RIETI Policy Discussion Paper Series 19-P-005

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RIETI Policy Discussion Paper Series 19-P-005

March 2019

Digitalization of manufacturing process and open innovation: Survey results of small and medium sized firms in Japan [1]

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Abstract

Digitalization has a transformative impact on innovation in firms and industry. In this paper, the results of the Survey on the Changing Nature of Manufacturing Processes and New Product Development are presented to show how the nature of Japanese SMEs in manufacturing industry is changing in the new IT era (AI, big data and IoT). It is found that a firm applying new IT, such as data analytics by machine learning, is likely to be involved in delivering digital services as well as new products (servitalization) and innovation ecosystem, interacting with multiple firms. Such firms address wider customer needs, instead of just meeting existing customer requirements, meaning that its product innovation is likely to happen in new business fields. In addition, a firm which extensively uses its customer data gains more sales and profit contributions from its new product.

Keyword : Digitalization; Servitization; Innovation Ecosystem

JEL Classificaiton: L60, O33

[1]This study is conducted as a part of the Project "Empirical Analysis of Innovation Ecosystems in Advancement of the Internet of Things (IoT)" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). This study utilizes the data from the Survey on the Changing Nature of Manufacturing Processes and New Product Development. The author is grateful for the helpful comments from the Discussion Paper seminar participants at RIETI.

1. Introduction

Digitalization has a transformative impact on innovation in firms and industry, where new business models are disrupting traditional industries. Ubiquitous IT infrastructure enables sharing goods services such as Uber and Airbnb, big data analytics and AI technologies are used for condition based maintenance (CBM), by which industrial machinery producers such as GE can provide new value to their customers, and an advancement of automated driving technology may change the landscape of mobility related goods and services industry completely. An advancement of sensor and network technologies allows a firm to understand its customer's needs precisely, and to deliver value added services timely via digital infrastructure. Accordingly, a manufacturer is required to adopt solution oriented business model in science economy, instead of sticking to product oriented one in industrial economy (Motohashi, 2014).

Digitalization of manufacturing business entails transformation of innovation model as well. The cost of searching, verification and product delivery reduced substantially, by using digital platform, so that in-house innovation model becomes obsolete. Open innovation is taking place with various players, including customers, suppliers, universities and even competitors. Not only speed, but also widening the scope is required for innovation competition, since the boundary of industry becomes blurred by emerging new business such as rider sharing service. In this sense, the concept of eco-system, involving with heterogeneous multiple players, instead of open innovation with some specific partner, is critical for a firm to survive in an era of digital transformation (Motohashi, 2016).

This paper presents the results of Survey on Changing Nature of Manufacturing Process and New Product Development, showing the relationship between digitalization of manufacturing business and open innovation, particularly eco-system making with multiple players. This survey is conducted for SMEs actively involved with new product development activities to understand their responses to digital transformation in terms of IT use (such as AI, Big data use and IoT) and open innovation (such as participation in innovation consortium). It is found that these two activities are positively correlated, and lead to higher performance in terms of sales and profit.

2. Conceptual framework and survey strategy

What is new on manufacturing innovation in digital era? What are key concepts underlining fundamental changes of manufacturing firm's activities. We will pick up two concepts, servitilization and innovation eco-system.

Servitazation, referring to the phenomenon of increasing value added by services provision related to the product, was pointed out even before internet was started (Vandermerwe, S. and J. Rada, 1988). However, recent IT technologies enable efficient implementation of product related services (Rymaszewska et. al, 2017). Cusumano et. al (2015) discuss on the relationship between servitization and competitive strategy of product firms. Product related services are categolized into three (1) smoothing (such as technical service), (2) adapting (such as customization service) and (3) substituting (such as cloud service of storage and computer power). The first two are complement to the product and its emergence is basically beneficial to the producer. In contrast, the new entry of service provider of the last category could disrupt existing product providers. In general, an advancement of internet platform and new IT applications such as AI and IoT, opens new opportunities of such product related services, both by existing producers and new entry of service providers.

Another feature of IoT and big data analytics is that it enables a firm to know more about its customer. Therefore, interdependency in supply chain becomes stronger (Vendrell-Herrero et. al, 2017). Co-innovation between supplier and its customer has been investigated for a long time, particularly in the case of automotive industry (Dyer, 1996; Sako, 1991). However, collaboration in innovation with business partner (such as supplier and customer) is not one-to-one relationship, but a firm seeks for multiple partners in IoT era. For example, GE offers IoT platform, called PREDIX, which facilitate ecosystem of its business customers to develop their new business solutions using GE's products such as jet engine, energy plant and heath care equipment. Therefore, creating eco-system or platform to attract business players providing complementary goods and services is also important business strategy actions (Adner, 2013; Gawer and Cusumano, 2013). In addition, a firm has to be aware new industry boundary where digitalization allows disruptive innovators entry in the market (Porter and Heppelmann, 2014). In this sense, innovation ecosystem in those industries spans widely to some area which are totally separated in era of traditional manufacturing mode.

The strategy of our survey is focusing on small and medium sized manufacturers (as well as product related service providers such as software and technology service firms) to obtain a picture of digital driven servitization and ecosystem activities in manufacturing industry. A targeted firm is often a suppler to a large firm and is required to know better its corporate customer. In addition, some of them are eager to find new customers either in their current business or new business, in a digital transformation of industry. Therefore, we may be able to detect emerging pattern of IT use and ecosystem activities in their new product development process.

3. Survey methodology

A questionnaire survey is conducted. A sample firm is drawn from the firms listed in J-Good Tech and New Value Chain NAVI, both of which are website for matching SMEs with its potential (corporate) customers. The website is organized by SMRJ (Organization of Small and Medium Sized Enterprises and Regional Innovation, Japan), non profit organization affiliated with METI (Ministry of Economy, Trade and Industry), and it is based on voluntary registration by a firm who wants to appeal its technology and/or product to potential customer via the web-site. Therefore, the survey is not based on the systematic sampling framework, but the list of firms with intentions of expanding their customer base. According to National Innovation Survey of Japan in 2015, the share of product innovation firm is 16% for small firms (employment size is between 10 and 49), and 23% for medium firms (employment size is between 50 and 249) (NISTEP, 2016) . The target of this survey is a SME with product innovation, so that it should be noted that the results of this survey cannot be generalized to all SMEs in Japan.

Out of 5,925 firms (in manufacturing software and technology service industry) from the list supplied by SMRJ, 5,000 firms are randomly selected for the survey, and 1,629 effective responses (response rate: 32.6%) are collected. The survey period is October 1 to November 15, 2019. As is shown in Table 1, about 85% of firms are manufactures, which can be roughly split into material/parts industries and machinery industry.

FOOD, BEVERAGES, TOBACCO	26	1.6%
TEXTILE MILL PRODUCTS	29	1.8%
PRINTING AND ALLIED INDUSTRIES	73	4.5%
CHEMICAL, PETROLEUM AND COAL PRODUCTS	143	8.8%
IRON AND STEEL, NON-FERROUS METALS AND FABRICATED METAL PRODUCTS	367	22.5%
GENERAL-PURPOSE, PRODUCTION AND BUSINESS ORIENTED MACHINERY	244	15.0%
ELECTRONIC PARTS, DEVICES AND ELECTRONIC CIRCUITS	63	3.9%
ELECTRICAL MACHINERY, ICT EQUIPMENT	182	11.2%
TRASPORTATION EQUIPMENT	70	4.3%
MISCELLANEOUS MANUFACTURING INDUSTRIES	170	10.4%
SOFTWARE AND TECHNICAL SERVICES	192	11.8%
NA	70	4.3%
TOTAL	1629	100.0%

Table 1. Industry Distribution

The questionnaire has two parts. One is asking the information for a whole company, such as

- Basic information, such as location, industry code, year of establishment

- Perception in terms of business environment, such as competitive pressure, customer requirement for new product and importance of science knowledge
- Use of IT such as AI/machine learning, IoT consortium, data communication with customer and/or supplier and provision of digital service related to product.
- Type of business activity by digitalization (R&D, product planning, design, digitalization of skills)
- Partnership for new product development by type of partner, such as customer, supplier, university etc.
- Type of university industry collaboration, such as joint R&D, contract research, IP license, providing internship opportunity etc.
- Participation in consortium, involving multiple players.

And, the second type of questions are related to particular product innovation within 5 years. Then, the following questions regarding to the new product and are asked

- Whether it is developed for main business, or in diversification activity.
- Type of new product, by existing or new technology and for existing or new market.
- Type of customer, corporate or individual, number of customers, the type of firm in case of corporate customer (its size and industry)
- Relationship with corporate customer, such as existing customer, monitoring customers requirement, monitoring customer's usage of the product
- Competitive environment for the new product, such as number of competitors.
- IPR related to the new product, such as patent, design, trademark, etc.
- Relationship with corporate customer regarding digital communication such as obtaining digital data, providing digital data, use of digital data for another product development activities.
- Business contribution of the new product in terms of sales, profit, customer satisfaction, new customer development, etc.

4. Results

4-1. IT Use and Open Innovation

First, the condition of business environment for surveyed firms is described. Fig 1 shows how they perceives recent changes in their main business as well as new product developments. Their customers tend to request for more small batch diversified products, as well as their product information. In addition, more than half of firms show positive opinion regarding "importance of partnership" and "servitization", two keywords in digitalization of manufacturing innovation discussed in the section 2. In contrast, increasing domestic and international competitive pressure is less relevant as compared to the customer demand factors above. This is because the respondents are SMEs specializing into particular technology and product. Finally, the pressure from customer/supplier for big data and IoT application is not so high as this moment (about 25% of firms say “pretty much” or “yes”). This finding is consistent with the results of RIETI Survey on Manufacturing Big Data Use, showing the diffusion rate of IoT is less than 20% even for large firms (Motohashi, 2017).

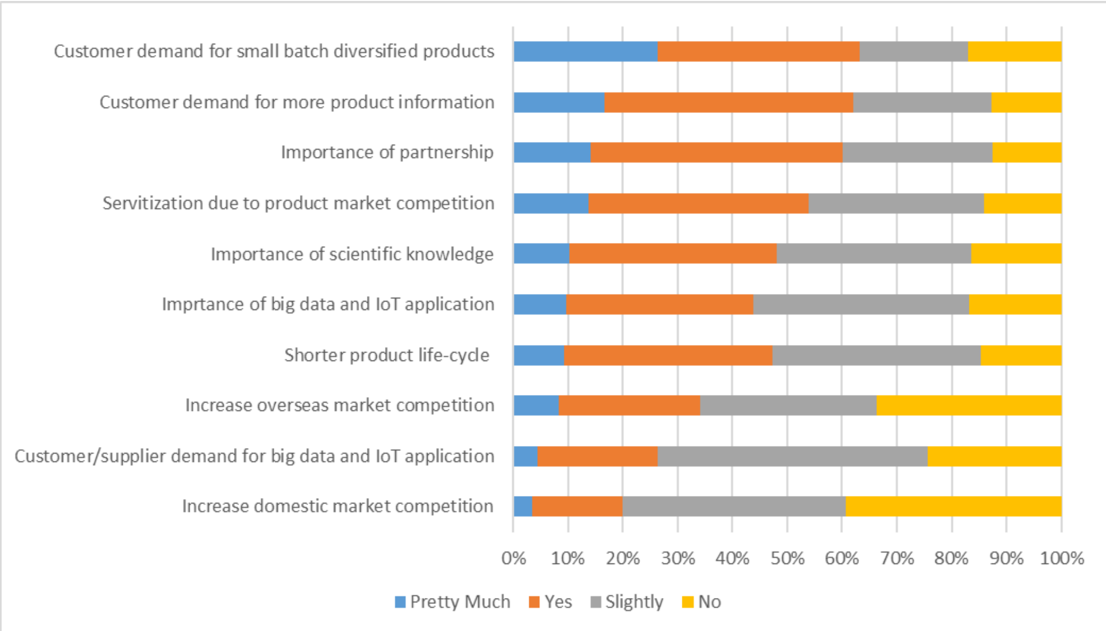

Figure 1: Changing business and innovation environment

Figure 2 shows the diffusion rate of various IT applications. More than 30% of firms apply data exchange with customer and cloud service already. Customer interaction with SNS, data exchange with supplier and providing digital service related to product follow, but its diffusion rate is less than 20%. Finally, business application of new IT, such as IoT and AI, is still under planned or no use in most of firms.

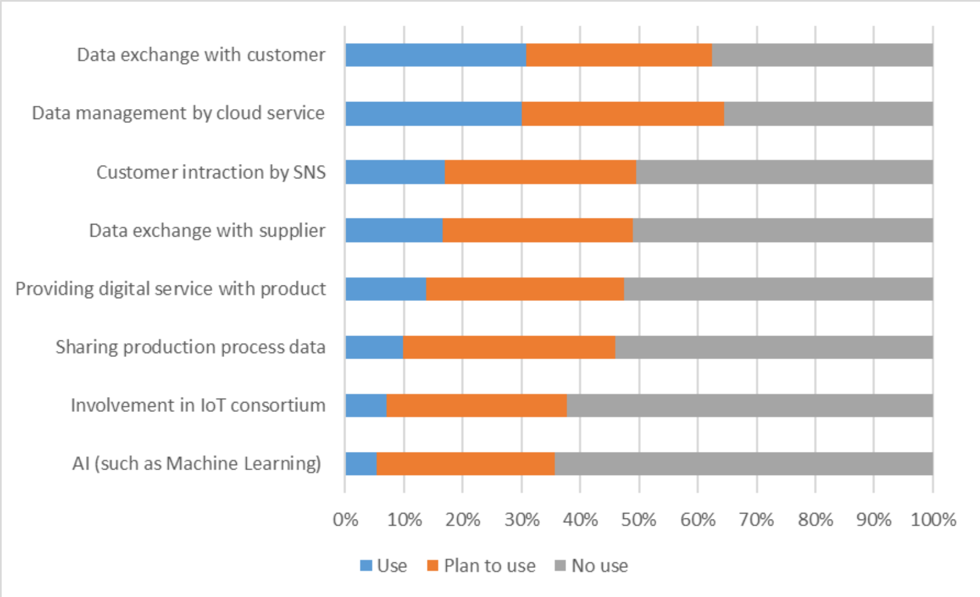

Figure 2: Use of IT by application

Then, what about open innovation? Whether does a firm have a partner in new product development process? A partner can be its customer, supplier, university, consultant etc. In addition to partnership, our survey covers the item regarding participation in product development consortium, involving with multiple firms and organizations. The table 2 is a cross tabulation of these two. In terms of partnership, more 70% of all responding firms (1537 firms) have any type of partner in new product development process. Out of with partner firms (1096 firms), whether they participate in consortium or not is about half (532 firms) and half (564) firms. While there are small number of firms with consortium and without partner (just participating in consortium for information gathering etc), we break up our samples, into three categories, i.e. (1) with partner and consortium firms, (2) with partner and without consortium firms and (3) in-house development firms (without partner and without consortium) for subsequent analysis.

	Consortium=	
	Yes	No
Partner=Yes	532	564
Partner=No	52	389

Table 2: Partnership in new product development process

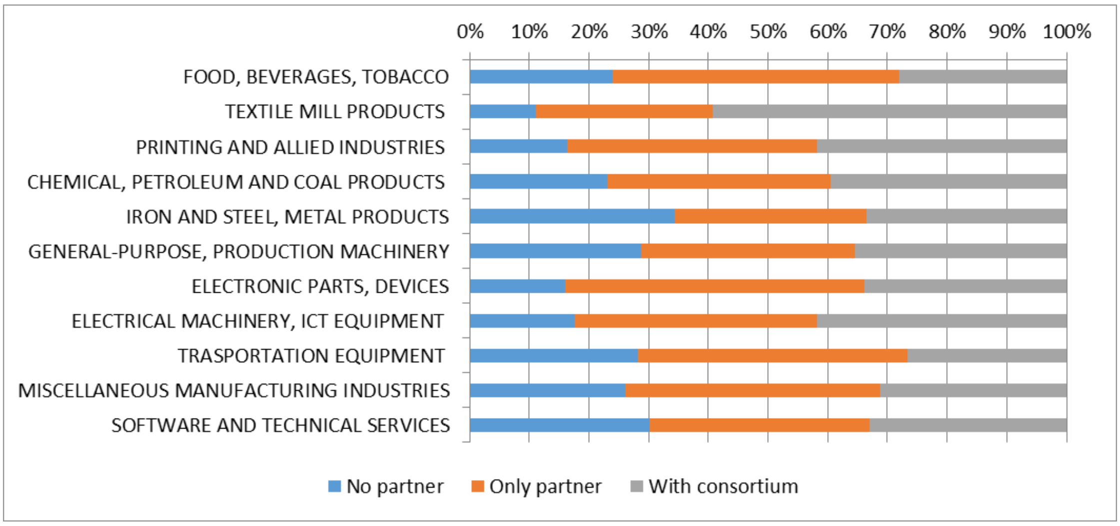

Figure 3: Industry distribution of open innovation

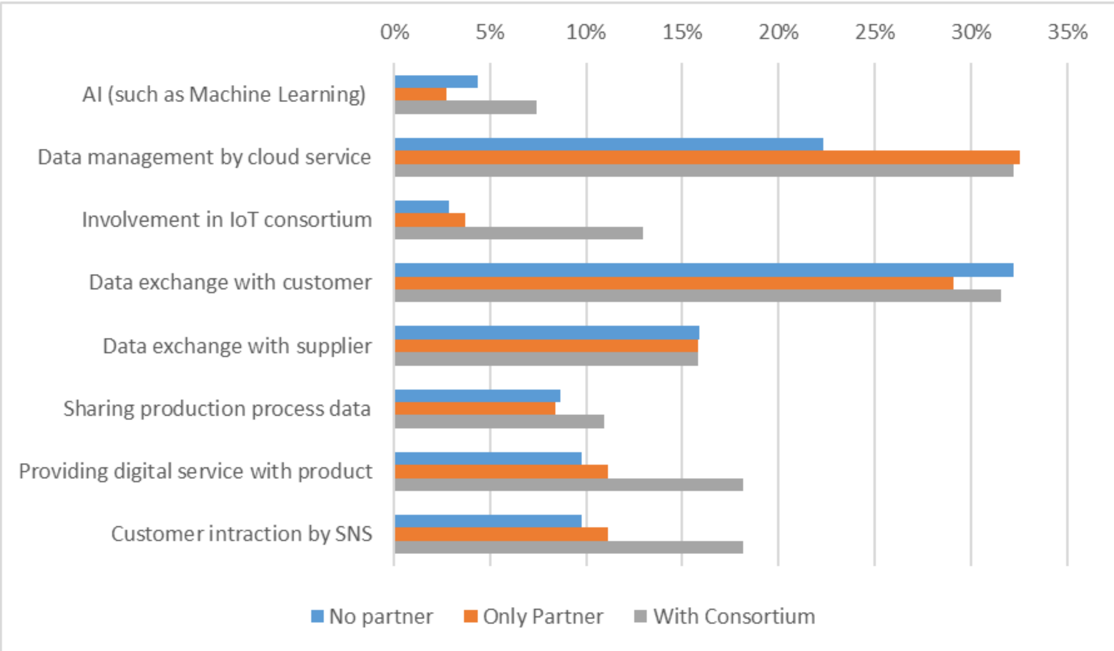

Figure 4: IT Use and Open Innovation

Figure 3 show the industry distribution and open innovation, and Figure 4 shows the relationship between IT use and open innovation. First, it is found that the diffusion rate of new IT such as AI, IoT consortium and SNS is higher for with consortium firms. In contrast, the diffusion rate is not so different across types of open innovation for data exchange with customer and supplier, which can be implemented by traditional IT system, such as SCM (Supply Chain Management). These findings are consistent with the view that recent developments in IT, typified by AI/Big Data/IoT, transforms open up one-to-one business relationship to eco-system type (Motohashi, 2018).

Table 3: Descriptive regression results of new IT and traditional IT

	AI	Cloud	IoT Consortium	Customer data	Supplier data	Production Process	Digital service	Social Net
(Biz Function for IT Use)								
R and D	++		+++				++	
Product plan (marketing)				---			+++	++
Product design								
Digitalization of skills				+		+		
(Customer Needs:CN to be filled)								
Deeper understanding CN								++
Address wider CN	+							
Speed response to CN		+		+++				
Precise understanding of CN			+					

(+++ positive at 1% level, ++ positive at 5% level, + positive at 10% level, --- negative at 1% level, -- negative at 5% level, - negative at 10% level)

In order to further understanding the impact of new IT, descriptive regression is conducted by using various types of IT use as explanatory variable. The variables to be regressed is business function to be address by IT use and various types of customer needs to be addressed by IT use. Table 3 shows the summary of the results.[2] It is found that new IT (AI, IoT, digital service related to product) is used for R&D and marketing function, and for addressing wider and precise understanding of customer needs. In contrast, traditional one (data exchange with customer) is negatively correlated with marketing function and used mainly for speed response to customer needs. Therefore, the motivation of new IT use tends to be exploration of new business, while that of traditional IT use is exploitation of existing business by strong linkage with existing customer.

The survey respondents are SMEs which may not have enough capacity to apply advanced technology such as AI to business, and such capability gap could be filled by collaborating with university. Table 4 shows the results of descriptive regressions between IT use and type of university collaboration. A strong positive association is found in IP license with AI and digital service delivery. Student internship is also positively correlated with AI, Cloud and use of customer data. These findings reflect that university has relatively abundant pool of skilled talents in AI and data analytics, as well as software to model business analytics to be licensed out.

[2] A regression is conducted by using all types of IT use as well as industry dummies as explanatory variables for each type of business function and customer needs.

Table 4: Regression results of UI collaboration and IT use

	AI	Cloud	IoT Consortium	Customer data	Supplier data	Production Process	Digital service	Social Net
Joint Research								
Contract Research					+		+	
Participate in Consortium			+++					--
Collab with Univ Startup								
IP License	+++						++	
Student Internship	+	++		+				
Inviting Univ. Researchers								
Technology Consulting								
Use Univ Training Program								+

(+++ positive at 1% level, ++ positive at 5% level, + positive at 10% level, --- negative at 1% level, -- negative at 5% level, - negative at 10% level)

4-2. New product and customer relationship

The second part of the survey is devoted to asking questions regarding a specific new product (services). The definition of new product is based on OECD's Oslo Manual (new or significantly improved product/service), except for the newness. In our survey, the responds are asked to pick up one representative new product/service recently, say around 5 years. This can be a product/service even older than 5 years old, in order to increase the size of positive responses for this section (in case of no product innovation, there would be no answers for a whole section).

Table 5 gives some information on the characteristics of new products. First, out of 1314 responses to this section, 46% of them (612) are introduced within 3 years (corresponding to OECD's definition). Second, most of them (1228) has some corporate customer.

Table 5: Characteristics of new products in the survey

	With Corporate Custmer		
	No	Yes	Total
>1 year ago	19	143	162
1-3 years ago	30	420	450
3-5 years ago	22	336	358
5 years or more	14	253	267
Do not know	1	76	77
Total	86	1228	1314

Figure 5 shows whether a new product is developed within existing line of business or new business, by type of open innovation status. As is discussed previously, with consortium firms is more likely to have new product in new business (exploration), while the share of new product in existing business (exploitation) is relatively large for the other two categories.

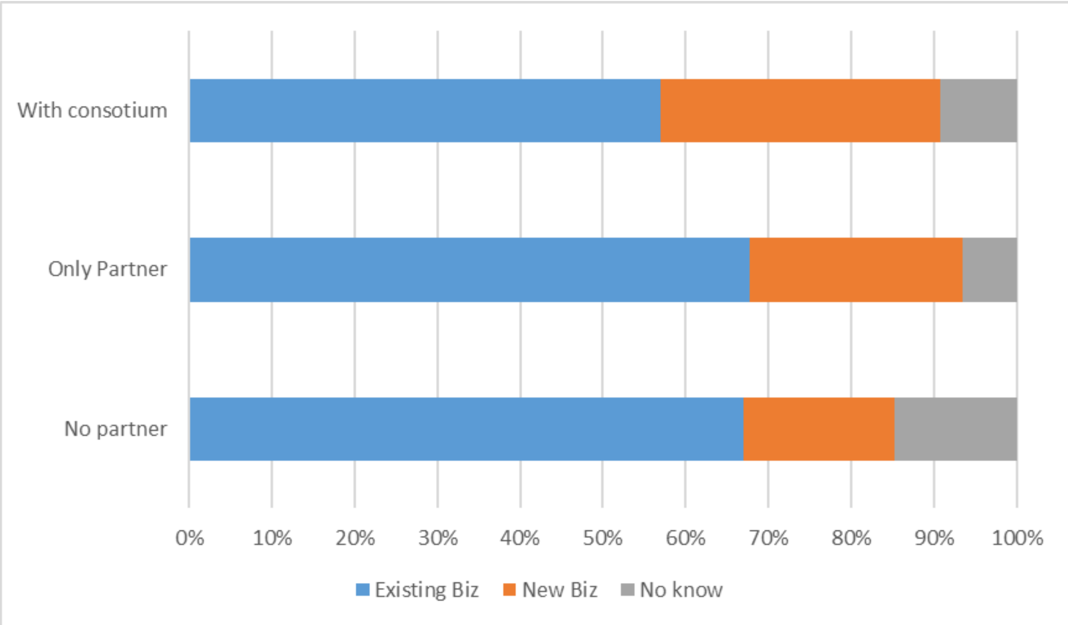

Figure 5: New product in existing or new business

Next, we look into the type of new product, again exploration or exploitation by its market and technology (Daneels, 2002). Again, we have confirmed that the more actively a firm is engaged with open innovation, the more their new product is in explorative nature, both in technology and market.

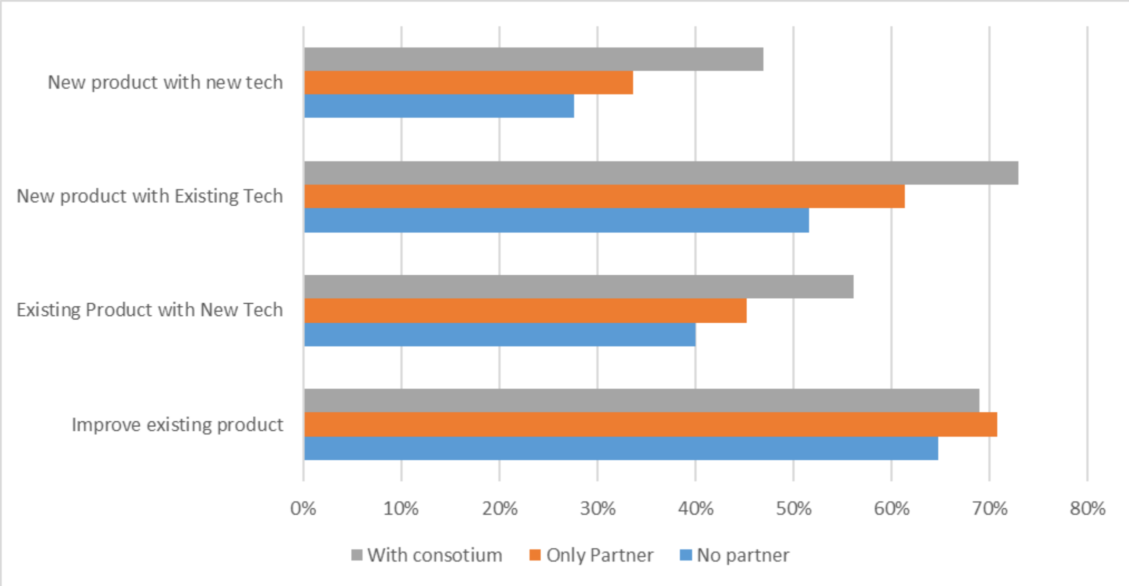

Figure 6: Exploration or exploitation by technology and market

Then, we check the use of IT for developing the new product and its relationship with the status of open innovation. As is shown in the Figure 7, the share of firm with delivering technical data to customer is relatively larger for with consortium firms. In addition, the customer data is more likely to be used for R&D for this group. In contrast, there is no clear pattern emerged in "obtaining customer usage data by digital" and "use of customer data for additional service" by the status of open innovation. These two types of customer data use can be facilitated by bilateral collaboration with customer, by strengthening the linkage with a specific partner. On the other hand, with consortium firms tends to approach wider customer base, not only by using customer data, but also by strategically delivering their own technical data to potential customers.

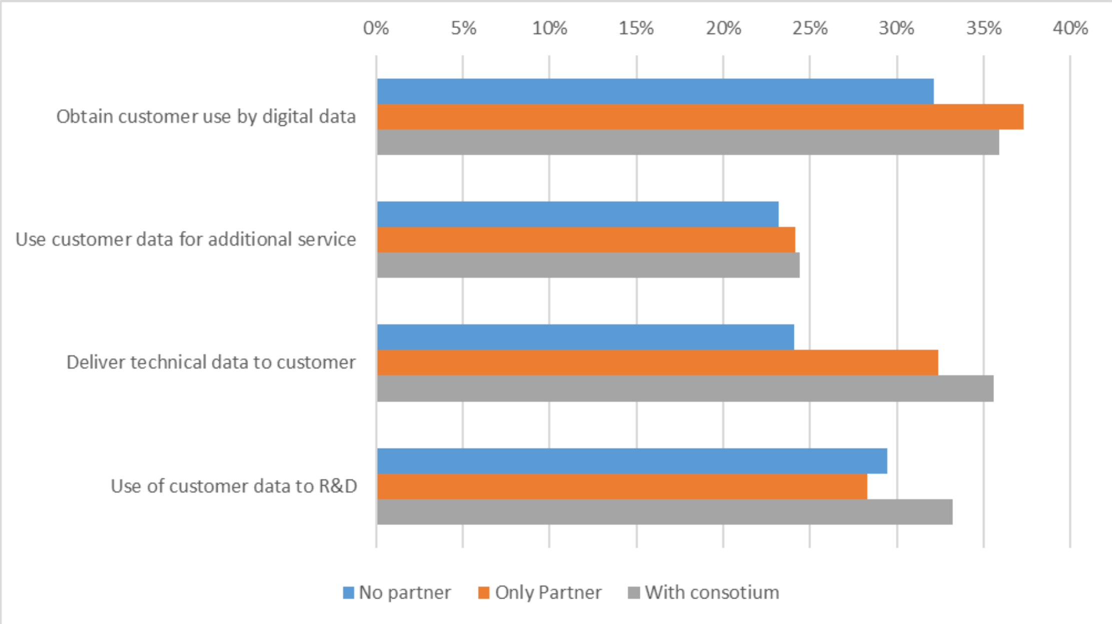

Figure 7: Digital communication with customer by state of open innovation

Finally, performance contribution of the new product is evaluated. The new product's contribution to each of 7 types of performance indicators, that is, sales, profit, domestic and international market share, customer satisfactions, new customer and technological upgrade, is regressed by items regarding the relationship with customers. As is shown in Table 6, both "obtain digital data from customer" and "providing technical data to customer" are positively correlated with sales and profit increase. Therefore, bilateral digital data communication is important for business performance. In addition, "Obtaining product usage information from customer" is positively correlated not only to sales and profit increase, but also to domestic market share, new customer development and technological upgrading.

Table 6: Regression results of new product contribution to business performance

	Sales Increase	Profit Increase	Domestic Market Share	Intl Market Share	Existing Customer Satisfaction	New customer dev	Technical Improve
Obtain digital data from customer	0.573	0.587	0.276	0.198	0.141	-0.153	0.404
	(0.283)**	(0.256)**	(0.230)	(0.219)	(0.255)	(0.251)	(0.324)
Use customer digital data for additional service	0.357	0.269	0.085	0.337	0.007	0.083	0.229
	(0.291)	(0.263)	(0.239)	(0.229)	(0.263)	(0.263)	(0.331)
Provide technical data to customer	0.541	0.456	0.500	0.315	0.213	-0.003	0.523
	(0.294)*	(0.263)*	(0.237)**	(0.218)	(0.263)	(0.253)	(0.342)
Use customer data for new product development	0.594	0.527	0.458	0.331	0.342	0.268	0.859
	(0.301)**	(0.272)*	(0.246)*	(0.227)	(0.274)	(0.269)	(0.363)**
Incorporate existing main customer needs (1)	0.371	0.127	-0.277	-0.427	0.384	-1.060	-0.147
	(0.276)	(0.271)	(0.268)	(0.288)	(0.280)	(0.351)***	(0.327)
Obtain main customer needs for continuous upgrading (2)	0.321	0.187	0.395	0.929	0.338	0.574	0.452
	(0.302)	(0.293)	(0.285)	(0.348)***	(0.311)	(0.328)*	(0.339)
Obtanin info of main customers product usege (3)	0.482	0.760	0.567	0.026	0.292	0.481	0.705
	(0.260)*	(0.247)***	(0.241)**	(0.267)	(0.271)	(0.279)*	(0.290)**
Use of IT to obtain info regarding (1) - (3) above	0.219	-0.063	0.373	0.056	0.103	-0.190	-0.204
	(0.261)	(0.237)	(0.229)	(0.227)	(0.258)	(0.250)	(0.287)
Constant	-0.894	-0.974	-0.471	-2.264	-0.083	1.517	0.178
	(0.433)**	(0.407)**	(0.388)	(0.439)***	(0.410)	(0.457)***	(0.495)
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of observations	577	577	566	577	566	566	577

5. Synthesis of findings and policy implications

In this paper, the relationship between digitalization and open innovation is analyzed, based on results of the RIETI's survey on changing nature of manufacturing process and new product development. It is found that these two, particularly new IT (typified by AI/Big Data/IoT) and ecosystem (new style of open innovation, involving multiple firms and organizations), are positively correlated.

More specifically, Figure 8 describes a synthesis of our findings. In terms of digitalization part, new IT and traditional IT are distinguished. Within our samples, a small portion of manufacturing SMEs have started introducing AI (machine learning) for data analytics and participating in IoT consortium. In addition, a new customer services by digital service delivery and use of SNS are introduced. These new IT applications are used for R&D activities to widen its customer base. In contrast, traditional IT applications such as data linkage with supply chain (supply chain management) are diffused more widely, but those firms which use mainly such system focuses on speed response to existing customer requirement.

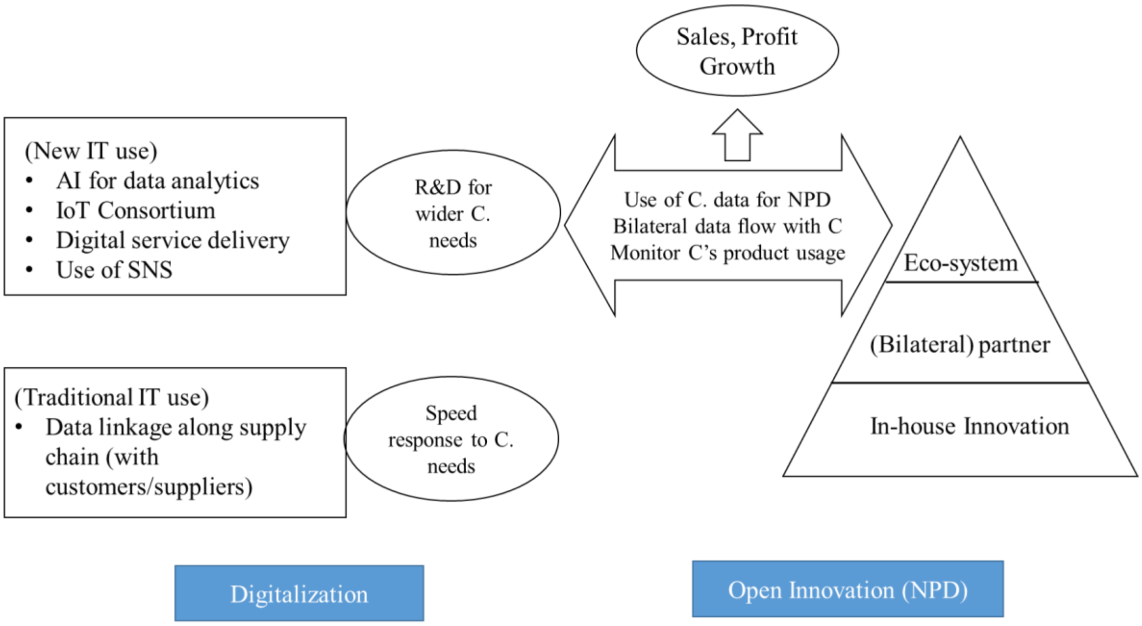

Figure 8: Digitalization and Open Innovation

As for new product innovation part, two styles of open innovation are distinguished, that is, participating in eco-system involving multiple players, and bilateral partnership. Therefore, three layers of open innovation status (2 types of OI and in-house) can be drawn in Figure 6.

Then, these two pillars are interlinked by new IT with ecosystem and traditional IT with bilateral partner. The new IT and ecosystem group tends to seek for explorative product development to challenge to new business field and to widen its customer base. In contrast, the traditional IT and bilateral partnership group (as well as in-house development group) tends to invest in exploitative product development to strengthen the relationship with existing customers. And, the business contribution of new product is generally higher for the first group, as compared to the second one.

A broad policy implication drawn from our findings is that supporting to SME's moving up such ladder is important. More specifically, IT diffusion policy to promote business adaptation of new IT such as AI and big data and open innovation policy to promote ecosystem building should be coordinated, instead of implementing separately.

More specifically, skilled labor for data analytics is essential to make advanced technology (new IT such as AI, big data and IoT) applicable to individual firm's business. Therefore, supporting to skill development is an important policy. In addition, our survey reveals that such talents can be found in university, and there are some firms to offer internship to access to such skills. Policy implication drawn from this finding is that university industry collaboration via talent exchange should be supported. Or more generally speaking, human base interaction between firm and university, instead of formal contract such as joint research, should be promoted in a field of data analytics.

Ecosystem building and involvement is a highly strategic question for private firm. However, there is some way for public policy to make it efficient. First, an easier access to existing ecosystem or platform should be ensured. The role of key stone firm in business ecosystem to maximize its whole value to ensure appropriate profit sharing with its participants (niche players) (Iansiti and Levien, 2004). But if a keystone firm is too exploitive in case of its monopolizing market, anti-competition authority should move. In addition, an appropriate IP rule on essential data platform should be discussed. Second, a new role of university as place for ecosystem building is emerging, where potential ecosystem participants discuss and work together for collaboration. Such trend should be promoted.

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