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Relationship between Innovation and Corporate Performance in Japanese SMEs by Two-stage Panel Data Analysis: Focusing on the Joint Effect of ICT and R&D

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Abstract

The innovation theory tends to focus on innovation capabilities and estimate how these promote innovation. However, the final aim of innovation is not innovation itself but enhancing profits or sales. To complete the innovation theory, it is required to show whether innovation achieved contributes to improve in business performances. A further focus of this paper is on the role of ICT and R&D in the innovation process. ICT plays a vital role in absorbing information from outside the firm, while R&D is essential for assimilating obtained information with existing resources to create something novel. This paper focus on the joint effect of these two factors. The estimation is based on the two-stage panel IV model and authors' own data of 2012 and 2017. The dependent variables are innovation in the first equation and sales in the second. The results obtained show that (i) Innovation enhances sales; (ii) R&D is significant for innovation; (iii) ICT is not significant for neither of equations; and (iv) the cross term of R&D and ICT is significant for innovation, implying ICT is an enabler of innovation. This is a novel result of the paper.

Keywords: Open innovation, instrumental variable, mediation, cross term, enabler

1. Introduction

The COVID-19 pandemic has been deteriorating the global economy because of destruction of supply chains or the shortage semi-conductors, for example. Business activities also have been affected greatly by lockdown, even though the usage of ICT (Information and communications technology) such as telework was widely utilized, implying that face-to-face communications seems to be more potent than ICT. Innovation activities also have been disrupted; according to authors' interviews to SMEs (Small and medium-sized enterprises), communications with business partners which can convey useful information on technologies, consumers, or markets have been affected greatly. These are important sources of innovation for SMEs. Communications inside SMEs among R&D sections or personnel, however, have been less affected.

Most of innovation models thus far attempt to explore the innovation process which indicates how the innovation capability achieve innovation. The innovation capability includes human resources, R&D, the level of technology, the ability of the top management, and so forth. However, the final aim of innovation is not innovation itself but enhancing firm performances such as the amounts of sales, profits, or the growth of these. Innovation is one of measures to achieve better business performance. To complete the innovation theory, it is required to show whether innovation achieved contributes to the improvement in business performances. Innovation is thus one process of achieving profits by creating new products which own better quality and cheaper price or by improving current products. This paper examines two processes of achieving profit: firms make use of all resources to achieve profits as usual business activities and innovation activities. These two processes conclude the whole process starting from ideas or seeds of business to ending up with profit. The framework of the model is shown Figure 1.

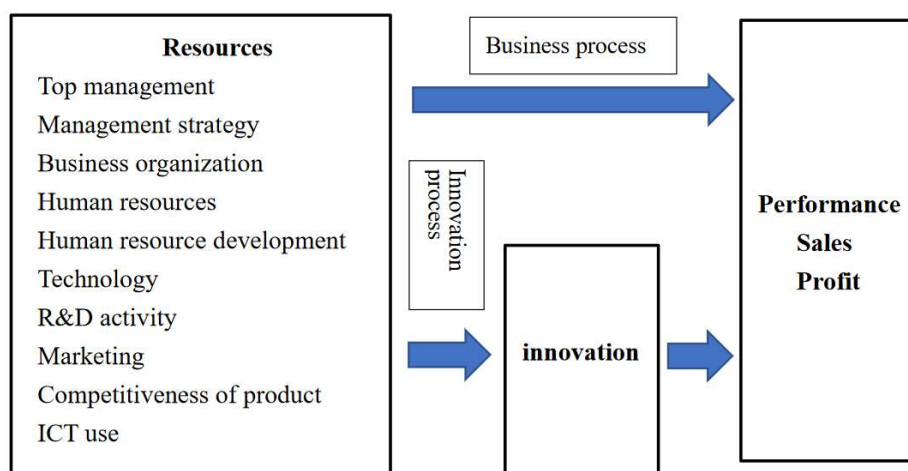


Figure 1 Framework of the model

Another focus of this paper is on the role of ICT and R&D in the innovation process. ICT plays a vital role in absorbing information from outside the firm, as already mentioned, while R&D is essential for assimilating obtained information with existing resources to create something novel. This paper focuses on the joint effect of these two factors. Traditional studies on innovation in general have focused thematically on individual factors such as absorptive capability, R&D, HR (human resources), managerial capability, technology management, ICT, and so on. Although this approach has its advantages, it is critical to consider innovation as a single process from a broad perspective and framework, and analyze how SMEs obtain new information and ideas as sources of innovation, organize and conduct R&D to assimilate these ideas with management resources within the firm and finally achieve new products (Cohen and Levinthal, 1990; Zahra and George, 2002). At each step of the process, one particular factor is focused on. ICT, for example, plays a vital role in absorbing information from outside the firm, while R&D is essential for assimilating information obtained with existing resources to create something novel. Along with this, a great amount of diverse research on R&D has been published since the 1980s, because R&D is recognized as risky and having a high failure rate (Booz, Allen, and Hamilton, 1982; Crawford, 1987). As for ICT, it is a general-purpose technology that has various roles (Bresnahan and Trajtenberg, 1995). In fact, ICT has created opportunities for assessing and sharing information, both within and outside the firm, reducing related costs and improving efficiency in the business process, including innovation activities. However, only a handful of papers have provided evidence of the joint activity of R&D and ICT in this respect. Tsoukatos et al. (2017), using original survey data on 405 Greek manufacturing SMEs, is one example. The point in which this study differs from that of Tsoukatos et al. (2017) and traditional studies lies in the following two aspects: One is that the roles of R&D and ICT are analyzed together, namely, the focus of this study is on how these two elements jointly promote innovation. In contrast, in their empirical model, Tsoukatos et al. (2017) control R&D and ICT separately as variables. In addition, this paper focuses on the functions of R&D and ICT, which leads to an exploration of how these two promote innovation. Most previous papers have used the amounts of R&D or ICT investment as a proxy of R&D or ICT, but in this setting, it is difficult to grasp the roles of these in innovation, namely, how and why these two promote innovation. This study, on the other hand, focuses on the functions of R&D and ICT as variables, which makes it possible to clarify their essential roles in the innovation process.

From the above discussions, the RQs are summarized as follows:

RQ1: How SMEs promote product innovation by using what kinds of innovation capabilities they own

RQ2: Whether product innovation enhances corporate performance

RQ3: How ICT and R&D jointly affect the innovation process

With these questions in mind, the paper is structured as follows to shed light on the mechanisms of innovation in SMEs. Section 2 surveys related literature, and in Section 3, data obtained from the questionnaire, and the model for analysis are presented. Section 4 shows the results from the two-stage panel data model. Discussion and conclusion is provided in Section 5. In this paper, the innovation process and innovation performance are integrated into one model, the aim being to explore the real objective of innovation.

2. Literature survey

2.1. ICT uses for innovation

ICT can contribute to the promotion of innovations through the following two functions: Firstly, SMEs can utilize ICT to search for and access cutting-edge information outside the firm. One example of this channel is open innovation (Chesbrough, 2003), which is a key factor for SME innovation, these channels consisting of intellectual and transaction channels (Tsuji et al., 2016, 2017). The former is used for collaboration with universities and research institutions, whereas the latter is for obtaining information from customers and suppliers via the supply chain (Pietrobelli and Rabellotti, 2011), enabling information flows through orders, claims or improvements to interact more efficiently (Todo et al., 2016). Secondly, SMEs assimilate information obtained through managerial resources they own and transform it into new knowledge, this process being referred to as “knowledge management.” ICT can support the sharing of information among R&D teams, which may shorten the R&D period or transform tacit knowledge into explicit knowledge. From these functions, ICT is termed “IT capability” (Karimi et al., 2007). The recent developments in various ICTs can assist innovation are follows:

The Internet of Things (IoT) is transforming the traditional innovation process into a novel one in which big data on consumers, firms, and markets is utilized in real time. IoT could never have been realized without ICT development. Equipment and machinery in the factory are operated without human assistance, and robots equipped with AI can replace human engineers and workers everywhere in the economy, which is resulting in a digital transformation even in traditional process innovation (Bilgeri et al., 2019). Agriculture has been transformed into a high-tech industry due to ICT (Alan et al., 2016; Paul, 2019). These observations show that IoT enhances innovation.

Huge amounts of data can be saved and stored to be subsequently utilized for business purposes. Such big data is allowing firms to create new business models to serve customers in new ways. The so-called GAFA (Google, Apple, Facebook, and Amazon) are typical examples of the expansion of new business models. The kinds of characteristics of big data that enhance core competency or innovation have become the focus of research, Lee (2018), Maryam and Goran (2019), and Jaime et al. (2019) identifying these as the three Vs of big data; Volume, Velocity, and Variety. Zhan et al. (2017) analyze the merits of big data, finding that they reduce lead time and costs of innovation through efficient transactions with consumers and trade partners. Blackburn et al. (2017) focus on how big data transforms the R&D process through interviews and case studies. Big data is relevant not only for large firms but also SMEs, since the latter can access big data through open innovation with large firms or universities (Pasquale et al., 2018). The age of big data has just begun, but new ICTs will surely bring about a transformation to the data-driven economy (Tsuji, 2019).

Social media such as Twitter, blogs, Facebook, Instagram, and others have become popular in all kinds of businesses. Firms have come to recognize that the use of social media is a strategic measure not only for the collection of information on promoting marketing but also for developing new goods and services (Idota et al., 2017, 2019). Consumer involvement in social media has the three dimensions of consumer brand engagement; cognitive processing, affection and activation (Brandão et al., 2019).

2.2 R&D and ICT

Previous research has mainly addressed R&D from the perspective of organizational theory, focusing on areas such as acquisition of new information through the R&D organization, sharing of the information among R&D team members, and the conversion of the information to knowledge, and furthermore, from tacit knowledge to codified/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 other members of the organization (Freeman, 1979; Tsuji et al., 2016). To smoothly convey information, trustworthiness among 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.

As discussed earlier, in knowledge management, ICT offers effective measures for the promotion of R&D and innovations. The uses of ICTs are categorized according to their functionalities: (1) ICT used for obtaining external information on new technologies;

(2) ICT used for sharing internal knowledge on products and production; and (3) ICT used for sharing internal knowledge on the market and consumers. The ICT can also contribute to all aspects of the above innovation process; acquisition, assimilation, transformation, and exploitation (Ueki and Tsuji, 2019). In particular, ICT can activate and make these more efficient (Nicolas and Acosta, 2010; Omona et al, 2010; Ologbo and Nor, 2015). Information networks inside the firm promote the sharing of necessary information among R&D team members and other teams, which may shorten the time required for decision-making, or assist in the transformation of tacit knowledge to explicit knowledge (Polanyi, 1966; Nonaka and Takeuchi, 1996). ICT thus transforms information to knowledge efficiently and encourages innovation. Tsoukatos et al. (2017) examine the role of R&D and ICT using their survey data of 405 Greek manufacturing SMEs. They use ERP (Enterprise Resource Planning) and TQM (Total Quality Management) as variables to represent ICT and R&D investment. Least square regression shows that only TQM is significant.

3. Methodology

3.1 Questionnaire survey

This model is based on a survey conducted in February 2012. The samples were selected as follows: From the lists of the *Teikoku Data* Bank, 3,959 firms were selected from the manufacturing, construction, information and communications, and service industries. The criteria of the selection were that sample firms have to satisfy the following conditions: the firm (i) is unlisted; (ii) employs more than 20 workers, (iii) has earned positive profits in the most recent three terms, that is, in the last 18 months, and (iv) is experiencing increasing sales. The reason for these limitations is to reduce the number of samples to an appropriate size. The valid number of responses to the first survey was 647, a response rate of 16.2%. A second survey was conducted in February 2018 with 620 of the above 647 SMEs which responded to the first survey, 27 unable to participate due to bankruptcy, change of address, or rejection of the survey. 122 SMEs among the 620 replied, the valid response rate being 9.7%. Summary statistics of the pooled data are shown in Table 1.

Table 1 Descriptive statistics and correlation matrix

	Mean	SD	1	2	3	4	5	6	7	8	9
1. Sales	0.562	0.498	1								
2. Transaction channels	0.414	0.494	0.221**	1.000							
3. Employee (log)	3.677	0.640	0.092	0.091	1.000						
4. Open innovation	0.740	1.521	0.075	-0.171*	-0.092	1.000					
5. Innovation	0.627	0.485	0.076	0.114	0.075	0.090	1.000				
6. ICT	0.397	0.490	0.039	0.0358	0.250**	-0.071	0.175**	1.000			
7. R&D orientation	0.007	0.885	0.163*	0.234**	0.107	0.093	0.371**	0.099	1.000		
8. ICT*R&D autonomy	0.603	3.320	0.065	0.045	0.069	0.035	0.415**	0.116*	0.053	1.000	
9. Subsidies	0.065	0.247	-0.001	-0.113	0.094	-0.105	0.149*	0.190**	-0.015	0.039	1.000

3. 2 Selected firm characteristics

The main industry the sample firms were engaged in was manufacturing, amounting to 60% of the total, followed by construction. Regarding the trend of sales in the past three years, in 2011, almost two thirds of the firms, whether they succeeded in innovation or not, had increased their sales amounts, which may have been due to recovery from the Lehman Shock. In 2017, on the other hand, the percentage of “Increasing” sales declined and those of “Almost the same” increased. The ratios of R&D over sales indicate that SMEs that achieved innovation tended to have a higher R&D ratio than those that did not achieve innovation. The ratio for more than half of the former was 0.1-0.3, whereas more than half (2011) or two thirds (2017) of the latter had no R&D expenditures, a substantially large contrast. Similar phenomena are also seen in the trends in R&D over the past three years; about 50% of SMEs that achieved innovation and 80% of SMEs that did not maintain the same R&D ratio in both the first and second surveys.

3.3 Dependent variable

The number of SMEs which achieved innovation in the questionnaire is taken in this paper as an outcome variable. That is, respondents were asked whether they supplied a new product or service to the market during 2006-2010 and during 2013-2017 (QII.1). Firms were asked to reply “yes” or “no,” and these are taken as explained variables for estimation. The numbers of replies to the two surveys are shown in Table 2. About two thirds of respondents answered positively in both surveys, these firms being genuinely innovative. The variable of “Innovation” is thus constructed.

Table 2 Distribution of replies

2011	2017
Achieved innovation: 80 (66.7)	Achieved: 52 (65.0)
	Not at all: 28 (35.0)
Not at all: 40 (33.3)	Achieved :5 (12.5)
	Not at all: 33(82.5)
	No reply: 2 (5)

Another dependent variable, sales, is asked in VIII.9 in the questionnaire, whether sales are increasing or not. If SMEs reply “yes,” it takes 1, and otherwise 0. More than half samples firms replied “yes.” Innovation is not the sole objective of firms, but profit or sales; innovation is one means of obtaining profit or sales. Many patents do not necessarily yield profits automatically. To make the whole process of innovation worthwhile, profit should accrue from the outcome. The hypothesis of this paper is seeking to substantiate related to innovation, and innovation is one variable that explains profit or sales. In addition, one further equation, which defines a firm’s profits, is required. Innovation, which is examined in this study, is included as one variable that explains profit or sales. A two-stage estimation model is thus a better formulation for examining the innovation process (Kesidou and Szirmai, 2008).

3. 4 Explanatory variable I: R&D

To construct variables related to R&D, suitable questions were chosen from QI and QIII of the questionnaire, as follows:

QI.1.3 Various basic technologies and know-how other than core technologies are owned

QIII.1.3. R&D is directly connected to new products and services

QI.1.5.5. Goals are assigned to employees, who are rewarded based on their achievements

QI.1.5.8. The top manager takes the lead in new business

QIII.1.4. Positive about offering owned technology to other firms

QIII.2.1. Speedy decision-making

QIII.2.2. Responsibility and authority are delegated to the R&D department

QVIII.3. Number of employees

The result of the factor analysis regarding R&D, shown in Table 3, extracts two factors which consist of two questions each. The first factor is named “R&D orientation,” while the second factor is named “R&D autonomy.” The first factor consists of “QIII.1.3. R&D is directly connected to new products and services,” These factors indicate the direction and performance of R&D and, accordingly, the latent variable based on these observed variables is referred to as “R&D orientation.” This variable, in other words, indicates whether R&D leads on to the achievement of innovation, which is an essential question for R&D. Various previous papers have also analyzed this aspect (Leonard-Barton, 1988; Iansiti, 1998; Sundgren et al., 2005).

The second factor extracted contains “QIII.2.1: Speedy decision-making,” and “QIII.2.2: Responsibility and authority are delegated to the R&D department.” Particularly, the latter question 2.2 is related to the decentralization and autonomy of R&D units. From our field research, it is observed that the speed of decision-making is a characteristic merit of SMEs (Tsuji et al., 2017). From these observations, it follows that the latent variable is referred to as “R&D autonomy.” Previous papers also discussed autonomy and found from Japanese data that autonomy as a variable elevates innovation, whereas Argyres and Silverman (2004) and Lerner and Wulf (2007) claim that centralization in R&D organizations is better in the pursuit of innovation in terms of efficient allocation of resources and coping with shifts in technologies, markets, and other environments related to R&D. This study supports autonomy as a factor promoting innovation.

Table 3 Factor analysis of R&D

Observation variables	Factor 1	Factor 2	Communality
Offer own technology for other firms positively.	0.946	0.222	0.945
R&D is directly connected to new products and services.	0.587	0.476	0.572
Give responsibility and authority to R&D department	0.204	0.836	0.740
Decision Making is speedy.	0.341	0.684	0.585
Goals are assigned to employees and reward them based on their achievements	0.194	0.215	0.084
The top management takes leading to do new business.	0.283	0.131	0.097
Various basic technologies and know-how other than core technologies are owned.	0.235	0.266	0.126
Number of employees (log)	0.102	0.066	0.015
Variance	3.009	1.050	
Proportion	37.608	13.126	
Cumulative	37.608	50.734	

3. 5 Explanatory variable II: ICT

The RQs of this study are to examine how ICT contributes to R&D and innovation in SMEs. Although the authors’ previous study adopted the number of ICT systems and practices, such as e-commerce, supply chain management, SNS, and so on as variables of ICT use, it is in line with the objective of this paper that the perceived effect of ICT is taken as a variable. In other words, instead of external differences, how successfully SMEs use ICT is evaluated in this analysis.

The questionnaire contains questions on the effect of ICT on 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 improves the speed of decision-making

QV.4.4: ICT shortens the development period for a new product

These questions required a response on the five-point Likert scale. Again, factor analysis is applied to extract latent variables. The results are shown in Table 4, which extracts one factor consisting of “QV.4.3: ICT improves the speed of decision-making” and “QV.4.4: ICT shortens the development period for a new product.” Thus, the related latent variable is referred to as the “ICT.” These are consistent with assertions in previous research (Brynjolfsson and Hitt, 2000; Brynjolfsson and Saunders, 2009).

Table 4 Factor analysis of ICT

Observation variables	Factor 1
ICT shortens the development period of new product	0.452
ICT makes the speed of decision making faster	0.442
ICT assists the advertisement of products	0.237
Variance	2.025
Proportion	67.502
Cumulative	67.502

3. 6 Explanatory variable III: Transaction channels

This variable explains the competitiveness of products. There are lots of possible indicators which explain this characteristic, but the questionnaire asks whether the number of transaction partners is increasing (QI.4.2). If so, they are attracted by either quality or price of products, indicating the competitiveness of products. To whom they answered affirmatively, another question was asked whether new trade partners approached to start transactions. This question is also related to product competitiveness. The dummy variable of “Transaction channels” is thus constructed.

3. 7 Explanatory variable IV: Number of employees

The number of employees is a proxy for the size of firm, which is asked by V.3.3. This question is used for individual firm characteristics. Logarithm is used for estimation.

3. 8 Explanatory variable V: Open innovation

The collaboration with other firms, universities, and public research institutions is a vital factor for innovation, which refers to open innovation (Chesbrough, 2003). Question IV. 2 asks whether SMEs own such collaboration. To elaborate the collaborative behavior, the question III.1.7 asks whether firms positively participate in open innovation, that is,

whether they incorporate in their advantaged fields. If they reply affirmatively to two questions, dummy variable of “Open innovation” takes 1, otherwise 0.

3.9 Explanatory variable VI: ICT*R&D autonomy

This variable is constructed as the cross term of ICT use and R&D autonomy (latent variable), indicating whether two variables together affect innovation. This variable also explains the intermediate effect of ICT on innovation, which will be discussed in detail in what follows.

3.10 Explanatory variable VII: Subsidies

Question VI.1. asks whether they received public supports for innovation such as financial assistances for R&D, investment, training, tax exempts, registering patents, participating in exhibitions and trade shows. If they received at least one of them, it takes 1, otherwise 0.

3.11 Estimation method

This paper at first conducts probit estimation based on the pooled data (Model 1), and the second analysis is the examination on the relationship between innovation and sales with instrumental variables (IV) panel data regression, in which a variable of innovation is instrument and the variable of sales is instrumented. then two-stage panel data estimation, which is IV probit model consisting of the first and second estimation, namely the first equation estimates innovation with internal innovation capabilities such as R&D, ICT, and subsidies (SB) and the second equation estimates sales with competitiveness of products (Transaction channels), collaboration with other entities (Open innovation), innovation and the firm size (Number of employees) is controlled as firm characteristic.

$$1\text{st eq. } Innovation = a + b_1R\&D_o + b_2ICT + b_3SB + b_4ITC*R\&D_a + e_1$$

$$2\text{nd eq. } Sales = c + d_1Innovation + d_2TC + d_3OI + d_4ICT + d_5NE + e_2$$

R&Do: R&D orientation, ICT*R&Da: cross term of IDT and R&D autonomy,

SB: subsidies, TC: number of transaction channels, OI: Open innovation,

NE: number of employees

3. Results

The results of IV probit panel data estimation are shown in Table 5. In the first equation, R&D orientation ($p < 0.01$), ICT*R&D autonomy ($p < 0.01$), and Subsidies ($p < 0.1$) are found to be significant, but ICT itself is not significant. Among factors which affect

innovation, two latent variables related to R&D strongly enhance innovation, which is consistent with results of previous studies listed in Section 1.2.1. In particular, it is natural that R&D orientation which consists of two characteristics such as “Offer own technology” and “R&D is directly connected to new products and services” promotes innovation, whereas R&D autonomy consisting of “Give responsibility and authority to R&D department” and “Decision making is speedy” is not significant. but R&D autonomy with help of ICT, that is the cross-term of ICT*R&D autonomy is significant to innovation. This is because ICT assists to make decision making faster, which is a nature of ICT. The role of ICT in this context will be discussed later.

In the second equation, Innovation ($p<0.01$), Transaction channel ($p<0.01$), and Open innovation ($p<0.05$) are found significant. Innovative SMEs which own competitive product due to the collaboration with universities and research institutes tend to achieve increasing in sales. But this result was not found for profit. ICT is not individually significant to sales nor innovation, whereas R&D is significant for innovation, but not for sales. ICT and R&D together promote innovation, but do not sales. In other words, these two variables together directly promote innovation, but indirectly promote sales, since innovation raises sales.

These results answer RQs asked in Introduction: Regarding RQ1, innovation capabilities such as the numbers of trades partners (Transaction channel), and open innovation, and R&D are identifies as promoting innovation. Innovation surely promotes sales, which demonstrates RQ2, and ICT and R&D jointly affect the innovation process (RQ3).

4. Discussion and conclusion

4.1 Role of ICT in the innovation process

To highlight the novelty of the above results, let us compare with those of authors' previous analysis used 2012 data (Idota, Bunno, and Tsuji, 2013), although this comparison may not be proper, since the estimation models are entirely different. The authors' previous paper employs profit estimation without an instrumental variable, which demonstrates that ICT and R&D are significant in all estimation models. On the other hand, this paper uses the two-stage panel data model with an instrumental variable, which is much more sophisticated, and then not all of the above variables are not significant. In particular, ICT is significant in neither of probit regression and two-stage IV model, indicating that ICT individually is not significant for innovation nor sales. In this aspect, a role of ICT may differ bit from that expected by earlier literature, such as

Brynjolfsson and Hitt (2000), Brynjolfsson and Saunders (2009) and Ueki and Tsuji (2019).

Table 5 Results of estimation

Variables	1	2	3
	Probit regression Sales	Two stage IV probit regression First Innovation	probit regression Second Sales
Innovation	0.263 (0.278)		1.037** (0.512)
Transaction channels	0.793*** (0.309)		0.832*** (0.320)
Open Innovation	0.181* (0.105)		0.205** (0.104)
ICT	0.003 (0.283)		0.019 (0.292)
Employee (log)	0.380 (0.245)		0.306 (0.234)
ICT		0.221 (0.311)	
R&D orientation		0.645*** (0.216)	
ICT*R&D autonomy		0.261*** (0.072)	
Subsidies		1.452* (0.805)	
Observations	182	168	168
Corr (e.innovation,e.sales)			-0.255 (0.397)
Corr (innovation[new_no],sales[new_no])			-0.655* (0.392)
Log likelihood	-115.53562		-185.68869
Prob > chi2	0.0959		0.0292

It follows from these results that ICT itself does not create innovation, but assists R&D teams to activate R&D functions such as “Speedy decision-making,” and “Responsibility and authority are delegated to the R&D department.” The former is precisely one of the merits of ICT and the latter enhances the motivation of R&D team members. These discussions lead to the answer for RQ3, that is, the roles of ICT and autonomy of R&D teams in shortening decision-making are particularly important for innovation. Accordingly, this paper identifies the mediation effect of ICT on innovation via R&D autonomy. ICT itself may not necessarily create innovation, but it is an “innovation enabler” that supports other factors (Martin and Nguyen-Thi, 2015). Taking the example of cloud computing, since cloud computing is general purpose ICT,

combining this with mobile phones is what has brought smartphones to realization (Lina and Chen, 2012). Thus, the mediation effect appears to be an essential nature of ICT, and the model in this paper demonstrates this.

4.2 Open innovation,

This model shows that Open innovation is significant in the second equation (Sales), but not in the first (innovation), which seems to be different from the reality; namely it is opposite. This may come from its definition. In the questionnaire, the related question includes other trade partners in addition to universities and public research institutions. For Japanese SEMs, there are two channels of information flow related to innovation though open innovation; intellectual and supply chains. The former is related to laboratories in universities or public research institutions, while the latter is customers or suppliers of transactions. Large firms have more information on technologies and markets, from which SEMs can absorb cutting-edge information (Tsuji et al., 2017). Because of this dual nature of supply chains, this estimation is more influenced by the physical transactions than the flow of information. To determine which is larger requires further analysis.

5.3 Further research

The followings are suggestions for further research. Most panel data analysis on R&D or ICT in the innovation process employed data constructed by government or international organizations. These have merits such as containing a large number of samples and using international data, which makes for much more rigorous and in-depth analysis. In comparison with firm-level survey data, however, official data on R&D or ICT contain less firm-specific characteristics such as the implementation of R&D, organizational structure, information flow among different R&D departments, leadership of top management, and so on. This paper aims to explain the role of R&D and ICT in the innovation process of SMEs and hypotheses are derived from the authors' in-depth field surveys. Because of this, it has been possible to include in this paper variables related to SME management, organization, implementation of R&D and ICT. Because of the sample number, not all the variables can be taken into the analysis and the variables analyzed here are limited. While the model used in this paper has these shortcomings, to the authors' limited knowledge there has been no analysis employing robust panel data analysis thus far.

Another requirement for further study should be a focus on policy. The estimation shows that Subsidies is significant in the first equation (innovation). SMEs wanted small

subsidies to support their investments in new fields, including funds for supporting consortia for the application of new technologies, exhibitions in trade shows, HRD (human resource development), and so on (Tsuji et al., 2017; Matsuzaki et al., 2021). Some SMEs may possess specific technologies, but due to a lack of manpower and financial capability they are unable to develop them into final products. The above policies assist SMEs in stimulating their innovation. The amount of funds offered by policy measures are not of such great significance; what is much more important is the priority of policy targets.

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