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The Effect of the Covid-19 Pandemic on the Innovation Process of Small and Medium-sized Regional Firms

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Abstract

The objective of this study is to analyze how the innovation process has been affected by Covid-19 pandemic by focusing on SMEs. The RQs are:

RQ1: Whether there is a difference in the innovation of SMEs between before and during Covid-19

RQ2: If any, how Covid-19 affects the innovation process

This study is based on two surveys in February 2014 and 2022 to the same 1324 SMEs and 87 which responded to both surveys are employed for analysis. Measures include (i) the ratio of R&D investment to sales, (ii) open innovation, (iii) sources of ideas, (iv) problem solving ability, (v) human resource development, (vi) business development strategies. In the second questionnaire, the level of the effect of Covid-19 on variables are asked for the five Likert scale. The method used in this study is PSM-DID, which is the combination DID and PSM and to cope with biases such as sample selection and time trend. For the construction of the model, in-depth field surveys were conducted, which leads to hypothesis such that face-to-face communications were impeded between partners of transactions by the COVID-19 pandemic. This hypothesis and RQs are demonstrated by PSM-DID.

Keywords: PSM-DID, measures of innovation, open innovation, R&D, open innovation, face-to-face communications

1. Introduction

The Covid-19 pandemic has been providing great damages such as deteriorated supply-chains and the shortage of semi-conductors. The effect on economic activities has been widely reported and analyzed, whereas its effect on innovation is less examined thus far. The reason is clear; since the Covid-19 pandemic is an on-going disaster and its data on

innovation is not yet available. Fortunately, the authors conducted a questionnaire survey in 2014 on SMEs located around the *Hanshin* area in Japan, and this time the same questionnaire was sent to the same SMEs to construct the panel data. To analyze the effects of economic shocks or policy, it is better to compare the situations before and after such events, which requires to use panel data. The panel data is much better than the cross-section data. In addition to data analysis, we conducted field surveys to owners and personal who are in charge of innovation or R&D by asking the effects of the COVID-19 Pandemic. The objective of this study is to analyze how the innovation process has been affected by the Covid-19 pandemic by focusing on SMEs' innovation process based on firm-level questionnaire surveys and in-depth filed interviews conducted by the authors. The research questions of the study are as follows:

RQ1: Whether there is a difference in the innovation of SMEs between before and during Covid-19 pandemic

RQ2: If any, how Covid-19 pandemic affects the innovation process

To achieve the above objectives, rigorous research methodologies are employed to make full use of panel data before and during the pandemic.

The structure of this paper is as follows: the next section explains basic concepts and measures to promote innovation. Section 3 presents the field surveys to local SEMs which shows the effects of COVID-19 they have been suffering from. Data and methodology are examined in Section 4 which also presents empirical estimation procedure and its results. Discussion and Conclusion are provided in the last section.

2. Conceptual framework for empirical analysis

2.1. Definition of innovation upgrading in this study

The original study in 2014 was aimed to analyze innovation upgrading and the questionnaire was to meet this objective (Matsuzaki et al, 2021). The second survey in 2022 was focused on innovation. Innovation and its upgrading similar so that these two concepts are used in the same meaning in this paper.

It is difficult to define the innovativeness or novelty of goods and services in general. Öberg (2019), for example, classifies the newness of innovation by incremental, radical and disruptive innovation. Even if a definition was constructed, it might be too complex to use in empirical analysis. This study defines a rather simple concept of innovativeness, making it more tractable for analysis and for preparing questionnaires for SMEs. This concept is indicated as follows:

Stage 1: Develop products with existing technologies for existing markets

Stage 2: Develop products with new technologies for existing markets

Stage 3: Develop products with existing technologies for new markets

Stage 4: Develop products using new technologies for new markets

Higher the stage, 1 to 4, the more advanced the innovation. This definition classifies product novelty from the two aspects, supply and demand, or technology and consumer acceptability. In other words, whether products embody cutting-edge technologies, and whether products are accepted by the market due to their novelty. However, there is a room for discussion as to which of stages 2 and 3 is more sophisticated. Products embodying even cutting-edge technologies are unable to survive without consumer recognition of the novelty or usability of a product. Rogers (2003) and Bass (Bass, 1969; Norton & Bass, 1987) are also emphasized characteristics of new products in the diffusion process, namely Rogers (2003) advocated five concepts, relative advantage, compatibility, complexity, trialability, and observability. All of these concepts are related to consumer acceptability of product novelty, rather than technological issues. Therefore, we assume that the latter, stage 3, is more advanced than the former, stage 2.

2. 2 Measures promoting innovation upgrading

This section discusses measures which promote innovation upgrading from previous literature and from our field research.

2.2.1 Measure 1: R&D

Internal innovation capabilities such as technology, human resources, and organization contribute to innovation upgrading. Among them, R&D is an important element in innovation and a large number of papers have been published on this subject. For example, regarding the R&D organization and system, the autonomy of the R&D team (Argyres & Silverman, 2004; Lerner & Wulf, 2007), communication mode (Noorderhaven & Harzing, 2005; Gallie & Guichard, 2005), trustworthiness among the R&D organization (Leven & Cross, 2004; Colquitt & Rodell, 2011), leadership (Hirst & Mann, 2004; Berson & Linton, 2005; Zheng et al., 2010; Wong & Tong, 2012; Shigeno et al., 2018), and award schemes (Lerner & Wulf, 2007; Kanama & Nishikawa, 2017) have already been discussed.

This paper, on the other hand, classifies the degree of innovativeness in terms of technology and novelty in the market and focuses on the dynamic nature of upgrading; continuous R&D is the basis of upgrading. This paper therefore selects the ratio of R&D investment to the amount of sales as a proxy of R&D activity. This ratio has also been

used in previous studies (Crescenzi & Rodriguez-Pose, 2013; Thomä, 2017; Lee & Walsh, 2016; Afzal, 2019).

2.2.2 Measure 2: Open innovation

This measure has been demonstrated in previous literature (Chesbrough, 2003). This paper also makes use of the concept of open innovation. The questionnaire asked the question: “Whether your firm is practicing open innovation or not.” The collaboration with other firms, universities, and public research institutions is a vital factor for innovation and refers to open innovation. For Japanese SMEs, there are two channels of information flow through open innovation; intellectual and supply chains. The former is related to laboratories in universities or public research institutions, while the latter refers to customers or suppliers of transactions. Question IV. 2 asked whether SMEs own such collaboration. To elaborate collaborative behavior, Question III.1.7 asks to mark partners of open innovation, which include (1) Parent company, (2) Affiliated company, (3) Customer, (4) Supplier, (5) Competitor in the same industry, (6) Industry association, (7) Public research institution, (8) University inside the prefecture, (9) University outside the prefecture, (10) Local government, and (11) others. If respondents reply affirmatively to Question IV. 2 and mark partners in Question III.1.7, the dummy variable of “Open innovation” takes 1, otherwise 0.

2.2.3 Measure 3: Sources of ideas

How regional SMEs obtain ideas and information related to innovation, such as technology, markets, and consumer taste is an important issue. Tsuji et al. (2017) identify and classify information into the following three types: (i) Owner type; (ii) Improvement type; and (iii) Development type. Owner type indicates that owners are engineers and who possess various ideas, and Improvement type implies that information is obtained via the supply chain. Development type absorbs information from university laboratories or regional research institutions. Sources indicated in (ii) and (iii) are referred to as external linkages or sources (Roper et al., 2008; Berchicci, 2013; Tsuji et al. 2016; Shigeno et al., 2018). To identify the sources of ideas, the questionnaire included the following questions.

“When you attempt to develop a new innovation, what kind of circumstances do you often experience?” The innovation was:

1. Initiated at your firm based on transaction with customers
2. Initiated at your firm based on market trends
3. Proposed by partner firms based on the latest technical information

4. Initiated at your firm based on competitor trends
5. Initiated at your firm based on your own ideas
6. Proposals/requests from specific customers
7. Proposals/requests from suppliers
8. Other

2.2.4 Measure 4: Problem solving

Problem solving in the innovation process, whether it be product or process innovation, has also been considered as a factor for promoting innovation (Iansiti, 1995; Thomke & Fujimoto, 2000; Sharp & Gadde, 2008). It is difficult to discuss this in general and most previous studies examine this as a case study of a firm or industry. Thomke and Fujimoto (2000), for example, discusses the prevention of errors and mistakes in the production process in the automobile industry, while Sharp and Gadde (2008) takes the steel industry and examines problems related to marketing and after-sale services.

This paper asked questions concerning measures for coping with problems. The questions are limited to those related to technology.

“When it is difficult to cope with technology you own, how do you solve problems?”

1. Assign personnel and have them study the necessary technology
2. Have employees participate in outside seminars or workshops
3. Ask the parent (or an affiliated) firm to dispatch the necessary engineers
4. Ask firms other than the parent (or an affiliated) firm to dispatch the necessary engineers
5. Ask for advice from or conduct joint R&D with universities or public research institutions which possess the necessary technology
6. Hire mid-career engineers who possess the necessary technology
7. Search for firms which possess the necessary technology and seek licensing or a merger with them
8. Other

2.2.5 Measure 5: HRD

Excellent capabilities, motivation and work ethics of employees are indispensable for innovation. SMEs which suffer from shortage of skillful R&D engineers must rely on the improvements on the job shop, the success of which depends on the abilities of the engineers and workers (Jensen et al., 2007; Thomä, 2017; Tsuji et al., 2018). Japanese SMEs practice various types of HRD schemes including on-the-job training (OJT), off-the-job training (OFFJT), job rotations, pairing with skilled workers, and so on. These

were commonly found during the authors' field survey (Tsuji et al., 2017). From these examples, HRD is also a learning process. The importance of these stems from the fact that most new workers in SMEs are regular high school graduates and it takes a great deal of time and effort to train them to become skilled workers.

The following responses were prepared for multiple-choice questions:

1. Ask workers to improve their abilities at their own expense
2. Participation in seminars or workshops at the firm's expense
3. Ask the parent (or an affiliated) firm to offer training to elevate worker abilities
4. Ask other partner firms to offer training to elevate worker abilities
5. Transfer skills and know-how by pairing with skilled workers,
6. Arrange the environment to provide higher-level work to workers aiming to elevate their potential

2.2.6 Measure 6: Business development strategy

The business development strategy adopted by SMEs is also important for advancing innovation. Whether aiming for radical innovation, from which can be expected greater profit but entails higher risks, or incremental innovation, which yields smaller profits but has lower risks, depends on the resources which SMEs own. In the questionnaire, we asked about the business development strategy in the following manner:

“Please choose the item closest to the business strategy you are currently developing”

1. We emphasize the expansion and enhancement of existing business
2. We emphasize areas in which we can utilize our experiences with technology and R&D
3. We emphasize areas in which we can utilize our experiences with sales and distribution channels
4. We emphasize areas in which we can simultaneously utilize both technical and sales aspects
5. We emphasize creating growing markets and growing products which are not related to the past
6. We do not follow a fixed strategy, and respond flexibly each time

The above six questions concern the promotion of innovation upgrading and those that were found to be significant in the estimation were used as explanatory variables affecting upgrading. An empirical analysis will be conducted in what follows.

2.3 Effect of COVID19 on innovation: literature survey

The number of research on COVID19 is limited thus far, only its effect on macroeconomies or firm performances such as profit, but none is found in innovation, except China and India. Regarding the former, Han and Qian (2020) examine the relationship between the level of pandemic emergency and the amount of R&D investment using the fixed effect model based on quarterly panel data from 2019 (before the pandemic) to the second quarter of 2020 (during the pandemic). The sample is about 16,000 listed companies in China. The dependent variable is R&D investment, while independent variables are days of the highest pandemic emergency level and GDP. The latter is also used as an instrumental variable. The paper demonstrates R&D investment is positively related to the pandemic, implying firms increase R&D investment to cope with the pandemic.

Biswas (2020) examines the performance of Indian firms during the pandemic by using the DID (difference-in-differences) method, which is used in this paper. The model covers 4,100 listed firms and the quarterly data from 2016 to the second quarter of 2020 is used. The dependent variables are ROS (return-on-sales) and GI (growth of income). The samples are categorized into treatment and control groups, and the former consists of firms that have been engaging in R&D activities, whereas the latter includes firms without R&D activities. The estimation results show that before the pandemic two groups have similar performances of ROS and GI, whereas during the pandemic the treatment group has better performances than the control groups, indicating that R&D enhances the resistance to COVID19.

Although both papers obtained interesting results, namely R&D prevents firms from the pandemic, it is not clear why R&D resists the pandemic. In particular, the pandemic has been hindering R&D, which was revealed from authors' field research. R&D and the COVID19 pandemic is a key issue in this study.

3. Findings from field survey

This section summarizes findings from the field surveys with several local SMEs conducted in January and February 2022, which become the basis of hypotheses to examine and the interpretation of results.

3.1 Firm A

Firm profile:

Established in 1955; amount of capital 18 million JPY (US\$140 thousand); number of annual sales 500 million JPY (\$4 million); major products completed parts and components by prototype development; majoring in the R&D of prototype and its amount

of R&D investment is more than 5% of total sales. It conducts R&D with customers in its factories to realize their requests such as materials and shapes. It owns five axis machining centers.

Effect from COVID-19:

Orders have been reducing since the COVID-19 outbreak, and online communications became dominant with customers. In addition, they could not witness trial production or prototype, which delayed the innovation process. Since it is small SMEs, ideas for innovation come from discussions with customers. Once they obtained an idea, all related sections including owner and executives participate in the R&D project. Its factories did not close because of COVID-19, but the general affairs section conducted telework couple of days a week. Outside OJT courses were not opened, which hindered engineers training.

3.2 Firm B

Firm profile:

Established in 1906; capital 30 million JPY (US\$ 230 thousand); amount of sales 500 million JPY (\$4 million); number of employees 20-49. Major products automotive parts such as cable. This firm sells auto parts automotive assembles through trading companies, which amounts to 70% of its sales. R&D amounts to 1% of total sales. It does not own a specific R&D section. It improves quality of its products based on the ideas or comments of trading companies or customers. The products for exports are developed by itself.

Effect from COVID-19:

Their auto parts are manufactured based on manual work, since automation is difficult and effect of COVID-9 was great, since they closed the factory one day a week. Telework did not conducted well and efficiency and speed of works are disturbed. It planned to introduce factory automation, which had to be postponed because of declining sales. The trails of innovation were also postponed.

Regarding HRD, it invites guest engineers outside of the firm, but these were not conducted due to COVID-19. It also practices OJT with skilled workers, which is effective to promote skill of young workers. COVID-19 disturbed this OJT inside the firm.

3.3 Firm C

Firm profile:

Established in 1927; capital 90 million JPY (\$690 thousand); number of sales 5 billion JPY (\$40 million); number of employees 300; major products, complete parts of

transportation and environmental equipment. The total amount of sales dropped by 25% in 2021 and was expected to decline by 20% in 2022.

Effect from COVID-19:

Export dropped by 15% due to COVID-19, which hindered continuous innovation. In particular, they could not visit foreign customers such as Spanish and Korean so that it could not obtain information for innovation or improvement. So as meetings with firms in the same industries, which is also a source of information on innovation. It conducted OFFJT (off-the-job training) by sending its engineers to courses offered by academic associations. Due to COVID-19, all courses were cancelled for two years. Regarding the ICT system, it introduced accounting and production management systems. But telework in the purchasing section did not work well which damaged ordering works. Mobile phones were provided to all employees, but they use only LINE WORK. The ICT system needs to promote further.

3.4 Summary of Interviews and hypothesis

Here let us summarize the above interviews. Regarding innovation, COVID-19 affected in the following ways: (i) It became difficult to obtain information related innovation because they could not meet customers or buyers; (ii) communications were not well conducted in online meeting or telework among personnel engaging in such as prototype development, design, and production technology; and (iii) dispatching engineers to OFFJT or inviting outside specialists were unable to realized, which hindered HRD. Among the above difficulties due to COVID-19, the most important obstacles are to obtain information on innovation. Authors' previous studies on the innovation of Japanese SMEs show that they obtain information outside the firm, namely through channels such as transactions or supply-chain and joint research with universities and public research institutions (Tsuji et al, 2017; Shigeno et al, 2022). The former channel is referred to as "transaction channel," whereas the latter as "intellectual channel." Based on the above observations, in what follows the hypothesis will be postulated such that the COVID-19 pandemic and resulting online communications affected SMEs' innovation by hindering their obtaining information.

4. Data and method

4.1 Data

This empirical analysis is based on two questionnaire surveys on innovation upgrading conducted before the COVID-19 pandemic in 2014 and in 2022 during the pandemic. The former survey sent the questionnaire to 1,324 SMEs located in the *Hanshin* area, which

includes Hyogo and neighboring areas of Osaka Prefecture. To collect firms for sampling, lists owned by local governments, industrial organizations such as the chamber of commerce, and so on, were used. The number of valid responses was 221, and the ratio of valid responses was 16.6%. The latter survey was sent to the same 1,324 SMEs but the questionnaire contained questions related to COVID-19. 87 SMEs responded, and the reply rate was 6.5%.

4.2 Responses from SMEs

The realized innovations in 2014 and 2022 are shown in Table 1. The percentages of SMEs which achieved innovations reduced from 81.7% in 2014 to 74.4 % in 2021, implying COVID-19 affects negatively on innovation in general. But innovations of Stages 1 and 4 are increasing in percentage in 2021, whereas innovations of Stages 2 and 3 are reduced. Then it is difficult to see some trend in this data.

Table 1 Innovation in two periods

III- 2 Realized innovation	2014	2021	Total
Stage 1 Innovation based on existing technology and products	37(17.0)	22(25.3)	59(19.3)
Stage 2 Innovation based on existing technology and new products	60(27.5)	8(9.0)	68(22.3)
Stage 3 Innovation based on new technology and existing products	37(17.0)	11(12.6)	48(15.7)
Stage 4 Innovation based on new technology and products	44(20.2)	24(27.6)	68(22.3)
No innovation	40(18.3)	22(25.3)	62(20.3)
Total	218	87	305

Source: Authors

The level of the COVID-19 effecting innovation and factors of innovation discussed in Section 2 is summarized in Table 2. The level of effect was asked in terms of Likert five scales, namely “Greatly,” “Somehow,” “Normal,” “Not much,” and “Not at all.” Regarding innovation, SMEs which achieved innovation 1 and 4 replied that COVID-19 affected more negatively, whereas SMEs which achieved innovation 2 and 3 responded more negatively. It is noticeable that more SMEs responded that OVID-19 affected negatively to transactions with partners, implying the hypothesis postulated based on field survey in Section 3 is consistent with this data. Again, it is rather difficult to find common trend related to the factors of innovation, which requires a rigorous statistical analysis to determine.

4.4 Empirical methodology: PSM-DID

In using panel data, it is important to obtain true difference between two period, The simple observed comparison between two period may miss real difference, since observed difference contains unobservable difference on data due to the elapse of time, that is, real

difference can be expressed observed difference minus natural reduction. The DID (difference-in-differences) method is a quasi-experimental approach that compares the changes in outcomes over time.

Table 2 Level of COVID-19 effect on innovation and its factors

Effect of COVID-19 on	Level of negative effect				
	Greatly	Somehow	Normal	Not much	Not at all
Innovation (in general)					
Stage 1 Innovation based on existing technology and products	5 (6.3)	7 (8.9)	5 (6.3)	10 (12.7)	3 (3.8)
Stage 2 Innovation based on existing technology and new products	2 (2.5)	9 (11.4)	7 (8.9)	5 (6.3)	5 (6.3)
Stage 3 Innovation based on new technology and existing products	2 (2.5)	4 (5.1)	3 (3.8)	1 (1.3)	2 (2.5)
Stage 4 Innovation based on new technology and products	1 (1.3)	2 (2.5)	2 (2.5)	3 (3.8)	1 (1.3)
Transactions with partners (in general)					
Large firms	12 (15)	19 (23)	2 (2)	11 (13)	1 (1)
SMEs	11 (13)	17 (21)	3 (4)	6 (7)	0 (0)
Sources of information on costumers, suppliers, markets, etc.					
Customers	5 (5.2)	12 (12.4)	14 (14.4)	11 (11.3)	12 (12.4)
Suppliers	4 (4.1)	4 (4.1)	4 (4.1)	5 (5.2)	7 (7.2)
Partners of open innovation					
Customers	3 (13)	5 (21.7)	4 (17.4)	5 (21.7)	6 (26.1)
R&D problem solving					
Appoint employees to study by themselves	6 (4.4)	9 (6.6)	7 (5.1)	10 (7.3)	
Ask for advice or conduct joint R&D with universities	5 (3.6)	9 (6.6)	7 (5.1)	15 (10.9)	
Send employees to seminars or training	5 (3.6)	7 (5.1)	7 (5.1)	11 (8.0)	
HRD problem solving					
Send to seminars and training with firm's expense	3 (3.4)	13 (14.8)	9 (10.2)	14 (15.9)	21 (23)
Transfer skills and know-how by pairing with skilled workers	2 (2.3)	4 (4.5)	7 (8)	7 (8)	8 (9.1)

Source: Authors

In comparing two groups, care should be taken for difference of samples, otherwise the results obtained may contain biases. To avoid this, it is required to choose the samples with the same characteristics among two groups, and this can be achieved by the PSM (propensity score matching) method. PSM is thus to reduce sample selection bias. PSM-DID is the combination of these two, which is initiated by Heckman et al. (1997, 1998b). There are various methods to estimate policy or event. The cross-section analysis which uses the data after events occurred and compares the ex-post situation with that of before the event occurs contains some ambiguity. On the other hand, although panel data analysis is more accurate than cross-section analysis, it cannot use the data before the event occurs since such data does not exist. We claim that this problem can be solved by using PSM-DID (propensity score matching-difference in differences) by comparing two groups: one is affected by the event and another is not. PSM-DID can cope with the above two sources of bias; PSM can takes care of sample selection bias and DID time trend. This method is used for the evaluation of policy. Some examples are found in Todo (2011) which examines the human resources development program in Indonesia, and Tsuji (2015)

estimates the amount of the reduction in medical expenditures by using telemedicine in the rural town in Japan.

This paper aims to estimate the effect of COVID-19 on innovation as accurate as possible by avoiding the above two biases. However, this paper faces two additional serious challenges: grouping and identifying sample firms. First, grouping must be based on a factor which firms can choose. In case of Todo (2011) and Tsuji (2015), the samples are divided into those receive or those did not receive the service from the programs, which is quite clear. On the other hand, the effect of COVID-19 is entirely different, namely all samples suffer COVID-19 and then they cannot be divided into those suffered COVID-19 and those did not suffer. Second, another challenge is the number of samples. This paper uses authors' two mail surveys conducted in 2014 and 2022; eight-year differences make the sample size smaller because of bankruptcy or moving offices, and so on. We need some method to take care of the reduction of samples.

4.5 Construction of two groups

To conduct PSM-DID estimation requires samples to be divided into two groups. In this paper, as mentioned earlier, it is natural to divide samples by whether innovation of firms is affected by COVID-19 or not. But according to PSM-DID, grouping should be based on the question which firms can be choose. Whether infected by COVID-19 is not the decision of firms, and accordingly this cannot be used for grouping. Then, from the results of field surveys, it is postulated that COVID-19 influences communications with partners of open innovation and then affects innovation. SMEs can decide whether they practice open innovation or not. The procedure of examination is to analyze firstly whether there is any effect of COVID-19 on their open innovation. If any, then secondly we can assert COVID-19 affects innovation via open innovation.

The following Question IV-5 is used for categorizing two groups.

IV-5: Is your company practicing to develop new technology or new product with agents outside the firm? Please choose the most suitable answer:

1. Practicing, 2. Not, 3. No plan to practicing

Depending their replies to IV-5, samples are categorized into two groups:

SMEs practicing open innovation (replied 1)

SMEs not practicing open innovation (replied 2, and 3)

The firms responded 1, 2, and 3 are referred to as the treatment group, whereas those responded 4 and 5 as the control group.

It is required to use firms as samples which respond two mail surveys, and 32 firms are found to satisfy this. DID was conducted to these 32 firms which were divided into two groups based on their replies to the above question IV-5. Since the sample size is too small to obtain meaningful results. To raise the number of firms to examine, the following procedure is used by PSM. Firms replied either of two surveys are divided into two groups based on IV-5. Firms in the treatment group answered either of surveys, but the samples of PSM-DID must reply both surveys. One firm replied to the survey 2014 must find a “similar” firm replied to the 2022 survey. This similar firm is considered as the “same” firm in 2022. Then PSM is applicable to this matching. The similarity of attributes of firm is expressed by the “propensity score” calculated PSM. Firms with the same propensity score in both 2014 and 2022 are considered as the same firm, making DID to be employed (Ichikawa and Tsuji, 2016).

Stata, v. 17 used for estimation can identify the firm with the same score, but the score itself is not shown. 24 firms are matched and then the total number of samples become 56 for each group by adding 32 firms which originally replied to both surveys.

4.6 Result of matching

The number of SMEs in both groups increases by the help of the matching scheme of PSM. Here we verify that SMEs in each group are the “same” firms by examining whether there is a real difference between the averages in two groups. In this section, the number of employees, sales in the previous three years, the sales trend, profit in the previous three years are selected to verify two groups consists of firms with the same propensity score. t-test was conducted to examine whether there is any difference between two groups in terms of the following four variables: the number of employees (Table 3); sales in the previous three years (Table 4); and Profit in the previous three years (Table 6). The results of above t-test data indicate that two groups have SMEs with the same propensity score.

Table 3 Result of t-test (number of employment)

Group	Obs	Mean	Std. err.	Std. dev.
Control group (0)	67	4.343	0.156	1.274
Treatment group (1)	44	4.386	0.235	1.558
Combined	111	4.360	0.132	1.387
Diff		-0.043	0.270	

diff = mean(0) - mean(1) t = -0.1594
 Degrees of freedom = 109

Table 4 Result of t-test (Sales in the previous three years)

Group	Obs	Mean	Std. err.	Std. dev.
Control group (0)	63	3.714	0.195	1.549
Treatment group (1)	43	3.884	0.243	1.592
Combined	106	3.783	0.152	1.561
Diff+		-0.169	0.310	

diff = mean (0) – mean (1) t = -0.5467
 Degrees of freedom = 104

Table 5 Result of t-test (Trend of sales)

Group	Obs	Mean	Std. err.	Std. dev.
Control group (0)	39	1.897	0.126	0.788
Treatment group (1)	40	1.950	0.107	0.677
Combined	79	1.924	0.082	0.730
Diff		-0.053	0.165	

diff = mean(0) - mean(1) t = -0.3182
 Degrees of freedom = 77

Table 6 Result of t-test (Profit in the previous three years)

Group	Obs	Mean	Std. err.	Std. dev.
Control group (0)	68	1.971	0.091	0.753
Treatment group (1)	43	1.744	0.116	0.759
Combined	111	1.883	0.072	0.760
Diff		0.226	0.147	

diff = mean(0) - mean(1) t = 1.5391
 Degrees of freedom = 109

These three test shows that there is no difference between treatment and control groups, and it becomes ready to employ DID.

5. Result of estimation

5.1 Probit estimation

According to the standard procedure of PSM-DID, first the probit estimation was conducted to identify factors which cause the grouping of sample firms. The summary statistics of variables used for the estimation and the result of probit estimation are shown in Table 7 and 8, respectively.

Table 7 Summary statistics

Variables	Obs	Mean	Std. dev.	Min	Max
Practicing open innovation	112	0.393	0.491	0	1
Number of employees	111	4.360	1.387	1	9
Sales in the last year	106	3.783	1.561	1	7
Sales in the past three years	79	1.924	0.730	1	3
Profit in the past three years	111	1.883	0.760	1	3

Table 8 Result of probit estimation

Practicing open innovation	Coefficient	Std. err.	z	P>z
Number of employees	0.137	0.158	0.87	
Sales in the last year	0.058	0.157	0.37	
Sales in the past three years	0.355	0.197	1.81	*
Profit in the past three years	0.135	0.209	0.65	
_cons	-1.435	0.846	-1.7	

Only the number of sales in the past three years is statistically significant in Table 4, indicating that firms consider the trend of sales whether participating open innovation or not. Based on probit estimation, PSM with the trend of sales as a variable was conducted, and the result is shown in Table 9.

Table 9 Result of PSM estimation

Achieving innovation	Coefficient	AI robust std. err.	z	P>z
ATE Whether practicing open innovation or not: Yes=1, No=0 (1 vs 0)	0.185	0.056	3.31	***

Note : ATE; Average effect of treatment

Table 5 indicates that eliminating sample selection bias, SMEs practicing open innovation have higher probability to achieve innovation than those do not practicing. The objective of this paper is to show how COVID-19 affected innovation, which requires DID to examine.

5.2 Result of DID

The next step is to estimate DID by using the variable which is significant in Table 4, which is the trend of sales. The result of estimation is shown in Table 10.

Table 10 Result of DID estimation

Achieving innovation	Coefficient	Robust std. err.	t	P>t
ATET Whether practicing open innovation or not: Yes=1, No=0 (1 vs 0)	0.275	0.080	3.42	***

Note: ATET: Average effect of treatment on the treated

The coefficient is significantly positive as shown in Table 10, implying that the treatment group has higher probability to achieve innovation than the control group. The former has

been practicing open innovation, while the latter has not. This result is entirely different from the original conjecture such that COVID-19 has an effect negatively on innovation. This result show that SMEs practicing open innovation are tolerant to COVID-19 and then innovation is not reduced, which is the similar result to Biswas (2020).

The main reason for this result is that participating open innovation is not a sole reason for innovation, but other measures such as R&D ability and management, technological capacity such as the number of patents or the level of engineers, human resources, quality control (QC) of all workers and engineers, managerial strategy of top management, and so on which were presented in previous 2.2. AThis paper does not use these measures, which leads to this result.

From the data shown in Table 1 may suggest this result. Let us compare the number of SMEs which achieve innovation in 2014 and 2022. The ratios of successful SMEs which achieved innovation in 2014 and 2022 are 81.7% in 2014 and 74.7% in 2022, indicating the ratio decreases, which may due to COVID-19. But Table 2 indicates that the level of effect on sources of information on customers, markets, etc. due to COVID-19. Regarding “Customers” and “Supplier” which are main partners of trade, 25 SMEs (32%) replied “Greatly” or “Somehow” affected by COVID-19, whereas 35 SMEs (44%) replied “Not at all” or “Not much,” indicating that SMEs which were not affected by COVID-19 are greater than SMEs replied as affected. These data may show that COVID-19 did not affect that much. These may indicate that their innovation system is robust against sudden disturbance, which will be discussed in the next section.

6. Discussions and conclusion

6.1 Characteristics of innovation process

The authors have been investigating the nature of innovation process of Japanese SMEs for many years and it is summarized in Table 11 (Tsuji et al, 2017) and the results obtained in this study are closely related to their specific characteristics of SMEs.

It is crucial for SMEs to obtain ideas or seeds of innovation. In the case of SMEs producing final products, searching, and finding seeds of innovation is carried out under their own responsibility, and owners are responsible for innovation. The owners are generally engineers with knowledge, skills, ideas, and experience, and at the same time they can manage all aspects of a firm, including marketing, HRD, and so on. They can independently invent new products and discover new production processes, and at the same time, they collaborate with universities or public research institutions to develop new products. The research institutions also need such SME owners as practitioner to

bridge theory and reality. The channel of information from these institutions to SMEs is termed by the intellectual channel.

Table 11 Types of innovation in Japanese SMEs

	Improvement type	Development type	Owner type
Number of employees	Large	Medium	Small
Type of product	Material and simple parts	Final products and complete parts	Simple and complete parts
Type of production	Make-to-stock, or mass production	Build-to-order, OEM	Build-to-order
Type of innovation	Process	Product	Product
Seed of innovation	Claim and model change of customers	Technology	Technology
Source of information	Custmors	Universities and other firms	Universities and other firms
Type of R&D	Formal and informal	Formal	Informal
R&D personnel	30-45 (R&D section)	19 (R&D section)	None
	150 (factory)	14 (factory)	
Cross functional team	Engineers and marketing	Less active	None
HRD of engineers	OJT	Own effort	OJT (intensive)
Evaluation system of workers' ability	Five scales of achieved skills	Less	Skill map for particular machine and operations

Source: Tsuji et al. (2017)

In contrast, when the products are simple parts or materials, seeds of innovation come basically from customers of their products. Typical examples are as follows: (a) model changes in the final product, (b) claims from customers, and (c) improvement of product quality. At the time of a model change in the customer's final product, SMEs which supply materials or parts are required to change their products, which, in a sense, is their innovation. That is, innovation initiated in one firm is transmitted to other firms via the supply chain. Due to customer claims regarding quality, SMEs as parts suppliers are required to improve their manufacturing process, which also implies process innovation. Thus, this channel of information is termed by the transaction channel.

The concept of open innovation consists of the above two channels, which characterizes the nature of SME innovation in Japan. One more important feature is that open innovation is based face-to-face communications. Accordingly, it is expected that the COVID-19 pandemic has been impeding information flow in the open innovation network, but the result of this paper is entirely different from this observation, implying that the innovation system of Japanese SMEs shown in Table 11 is much more robust. This is authors' next research question.

5.2 Direction of further study

Although this study has some merits such as initiating an impact analysis of COVID-19 pandemic on innovation, there are some points to be improved. The pandemic has been contemning more than three years, and when it terminates, the final effect can be analyzed. Innovation needs some time from idea to commercialization and three years are too short to obtain definite results. It requires to continue questionnaire and field surveys to update data.

Regarding the empirical method, the sample size of this analysis is 87 which may be small to obtain definite results. The original idea of this analysis was to construct the panel data of the same SMEs in two periods and thus the questionnaire of the second survey were sent to the same SMEs of the first survey. Only 32 SMEs responded to two surveys. The number of samples is too small. To cope with this, PSM-DID was employed. Since it is impossible to obtain the data prior to the pandemic, a cross-section analysis is one alternative and more considerations are required to construct questionnaire to examine the effect of the COVID-19 pandemic.

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