An impact analysis of COVID-19 on the relation between open innovation, IP openness and firm performance

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Research

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Abstract

This study empirically investigated how pre-COVID innovation activities and IP management affected business performance after the arrival of COVID-19. As a result, the following three points were clarified: First, the high level of R&D investment before the arrival of COVID-19 weakened the damage to sales and operating profit after its arrival. Second, we found that the firms that launched new products and services four years before the arrival of COVID-19 suffered more damage from COVID-19. Third, although innovation activities are vulnerable to the crisis as a whole, there are cases in which firms have not lost or improved their performance even after the arrival of COVID-19. Specifically, it became clear that the damage caused by COVID-19 was lesser for collaborative innovations involving many firms than for innovations realized by single firms. This was also demonstrated from the perspective of open IP management.

Introduction

COVID-19 caused a global economic crisis due to the loss of demand and depressed supply capacity (Apedo-Amah et al., 2020). EU countries recorded a historic downturn in economic activity in March and April 2020. Among them, manufacturing was considered one of the most severely damaged industries (ILO, 2020). In this context, studies have been conducted since mid-2020 that have attempted to quantitatively measure the impact of COVID-19 on businesses.

However, we have not seen enough research focusing on the relationship between firms' R&D and innovation activities in pre-COVID times and their business performance. Particularly, very few studies target the impact of the economic crisis on open innovation activities and business performance. One of the reasons for this is that open innovation has been gradually gaining momentum since the 2000s, especially since the 2010s when it spread worldwide. COVID-19 was the first global economic crisis since the global financial crisis of 2008 and the first crisis since the advent of the open innovation era.

Therefore, this study highlights the relationship between firms’ pre-COVID open innovation activities and the impact of COVID-19 from the perspective of business performance, such as sales and operating profit. This study empirically examines what kind of collaborative performance builds resilient and crisis-resistant open innovation activities. Economic crises, such as the global financial crisis in 2008 and COVID-19 in 2019, repeat intermittently. The Japanese economy faced the Great East Japan Earthquake in 2011. By clarifying the research agenda, this study aims to contribute to the preparation for the next crisis.

This study aims to make the following three academic and social contributions: First, it visualizes the relationship between a firm’s pre-COVID innovation activities and outcomes, and the impact of COVID-19. The presence or absence of the impact could change depending on how the firm conducts R&D and other innovation activities. Intuitively, firms with high R&D intensity seem to have suffered little or no damage from COVID-19. However, there is still very little evidence for this.

Second, this study provides a deep examination of the impact of COVID-19 and open innovation activities that involve a wide variety of collaboration partners. Effective knowledge and technology could come from external organizations, including suppliers, users, universities, competitors, and firms in different industries (Laursen & Salter, 2006; Laursen, 2012). In fact, several studies have also demonstrated that the use of external knowledge enhances the performance of innovation activities (e.g., Grimpe & Sofka, 2009; Garriga, von Krogh, & Spaeth, 2013; Nishikawa & Kanama, 2019). This study sheds light on whether a firm's pre-COVID open innovation activities reduce the damage from COVID-19, and if the answer is yes, what kind of open strategies and collaborations could minimize the damage.

Third, this study analyzes the relationship between the appropriability of innovation activities and the damage caused by COVID-19. While many advantages of open innovation have been reported, there is also research reports claiming disadvantages and challenges to business openness. One of them is the combination of openness width and appropriability (Lausen & Salter, 2014; Dahlander & Gann, 2010). Therefore, we also examine what kind of open intellectual property (IP) management suffers less damage from COVID-19.

Literature Review And Hypothesis Generation

2.1. R&D and innovation activities and COVID-19

Research reports examining the impact of COVID-19 on firms' innovation activities are gradually being conducted. Among them, Han (2020) used a fixed-effects model to demonstrate the impact of COVID-19 on R&D activities, focusing mainly on the Chinese manufacturing industry. They reported that COVID-19 increased R&D expenditures regardless of the size of the firm. In contrast, some studies have reported that COVID-19 has decreased R&D expenditures in other countries (Barrero et al., 2020). This may be because many firms have reduced their liquid assets to survive situations where demand has disappeared due to lockdowns, and efforts are being made to maintain employment and payroll as much as possible under such circumstances (Bosio et al., 2020).

However, these studies only measure the impact of COVID-19 on R&D activities and not on how it affects the firm's performance. In this regard, Biswas (2021) study measures and evaluates the relationship between COVID-19 and R&D on a sales basis. This study uses the cumulative abnormal return method and the difference-in-differences method for fixed effects, which are frequently used in event study evaluations. It does so to measure and evaluate the relationship between COVID-19 and R&D investment in listed manufacturing firms in India, demonstrating that R&D investment in the period immediately before COVID-19 weakens the damage to R&D activities and sales after the COVID-19 outbreak.

Moreover, Zouaghi et al. (2018) report that firms that had invested in innovation before the 2008 global financial crisis were more likely to mitigate the damage due to the crisis on innovation performance. Related to this, in a European study, firms with higher R&D intensity maintained higher business performance during and after the global financial crisis (Lome et al., 2016). In addition, in a study in

Korea, investment in R&D in the past led to a higher survival rate in the Korean market during the global financial crisis (Jung et al., 2018).

Following the above discussion, we generate the following hypothesis.

Hypothesis 1-1: Firms with higher R&D intensity before COVID-19 suffer less damage from COVID-19

Prior studies have rarely examined how firms that achieved single or multiple innovations just before COVID-19 were affected after the arrival of COVID-19. Brem et al. (2020) and Zouaghi et al. (2018) found that the global financial crisis had negatively impacted productivity and innovation. However, they did not compare the impact of the crisis on firms that were innovative before the crisis and those that were not. Intuitively, as in the case of R&D investment, the more innovative a firm is, the more likely it is to suffer less damage from COVID-19 by responding flexibly to changes in the market. However, innovations that were realized just before COVID-19 may not have been launched as products or services for a long time and may not have been fully established in the market. In this case, it is possible that businesses that have just launched new products and services are more vulnerable to the damage caused by COVID-19.

Thus, very few studies that have empirically demonstrated the relationship between the realization of innovation and COVID-19. Given that the estimated results could swing positively or negatively, this study generates and tests the following hypotheses.

Hypothesis 1-2: The damage caused by COVID-19 is less for firms that achieved product innovation before COVID-19.

2.2. Open innovation activities and COVID-19

As the knowledge and technology required in innovation activities are becoming more sophisticated, it is important to use widely distributed knowledge and technology in society to create new value (Laursen, 2012). Past research on open innovation includes research on the relationship between open innovation activities and business performance (e.g. Laursen & Salter, 2006; Mazzola, et al., 2012), research on diversification of open innovation activities (e.g., Nishikawa & Kanama, 2019; Belderbos et al., 2010), research on the relationship between standardization and platform business (e.g., Fehrer et al., 2018; Tatsumoto et al., 2010), and research on the relationship between appropriability and IP management (e.g., Laursen & Salter, 2014).

These studies show that firms that successfully open their R&D maintain their competitiveness, at least for a certain period. In addition, the previously observed collaboration that includes not only firms within their own group, suppliers, and universities, but also customers and others, builds a strong platform and enables long-term monetization (Jacobides, 2019). Empirical studies of firms in Japan have also shown that firms that realize innovations in collaboration with other organizations are more successful in monetizing them (Kanama & Nishikawa, 2017a).

Therefore, this study generates the following hypotheses to test the relationship between the openness of R&D activities and the impact of COVID-19.

Hypothesis 2-1: The impact of COVID-19 is smaller for innovations realized in collaboration with other firms than for innovations realized by the firm alone.

Hypothesis 2-2: The greater the number of collaborating partners in innovation activities, the smaller the impact of COVID-19.

2.3. Open IP management and COVID-19

When collaborating with external organizations, firms need to protect their technology and knowledge in some way (Breschi & Veugelers, 2002; Breschi & Lissoni, 2001). Firms must be open to some degree regarding their own knowledge to obtain knowledge from, or collaborate with, external organizations. In contrast, collaborating with external organizations and opening up about their own technologies involve the risk of confidential information leaks (Breschi & Lissoni, 2001; Cassiman & Veugelers, 2002). To deal with this unexpected leakage, firms have taken various defensive measures through legal procedures, including patents and design rights (Grimpe & Hussinger, 2014).

It is also said that the use of one type of IP encourages the use of other types of IP (Gambardella & Giarratana, 2013). For example, there are many cases where design rights are obtained at the same time as patents, or where technology that is not legally entitled is made a trade secret as separate know-how (Hussinger, 2006). In other words, IP does not function alone, but is mutually complementary (Cohen et al, 2000). Therefore, although it has been pointed out that IP is only a part of the results of R&D (Levin et al., 1987), the effect of the proprietary potential of legal protection on the monetization of innovation as described above has been confirmed (Arora & Gambardella, 2010). Therefore, we propose the following hypotheses:

Hypothesis 3-1: The more diverse are the obtained IP rights, the smaller the impact of COVID-19.

However, such legal protection is not complete, and useful technologies and knowledge will eventually be spilled over not only through written knowledge propagation, such as patents, but also through the withdrawal of engineers (Fujiwara & Watanabe, 2013) and reverse engineering (Hussinger, 2006). Therefore, firms need to increase the appropriability of their own technologies, and seek an open strategy to disclose certain technologies and knowledge themselves to maximize the results of collaboration with outside parties (Perkmann & Walsh, 2009). In a recent study on more than 1,000 Japanese firms, it was found that the more diverse the IP rights a firm had, the more likely it was to provide technology and have higher business performance (Kanama & Nishikawa, 2017b). Therefore, we propose the following hypothesis:

Hypothesis 3-2: The more collaborative is the means of IP utilization, the smaller is the impact of COVID-19

Methodology

3.1. Data

The dataset for this study consists of questionnaire results from 172 firms in Japan. The questionnaires were mailed sequentially starting in September 2020, and the sample population consisted of 134 firms from which data were collected until January 2021. The collection rate was 78%.

The questionnaire consisted of 16 questions, including four questions on the face sheet. The questions were designed based on the 4th National Innovation Survey conducted by the National Institute of Science and Technology Policy of the Ministry of Education, Culture, Sports, Science, and Technology. However, given that the survey has numerous of questions and places a heavy burden on the respondents, we used the survey as a reference but simplified it.

Table 1 presents the main descriptive statistics. The median sales amount was 7.4 billion yen, and the median number of employees was 260, which indicates that the number of small to medium-sized firms is slightly larger than that of large firms. Most previous studies have analyzed listed firms, and as a result, large firms have been the focus of the sample. As mentioned earlier, large firms generally have diversified businesses, therefore, it is difficult to interpret the impact of COVID-19 from a firm-level analysis. Normally, a subsample should be set up for each business, but if this is done, the difficulty of constructing the dataset will rapidly increase. In contrast, given that the scale of management of most of the firms in this study is not that large, we believe that the impact of COVID-19 is relatively straightforward and leads to the management performance of the entire firm. In terms of industry, 78 firms (58%) were in the manufacturing industry while 56 (42%) were in the non-manufacturing industry.

After the questionnaire survey was completed, additional interviews were conducted with five of the firms that responded to the questionnaire to supplement the interpretation and discussion of the results. The interviewees were the heads of the new business planning departments (two firms), the heads of the technology development departments (two firms), and the representative directors (one firm).

3.2. Estimation and variables

To examine the hypotheses, the following estimation model (1) is used:

$$damage_i = \alpha + \beta \times OpenInno_i + \sum_{k=1} \gamma_k X_i + \varepsilon_i \quad (1)$$

The subscript i denotes the person who posted the idea, α, β, and γ are the parameters to be estimated, and ε is the error term according to N(0,δ_ε^2). For the dependent variable, damage, we used the results for the impact of COVID-19 on sales and operating profit. Respondents were asked to choose between "increased," "unchanged," and "decreased" as of September 2020 for both sales and operating profit. In addition, the parameters were estimated using logistic regression, with "increased" or "unchanged" coded as 1 and "decreased" as 0.

The six explanatory variables are as follows: R&D intensity (the average ratio of total R&D expenditures to sales) from 2016 to 2019 (Hypothesis 1-1), product innovation (new or improved products introduced to the market between 2016 and 2019) (Hypothesis 1-2), dummy variables with 0 for products and services developed by the firm alone and 1 for products and services developed in collaboration with other institutions between 2016 and 2019 (Hypothesis 2-1), how many institutions did the firm collaborate with among those who answered 1 in Hypothesis 2-1 (minimum value 1, maximum value 5) (Hypothesis 2-2), the number of acquired or exercised IPs among patent rights, design rights, trademark rights, copyrights, and trade secrets between 2016 and 2019 (minimum value: 0, maximum value: 5) (Hypothesis 3-1), and the number of IP collaboration measures with other firms (Hypothesis 3-2).

Four control variables were set: the number of employees in 2019, a sales increase dummy (1 if sales increased from 2016 to 2019, 0 otherwise), a manufacturing industry dummy (1 if the firm is a manufacturer, 0 otherwise), and a public support dummy (1 if the firm received some kind of public support for innovation or R&D activities between 2016 and 2019, and 0 otherwise).

Estimation Results

Tables 2 and 3 show the estimation results with sales and operating profit as the dependent variables, respectively.

First, focusing on the results of hypothesis 1-1 regarding R&D intensity, the coefficients for sales were positive and statistically significant at the 1% level (Model 4), and those for operating profit were positive and statistically significant at the 5% level (Model 8). Therefore, hypothesis 1-1 was supported. This is in line with Biswas (2021) results, who found that R&D investment immediately before the arrival of COVID-19 weakened the damage to sales after its arrival. It is also consistent with Lome et al.'s (2016) results, who found that firms with higher R&D intensity showed higher business performance during and after the global financial crisis.

Next, confirming the results on product innovation for hypothesis 1-2, both sales and operating profit are negative and statistically significant at the 0.1% level. Therefore, hypothesis 1-2 is rejected. This hypothesis was generated with very little prior research to support it, so it was tested with the weakest evidence. However, the results show that, contrary to Hypotheses 1-2, the damage caused by COVID-19 is greater for firms that achieved product innovation before COVID-19.

Confirming the estimation results of Hypotheses 2-1 and 2-2 regarding open innovation, positive statistical significance was obtained at the 1% or 5% level for sales and operating profit with and without collaboration with other firms, and at the 5% level for sales only for the number of collaboration partners. Therefore, hypotheses 2-1 and 2-2 were supported to some extent. It can be considered that the damage from COVID-19 is smaller when the innovation is realized in collaboration with other firms than when it is realized by the firm alone.

For hypotheses 3-1 and 3-2 regarding Open IP, a positive statistical significance was obtained at the 1% or 5% level for sales and at the 1% or 0.1% level for operating profit. Therefore, hypotheses 3-1 and 3-2 are supported. As in the case of open activities in Hypothesis 2, COVID-19 damage is smaller for firms that actively engage in open IP activities.

Finally, confirming the results for the control variables, no statistical significance was obtained for firm size. Previous studies have reported the severity of damage to small- and medium-sized firms, especially in Europe, but this was not confirmed in this study. However, the dataset of this study does not have a sufficient sample of large firms in particular, and instead, it includes many medium-sized firms. Therefore, it is possible that statistical differences did not appear clearly. In contrast, the manufacturing dummy was negative and statistically significant at the 0.1% level. This is consistent with some previous studies (e.g., Apedo-Amah et al., 2020).

Discussion

5.1. High R&D intensity and the impact of COVID-19

Similar to several previous studies, this study found that R&D investment up to just before the arrival of COVID-19 weakened the damage to sales after its arrival. From a practical standpoint, it is easy to see how a firm investing in R&D just before the economic crisis hit determines its performance during the crisis. Such firms will be able to respond to sudden changes in demand and launch new products and services ahead of other firms when the crisis hits.

As an interpretation of this result, Biswas (2021) identifies the resource-based view as a theoretical pillar. According to Wernerfelt (1984), R&D investment strengthens a firm's internal core competence, which, in turn, increases the likelihood of winning the innovation race in the market. Thus, R&D investment strengthens a firm's internal core competence, and therefore, increases its likelihood of winning the innovation competition in the market. Even after this research report, many empirical studies have reported a positive relationship between firms' R&D activities and managerial performance (e.g., Hashi & Stojcic, 2013; Raymond et al., 2015).

Furthermore, additional interviews confirmed the following facts about the relationship between R&D investment and COVID-19. [1] “Our firm does not have a break in R&D investment. As a result, we have several development projects that were suspended in the past due to unpredictable demand. However, one of them emerged as a possibility to meet the customer's needs arising from the COVID-19, and we responded to it in a hurry”. (A head of the technology development department) [2] “Because the customer's demand had rapidly decreased or changed, the R&D staff was hastily pasted onto the sales staff to uncover the demand. At that time, we felt that we should do whatever we could, but two of those projects may become the mainstay even after COVID-19”. (A vice president of bio-tech firm)

In this way, rather than simply having a high R&D intensity, the firm's flexible management has been successful in taking advantage of it.

5.2. Relationship between COVID-19 and the realization of innovation in the past

In previous studies, there was little discussion on how innovations realized just before COVID-19 were affected after its arrival. In this study, we hypothesized and tested the hypothesis that firms that realized product innovation before COVID-19 would suffer less damage from COVID-19. However, the results showed the opposite. In other words, the damage caused by COVID-19 may be greater for firms that have just launched a new product or service.

In this study, we conducted an additional analysis using the results of the responses regarding the 14 strategies to examine them in more detail. In the questionnaire, respondents were asked to choose from "achieved the goal," "achieved the goal to some extent," "did not achieve the goal," and "did not adopt the strategy" between 2016 and 2019 for 14 strategies related to innovation. Of these, we set an explanatory variable of 1 when either "achieved the goal" or "achieved the goal to some extent" was selected for the five strategies of new product development, new production methods, new channel development, cross-industry collaboration, and data utilization, and conducted a multiple regression analysis with sales and operating profit set as the dependent variables as before. The results are listed in Table 4.

As a result, the coefficients of new product development and new production methods are both negative and statistically significant. This suggests that product innovation and process innovation, which were realized just before COVID-19, may still have suffered relatively large damage. In other words, at the very least, simply promoting innovation activities was not enough to minimize the damage due to COVID-19; rather, it exposed the vulnerability of innovation activities to the economic crisis.

In contrast, positive and statistically significant results were obtained for data utilization and cross-industry collaboration. Of these, data utilization is a feature of COVID-19 that is different from past global economic crises (McKinsey, 2020). According to a survey by the World Bank, 51% of firms are ramping up DX-related investments in 2020, such as improving IT skills, augmenting network environments, expanding digital platforms, and sharing data in supply chains (Apedo-Amah et al., 2020).

5.3. Relationship between Openness in R&D and COVID-19

Hypothesis 2, which states that the damage from COVID-19 is smaller for innovations realized in collaboration with other firms than for innovations realized by the firm alone, is supported. Table 4 also shows that the damage from COVID-19 is smaller for firms that have realized cross-industrial collaboration. In the previous section, we showed that innovation activities in Japan may be generally vulnerable to the economic crisis. However, there are some cases that have not suffered damage and have even improved their business performance after the arrival of COVID-19. Why are businesses that open up their innovation activities more resilient to crises in this way?

To confirm the results in detail, the relationship between the number of partner institutions and COVID-19 damage is shown in Figure 1. The minimum number of collaboration partners is one, and the maximum is six, specifically suppliers, customers, competitors, universities and public research institutions,

consultants, and NPOs. Of these, only two firms collaborated with all six organizations, so we removed them. As a result, the resistance to COVID-19 damage became stronger until the number of collaborators reached about three, and then saturated after the number reached four. The reasons for this result are summarized in the following two points based on the results of interviews with the five firms and previous studies.

The first is the high level of knowledge absorption and utilization in firms that have achieved innovation through cross-industrial collaboration, which has been widely recognized by Cohen & Levinthal (1990). Whether they have complementary assets is also important to search and access new knowledge (e.g. Arora & Ceccagnoli, 2006). All five firms interviewed had steadily accumulated these capabilities, and as a result, were able to demonstrate these capabilities even during the COVID-19 crisis.

Second, by having several collaboration partners, they secured a diversity of markets and sales channels for access. In particular, by collaborating closely with customers and other parties, it is possible that the firm is able to access more markets than it would be able to innovate on its own. As a result, it diversifies risks such as a significant drop in sales. However, even if they collaborate with many institutions, they are likely to be limited by their own organizational capabilities (Nishikawa & Kanama, 2019).

5.4. Open IP management and the impact of COVID-19

Openness in R&D can be broadly classified into "bringing external technology and knowledge into the firm (hereinafter referred to as "technology introduction")" and "sending internal technology and knowledge to the outside world (hereinafter referred to as "technology provision")." It is necessary to manage the innovation process from both perspectives. In the design of this study, there were three items related to IP outbound, three items related to IP inbound, and one item related to cross-license. Therefore, we integrated each of these items as IP outbound, cross-licensing, and IP inbound, and conducted multiple regression analysis with sales and operating profit as the explained variables as before. The results are listed in Table 5.

Regarding research on openness in R&D, it has been suggested that analyses focusing on technology adoption have accumulated richer knowledge than those focusing on technology provision (Felin & Zenger, 2014; Gassmann et. al., 2010). Most analyses of technology adoption have examined the relationship between the adoption of technologies located outside the firm (e.g., at universities, users, or venture firms) and innovation outcomes. As a result, it has been reported that the probability of producing innovation increases through technology adoption, and the quality of innovation also improves—these are becoming standardized facts today (e.g. Darby et al., 2004; Lööf & Brostrom, 2008; Momjon & Walbroeck, 2003; Motohashi, 2005; Robin & Schubert, 2013).

However, empirical studies on technology provision have been somewhat slower. This is because firms have not been able to clearly present their incentives for providing technology to other firms. Providing technology to other organizations creates potential competitors in the market. Therefore, from the perspective of traditional theoretical models that seek incentives to conduct R&D in terms of the benefits

of technological anticipation, the provision of knowledge and technology to other firms is a corporate behavior that is difficult to understand (Gilbert & Newbery, 1982; Reinganum, 1983). In this context, recent empirical studies on outbound have increased (e.g., Anado & Khanna, 2000; Takechi, 2008; Nagaoka, 2009; Lichtenthaler, 2010; Dang & Motohashi, 2014). The strength of these firms is that they can create new business models.

One of the strengths of these firms is that they have strong information networks. This enables them to respond quickly in times of crisis and react ahead of their competitors. Prior research has reported many examples of open innovation evolving into business ecosystems, forming systems that are resilient to external disruptive innovation and can be monetized over time (e.g. Siegel et al., 2016). Each actor contributes to the maintenance and expansion of the ecosystem, thereby ensuring a competitive advantage. These robust ecosystems not only increase the number of alliances and outsourcing R&D, but also eliminate many risks by triggering intermittent and sustained innovation and reducing growing technological and social uncertainties (Jacobides, 2019). Specifically, they complement disrupted supply chains, coordinate to meet rapidly changing demands, and replace subsystems. As a result, even in the case of sudden supply disruptions or changes in demand, such as immediately after the arrival of COVID-19, it is possible to supplement this within the ecosystem.

The social capital theory, which assumes that a firm's performance comes not only from the management resources it possesses but also from its social network, has often been used to explain differences in performance among firms. Social capital theory is based on the perspective of "social embedding" that resources are embedded in social structures, and that the actions and products of individuals and organizations are strongly influenced by the characteristics of the relationships and structures of social networks (Burt, 1992). This kind of resource utilization is considered to define the competitiveness in COVID-19.

Conclusion And Future Study

Using a questionnaire survey of Japanese firms, we analyzed how firms' innovation activities and IP management in the pre-COVID period affect their management performance after the arrival of COVID-19. As a result, the following three points were clarified:

First, the high level of R&D investment immediately prior to the arrival of COVID-19 was found to weaken the damage to sales and operating profits after the arrival of COVID-19. Previous studies have confirmed that the enhancement of internal resources is reflected in differences in the ability to respond to crises, such as the ability of such firms to respond to rapidly changing demand ahead of other firms when a crisis occurs.

Second, it is clear that the damage caused by COVID-19 is greater for firms that launched new products and services during the four years immediately preceding the arrival of COVID-19. In particular, product innovation and process innovation, which were realized just before COVID-19, may have suffered more

damage. This result raises the concern that innovation activities in Japan may be vulnerable to economic crises in general.

Third, although innovation activities are generally vulnerable to crises, there are cases in which firms have not suffered damage, and even improved their performance after the arrival of COVID-19. Specifically, it became clear that the damage caused by COVID-19 was smaller for innovations realized in collaboration with other firms than for innovations realized by the firms themselves. Especially, firms that collaborated with organizations such as customers, competitors, and NPOs were successful in reducing the damage caused by COVID-19. This was also demonstrated from the perspective of open IP management. The background to these results is thought to be the high knowledge-absorbing ability of firms that have achieved innovation through cross-industrial collaboration, the diversity of sales channels made possible by having many collaboration partners, and the existence of strong information networks and a robust business ecosystem. Particularly, this is a characteristic tendency for firms that actively promote technology transfer to other firms.

Finally, the issues of this study can be summarized in the following two points: The first point is sample bias. In this study, the data collection process was focused on immediate results, which greatly reduced the bias of the sample population. As a result, the composition of the dataset is not representative of Japan in several respects. To capture the impact of COVID-19 on innovation activities in Japan as a whole in the future, it is necessary to conduct a larger and more precise survey, like the National Innovation Survey.

The second issue is the time lag. Given that the dataset constructed in this study is for a single year, it is not possible to capture the dynamic impact of COVID-19 on firms. In addition, in this study, we set a time period of 2016–2019, referring to previous studies that estimated innovation performance with a time lag of about three years (e.g., Brem et al., 2020; Kanama & Nishikawa, 2017a). However, other previous studies have shown that, on average, it takes six to eight years for the results of cutting-edge R&D to lead to outcomes (Odagiri & Murakami, 1992). If we set the period to four years as in this study, we would have to include the cases in which COVID-19 arrives before the results of cutting-edge R&D come to fruition. In the present study, a period of four years would include cases where COVID-19 arrived before cutting-edge research and development came to fruition.

Declarations

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Tables

Tables 1-5 are available in the Supplementary Files section.

Figures

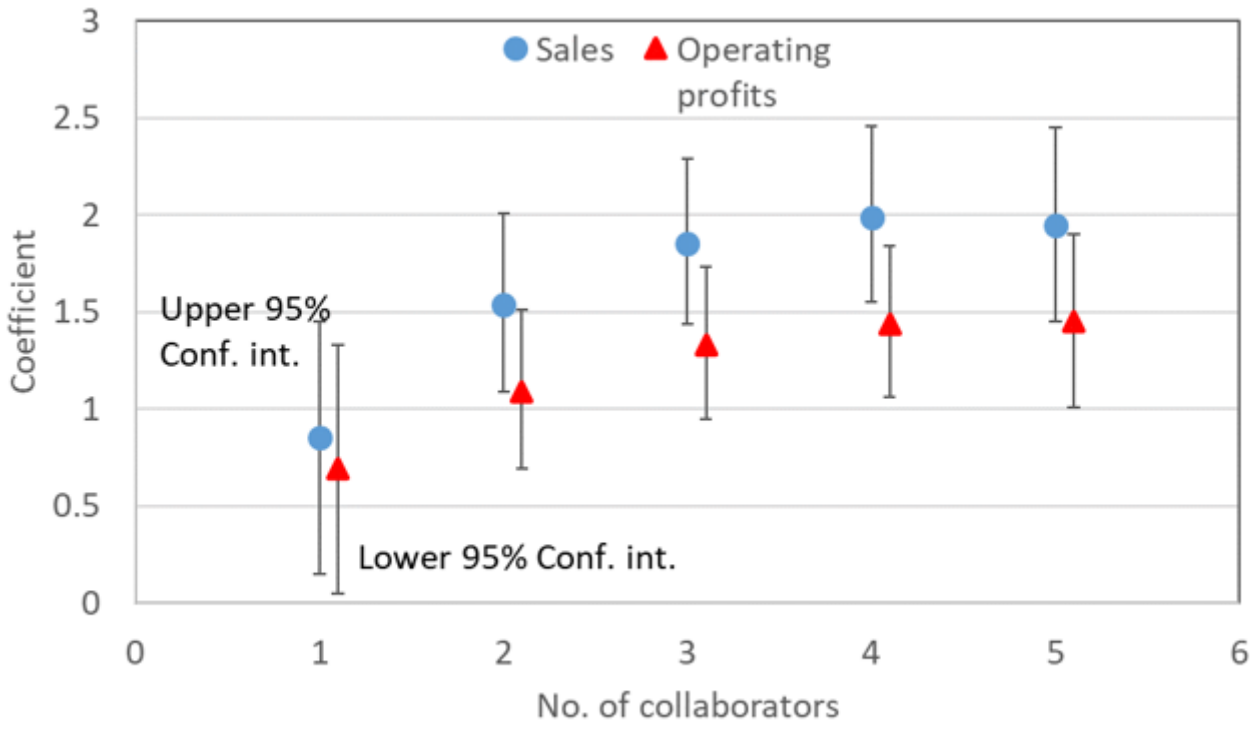

Figure 1

Number of collaborators and COVID-19 impacts

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