; firms with successful open innovation have many good group companies and venture companies with specific technology and knowhow.

3. Relationship with partners of open innovation

Here, the following two points are clarified: (i) relationship between middle-sized firms and partners which cooperate to enhance open innovation; and (ii) whether ICTs are useful tools for communication with partners or not. Similar to the previous analysis, the stepwise logistic regression model is also adopted by taking the number of innovation in 2005-2008 as an objective variable and taking type of partners as one of

explanatory variables (see Table10, 11, 12, 13).

3.1. Partners of Open Innovation

First of all, “Type of partners” is added to explanatory variable in this stepwise logistic regression model. Type of partners are categorized as “Supplier in region,” “Supplier outside region,” “Customer in region,” “Customer outside region,” “Same trade company in region,” “Same trade company outside region,” “Mother company or subsidiary company,” “Introduced company by intermediation agencies,” “University in region,” “University outside region,” “Public R&D institution in region,” and “Economic organization such as Chamber of Commerce, and so on in region”. Top three items were asked from these; three points were provided to the first item, two points to second place, and one point to the third place. Table10 indicates the results of estimations.

Table 10. Partners of open innovation

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	22.088	12.510	1.77	0.077	*	5.507
ln(capital)	0.216	0.141	1.53	0.127		0.054
Manufacturing	----------	----------	----------	----------		----------
Supplier in region	----------	----------	----------	----------		----------
Supplier outside region	0.281	0.213	1.32	0.186		0.070
Customer in region	0.627	0.214	2.93	0.003	***	0.156
Customer outside region	0.406	0.171	2.38	0.017	**	0.101
Same trade company in region	0.774	0.493	1.57	0.116		0.193
Same trade company outside region	----------	----------	----------	----------		----------
Mother company or subsidiary company	0.342	0.200	1.71	0.087	*	0.085
Introduced company by intermediation agencies	----------	----------	----------	----------		----------
University in region	----------	----------	----------	----------		----------
University outside region	----------	----------	----------	----------		----------
Public R&D institution in region	----------	----------	----------	----------		----------
Economic organization such as chamber of commerce, and so on in region	----------	----------	----------	----------		----------
Constant	-172.456	95.771	-1.8	0.072	*	
Log likelihood			-86.468			
Number of obs.			149			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

This estimation reveals that variables such as “Years of operation,” “Customer in region,” “Customer outside region,” and “Mother company or subsidiary company”

become positively significant. From these results, the following three assertions are also confirmed: (i) firms practice innovation which meets customers' needs; (ii) firms execute the innovation in cooperation with other firms in the region and outside region; and (iii) firms execute the innovation in cooperation with mother or subsidiary companies.

Next, the relationship with partners is analyzed; that is, we attempt to confirm whether they cooperate with each other because they are members of some specific business association, they are transaction partners or they have mutual capital-ties. In so doing, "Strength of connection with partners" is selected as the explanatory variable in the stepwise logistic regression model. As for explain variables, we choose the following questions: "Longtime customer," "Partner of joint venture for joint R&D," "Firm obtained by M&A," "Capital tie-up and making to subsidiary company," "R&D tie-up by contract," "Dispatching engineer for technical guidance," "Acceptance partner's employee," "Dissipating employee to partner," "Using patent and license," "Consortium member," "Member of technological standardization group," "Member of business exhibition," "Member of the industry association," "Member of exchanging group of different industries," "Firm donated chair university" and "Member of research group in academia". As a result of estimation, "Longtime customer," "Capital tie-up and making to subsidiary company" and "Consortium member" becomes positively significant.

The following three assertions are also confirmed as a result: (i) longtime customer has mutual trust with each other and becomes a partner for an open innovation; (ii) firm execute innovation with firms with capital ties, and (iii) the firm execute innovation in cooperation with firms in the same industry that participate in a consortium which has a specific common purpose. The results are similar to the previous results (Table 9). Moreover, it turns out that the customer who has a long-term relationship is preferable as a partner of open innovation.

3.2. Frequency, distance and means of communication with partners

"Frequent development with partners," "Distance (travel time in car)," and "Means of communication" are added to the explanatory variable and analyze the stepwise logistic regression analysis again. As for means of communication, firms were asked to select items from "Face-to-face," "Phone," "E-mail," "Tele-conferencing," "Blog and SNS" and "Other". Top three choices were answered from these, and again three points were provided to the first place, two points to the second place, and one point to the third 3rd place. However, because the number of answers was too small,

"Tele-conferencing," "Blog and SNS" and "Other" are excluded from the analysis. Table 12 indicates the results of estimation. "Frequent development with partners" becomes positively significant.

Table 11. Strength of connection with partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	----------	----------	----------	----------		----------
ln(capital)	----------	----------	----------	----------		----------
Manufacturing	----------	----------	----------	----------		----------
Longtime customer	1.189	0.523	2.27	0.023	**	0.285
Partner of joint venture for joint R&D	----------	----------	----------	----------		----------
Firm obtained by M&A	----------	----------	----------	----------		----------
Capital tie-up and making to subsidiary company	1.546	0.766	2.02	0.044	**	0.301
R&D tie-up by contract	----------	----------	----------	----------		----------
Dispatching engineer for technical guidance	----------	----------	----------	----------		----------
Acceptance partner's employee	----------	----------	----------	----------		----------
Dissipating employee to partner	----------	----------	----------	----------		----------
Using patent and license	----------	----------	----------	----------		----------
Consortium member	2.021	1.178	1.72	0.086	*	0.337
Member of technological standardization group	----------	----------	----------	----------		----------
Member of business exhibition	----------	----------	----------	----------		----------
Member of the industry association	----------	----------	----------	----------		----------
Member of exchanging group of different industries	----------	----------	----------	----------		----------
Firm donated chair university	----------	----------	----------	----------		----------
Member of research group in academia	----------	----------	----------	----------		----------
Constant	-0.709	0.462	-1.54	0.125		
Log likelihood			-56.608			
Number of obs.			91			

Note: ***, **, and * indicate the significant at the 1, 5, and 10 % level, respectively.

The following two points become clear: (i) firm which executes open innovation shows a tendency to engage in R&D frequently with partners; (ii) many firms execute the innovation with regional firms is the same result as the previous analysis. However, they are not always conducting innovation neither with geographically closer partners nor with who frequently communicate by the face-to-face basis.

3.3. Information exchange with open innovation partners

The analysis in the previous section shows information is frequently exchanged by e-mail with open innovation partner. Here, what kind of information is exchanged among partners for open innovation is identified. "Type of information" is added to the

explanatory variable in the stepwise logistic regression model. Types of information contain “Customer needs,” “New release information of the rival companies,” “Hot selling information,” “Demand forecast,” “Complaint information,” “Basic technological information,” “High-tech trend,” “Production machine (software) information,” “Design information,” “Raw material information,” “Information of parts and components,” “Technical intelligence of product (software),” “Development period information,” “Production management information,” “Quality-management information,” “Development cost information,” “Environmental measures information,” “Maintenance technology information,” “Procurement information,” “The lead user's introduction” and “Introduction of joint R&D partners”.

Table 12. Frequency, Distance, and Means of Communication with Partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	----------	----------	----------	----------		----------
ln(capital)	----------	----------	----------	----------		----------
Manufacturing	----------	----------	----------	----------		----------
Frequency of development with partners	0.525	0.251	2.09	0.036	**	0.125
Distance (travel time in car)	----------	----------	----------	----------		----------
Face to Face	----------	----------	----------	----------		----------
Phone	----------	----------	----------	----------		----------
E-mail	0.287	0.215	1.33	0.182		0.068
Constant	-1.311	0.722	-1.82	0.069	*	
Log likelihood			-60.628			
Number of obs.			95			

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

Table 13 indicates four types of information become positively significant; namely, “Customer needs,” “New release information of the rival companies” and “High-tech trend”.

The following points are clarified from the result: (i) in the market, the firm tries to develop a new product and service with the competitive advantage by knowing rivals’ information of new products and the customer needs; (ii) firm tries to know the trend of high technology and to attempt to catch up with the trend.

Table 13 information exchange with partners

	Coef.	Std. Err.	z-Value	p-Value		Marginal Effect
ln(years of operation)	----------	----------	----------	----------		----------
ln(capital)	----------	----------	----------	----------		----------
Manufacturing	----------	----------	----------	----------		----------
Customer needs	1.435	0.508	2.82	0.005	***	0.335
New release information of the rival companies	1.482	0.589	2.52	0.012	**	0.302
Hot selling information	----------	----------	----------	----------		----------
Demand forecast	----------	----------	----------	----------		----------
Complaint information	----------	----------	----------	----------		----------
Basic technological information	----------	----------	----------	----------		----------
High-tech trend	1.278	0.564	2.27	0.023	**	0.264
Production machine (software) information	----------	----------	----------	----------		----------
Design information	----------	----------	----------	----------		----------
Raw material information	----------	----------	----------	----------		----------
Information of parts and components	----------	----------	----------	----------		----------
Technical intelligence of product (software)	----------	----------	----------	----------		----------
Development period information	----------	----------	----------	----------		----------
Production management information	1.087	0.715	1.52	0.129		0.217
Quality-management information	----------	----------	----------	----------		----------
Development cost information	----------	----------	----------	----------		----------
Environmental measures information	----------	----------	----------	----------		----------
Maintenance technology information	----------	----------	----------	----------		----------
Procurement information	----------	----------	----------	----------		----------
The lead user's introduction	----------	----------	----------	----------		----------
Introduction of joint R&D partners	----------	----------	----------	----------		----------
Constant	-1.380	0.487	-2.83	0.005	***	
Log likelihood			-53.478			
Number of obs.			98			

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