Effects of University-Industry Collaboration to R&D efficiency of MNEs

: The case of MNEs in the electronic industry

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Iguchi Seminar 5th

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Abstract

In recent years, university-industry collaboration is increasing in importance. Nevertheless, there are not enough previous studies that show how university-industry collaboration impacts on firm's business activities. In this study, our objective is to indicate the effectiveness of university-industry collaboration as a strategy for Japanese electronics firms to revitalize their competitiveness. In order to prove it, we measured the correlation between the number of university-firm joint patents and university-firm joint papers as the outcome of university-industry collaboration and the R&D efficiency. As a result, we found a positive correlation between the number of university-industry collaboration and firm's R&D efficiency. Furthermore, Japanese electronics firms are increasing the number of joint researches with overseas universities to seek for the global competitiveness. However, we found out that international university-industry collaboration does not necessarily improve the R&D efficiency of the firms.

Keywords: Open Innovation, University-Industry Collaboration, International University-Industry Collaboration, Electronic Industry, R&D Efficiency

7656 words

1. Introduction

In recent years, the significance of the university industry collaboration (UIC) both inside and outside of Japan is receiving greater attention. UIC is a way to enhance R&D innovation through conducting collaborative research among industrial and scholarly organizations, which inherently have different characteristics and values (Yamaguchi, 2005). The position of universities has changed from "the ivory tower" to "knowledge broker", accelerating the commercialization and the further development of research (Gassman, Enkel and Chesbrough, 2010). The idea of open innovation requires firms to use external networks as well as internal ideas (Chesbrough, 2006). UIC consists of joint research with universities, consortiums, and collaborating with affiliated companies. It is said that open innovation is an effective way to fight against the impacts of the shortening product life cycles (the Ministry of Economy, Trade, and Industry (METI), 2017). In particular, UIC enables firms to gain the latest technology from universities, as the source of deep knowledge. Since it allows firms to develop a competitive advantage globally, it is important for industrial societies to enhance UIC.

More and more firms are paying attention to UIC. The number of joint researches between Japanese firms and universities increased 1.5 times in eight years (the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), 2017). In addition, the amount of R&D expenditure of universities or institutions in OECD countries has increased 1.6 times in ten years (OECD, 2016). The universities' amount of patent loyalty

income has increased to 165 times more, compared to those in 2001(MEXT, 2015). Despite the fact that UIC has drawn attention in recent years, previous studies underestimated the impact of UIC on business activities. When considering the effects of UIC from a commercial standpoint Mansfield (1991) indicated that academic research contributed to industrial innovation considerably in the pharmaceutical industry. However, there are few researches that have analyzed the effectiveness of UIC in other industries.

Our objective in this paper is to reveal the effectiveness of UIC by using R&D efficiency as an indicator of success or failure of the collaboration. Our study will validate the correlation between R&D efficiency and the outcome of UIC by analyzing both papers and patents. These patents and papers which are co-held and coauthored will be treated as proxy variables.

Therefore, this analysis starts with the section that analyzes the struggles of Japanese electronics firms in the global market. Following this will be a section of literature review, and our thought process leading to our hypotheses in section four. The description of our data collection process and research methodology is provided in section five. Section six examines the results of our study and discusses the implication of the findings for UIC impact. Finally, section eight will cover the research conclusions.

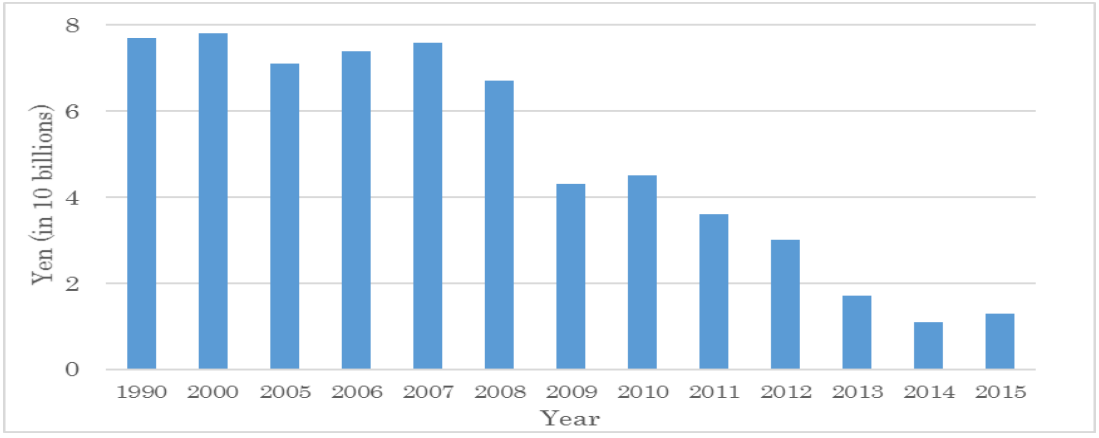
2. Current Situation of Japanese Electronic Industry

This section will examine the current state of the Japanese electronic industry and Japanese industrial society.

(1) The Decrease of Global Competitiveness of Japanese Firms in the Electronic Industry

Japanese electronics firms have lost their global competitiveness. Transportation equipment, electrical machinery and generic components have been the three main driving forces of exports from Japan for a long time (METI, 2017). Looking back to decades past, there is research exploring reasons for the economic growth. There are studies which analyzed the factors that lead to Japan's manufacturing industry growth (Abegglen, 1973: Freeman, 1987:, 1981). Of the core three factors, the most widely recognized among researchers is the decline of trade surplus in electrical machinery.

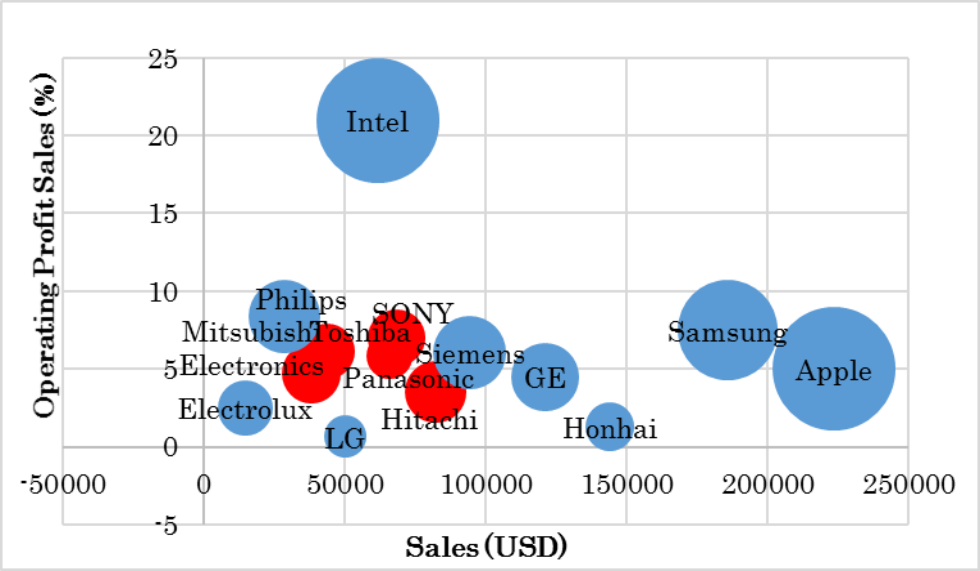
Figure1: Transition of the trade balance of electrical machinery in Japan(1990-2015)



Source: METI(2015)

If you compare the sales operating profit margin of the major companies, the profit margin of Japanese companies is low compared to overseas leading companies.

Figure 2: Sales operating profit margin of the major electronic companies (2016)



Source : Capital IQ Income Statement

In the 1980's, the Japanese innovation system was praised for the strength of its centralized research laboratories of large firms (Motohashi, 2005). Motohashi (2005) pointed out that the typical large Japanese firm was not motivated to cooperate with external institutions because it held vast research complexes. This idea is called "NIH (Not Invented Here) syndrome", which means the proneness not to pay much attention to external knowledge and invention (Katz & Allen, 1982).

Goto & Kodama (2006) explained that Japanese firm's concentration on fundamental research after finishing the "catch-up era" to Western countries led to the creation of Japanese firm's stand-alone attitude and situation. In particular, it is said that

the deterioration of R&D efficiency is one of the main causes of falling global competitiveness of Japanese electronics firms (Genba,Takeoka,Imanishi, & Uenishi, 2016: Sakakibara & Tsujimoto, 2003: Sakakibara, 2005). Sakakibara & Tsujimoto (2003) indicated that Japanese electronics firms decreased their R&D efficiency because of their proprietary technical strategy in the late 1980's. Furthermore, Cabinet Office (2015) showed that R&D efficiency of the Japanese manufacturing industry was lower than that in United States and 15 of the E.U. countries.

These studies imply that improving R&D efficiency would be an effective strategy for Japanese electronics firms to reinvigorate their competitiveness. Since approximately 70% of the electronic products have a life cycle shorter than three years it is essential to continuously provide advancements in R&D activities and to introduce new products to the market. Yonetani (1998) also indicated that the firm's core activity is the development of new products, therefore firms are required to promote R&D activities in order to make innovation necessary to survive. The diversified needs of consumers nowadays is impossible to serve by the conventional R&D speed (Nomaguchi & Fujita, 2013). Also, Branstetter & Nakamura (2003) suggested that the formation of technology-sharing alliances works for improving R&D efficiency. It is presumed that external knowledge that firms obtain would help improve R&D efficiency.

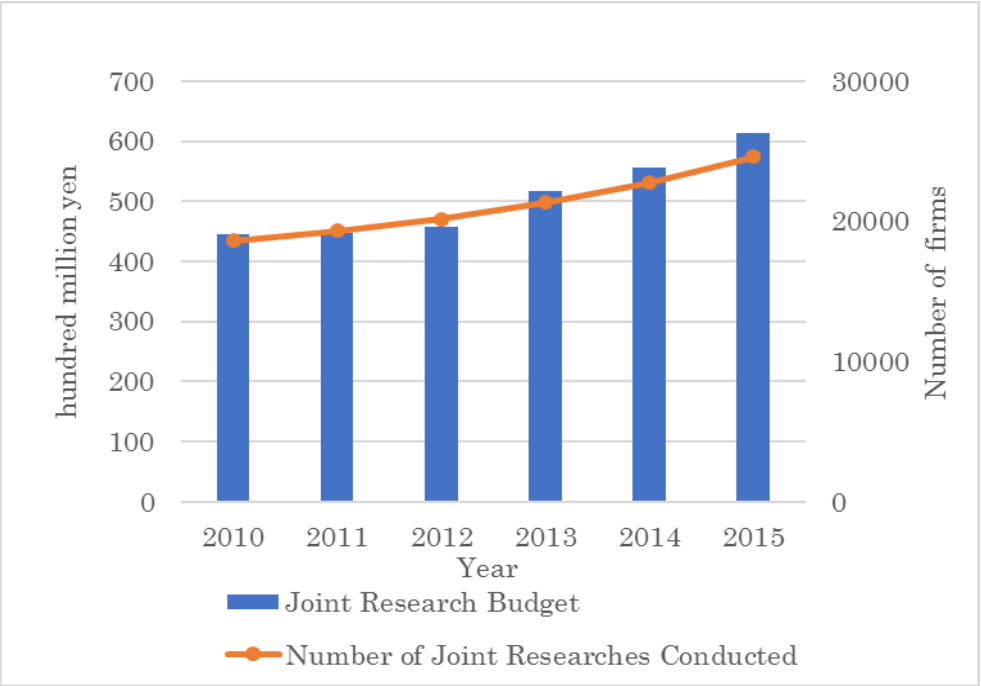
(2) Open Innovation as a Solution and UIC

Open innovation is one of the solutions to help improve R&D efficiency. To begin

with, R&D efficiency is a management indicator which quantitatively measures the results of firm's business activities for R&D expenditure. Many different calculation methods have been established to measure R&D efficiency. For instance, Montgomery & Hariharan (1991) defined R&D efficiency as the firm's sales divided by amount of expenditures a firm spends on its R&D. There are some studies that analyzed the impact of R&D expenditures on total factors in productivity, or in other words the effect of R&D budget intensity to the firm's profitability (Bernstein & Nadiri,1988: Foster & Kaplan, 2001). In Japan, Murakami (2000) firstly pointed out the importance of R&D efficiency in the Japanese electronics industry, following suit the government and think tanks also depicted the problem of diminishing R&D efficiency.

It is said that universities can contribute to society. The contribution of universities to the economy and society of Japan as sources of innovation has been a subject of many studies (e.g. Cohen, Nelson & Walsh, 2002b: Mansfield, 1991: Mansfield & Lee, 1996: Pavitt 1991). In fact, the movement of UIC has been accelerating. The number of firms conducting joint research with universities has increased 1.5 times in eight years (MEXT, 2017). The total amount of research funds received by universities conducting joint research with corporations reached approximately 57.7 billion yen and the incomes from patents exceeded to 2.5 billion yen (MEXT, 2017).

Figure 3: Transition of the Joint Research Budget and the Number of Joint Researches conducted



Source: MEXT(2015)

In addition, according to the results of the survey (N=1,662) conducted by Japanese firms, 77.3% of the firms conducting joint research with universities or institutions experienced difficulties (MEXT, 2015). On the other hand, 71.1% of the firms did not conduct joint research with overseas universities and institutions due to the underdevelopment of the collaboration systems (MEXT, 2015). Therefore, as Japanese firms still have concerns to conduct UIC, the impact of UIC on the firms in the electronic industry is without a doubt major.

3. University-Industry Collaboration

This section is divided into three parts: “Definition and Historical Background”, “Forms and Purposes of UIC”, and “Evaluation Methods of UIC”.

(1) Definition and Historical Background

UIC is a way of R&D activity to enhance innovation through collaborative research conducted by organizations which have different characters and purposes (Yamaguchi, 2005). That is, UIC is an activity for producing a synergistic effect by transferring knowledge, human resources, and capital between university and industry. Public institutions are excluded in this paper.

Originally, UIC studies were traced to the idea that universities should play the role of contributing to the industrial society, in addition to education and research (Etzkowitz, 1998). The study on UIC developed within 20th-century United States (Mowery & Rosenberg, 1999). The research on UIC made especially rapid progress with the slogan going “United States, by means of science, overtaking Japanese firms that relies on experience and intuition” (Nagahira & Nishio, 2006). This progress was against Japanese MNEs, especially manufacturing firms, had international presence in 1980’s (Nagahira & Nishio, 2006). Bock (2003) deduced both the enactment of Patent and Trademark Act Amendments of 1980 and a sudden rise of biotechnology industry strengthened cooperation between universities, industry, and public research institutions. In Japan, it

was not until the burst of the economic bubble that the importance of UIC came to be realized to decrease R&D expenditure and innovation. As a result, the government of Japan enacted laws pertaining to UIC or knowledge transfer such as Act on the Promotion of Technology Transfer in 1988, Act on Special Measures concerning Industrial Revitalization in 1989, and National University Corporation Act in 2004.

(2) Forms and Purposes of UIC

There are various formations of UIC. First of all, Tamai & Miyata (2007) identified eight UIC formations: joint research, contract research, licensing, consortia, donation, and consulting, university-originated ventures and personnel exchange. Watanabe (2008) classified joint research, contract research, consortia for academia and licensing and university-originated ventures for industry. Lee & Win (2004) deliberated the case in Singapore and concluded the more firms engaged, the better the UIC process would be.

Second, expectations toward UIC differ among stakeholders. Kennedy (1986) demonstrated that although the U.S. government provided a vast sum of subsidies for basic research, the amount of subsidies tended to decrease in 1960s. Universities began cooperating with industry as the necessity of research expenditure matched with the needs of technology transfer.

Mowery (1998a) pointed out that UIC is beneficial in helping expedite the commercialization of a new technology. In fact, Cohen et al. (2002b) showed that

universities and public research institutions significantly influence R&D in manufacturing industry. Gassmann et al. (2010) remarked UIC advanced both the commercialization competition of research results and the deepening of R&D. Furthermore, it is demonstrated that the biggest industrial expectation toward UIC is to access to applicable research from universities, while universities expect mostly R&D funds (Lee, 2000).

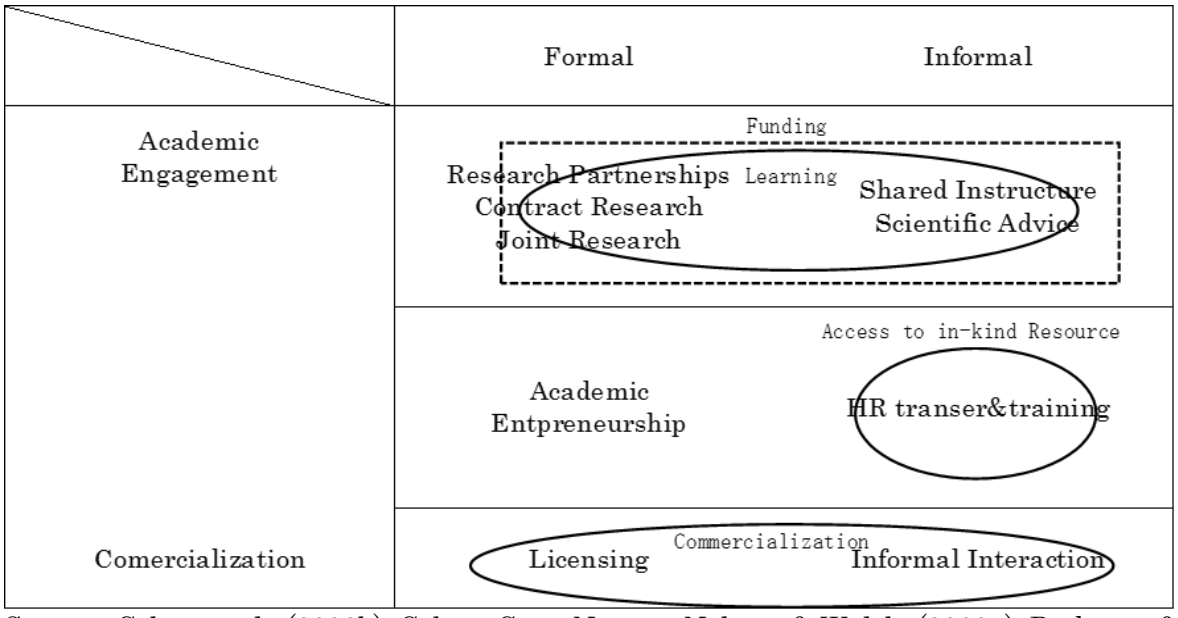
In this wise, formations of knowledge transfer depend on the different expectations toward UIC. Universities are ideal partners for collaborative R&D as a method to obtain R&D results that universities have for firms from the point of view of industry, which is our object in this paper.

In reality, Japanese researchers who work in Japanese firms (N=704) are strongly motivated to participate in UIC by forming human resources and organizational networks with universities, solving essential technological problems of their businesses (Needs-oriented), gaining know-how from universities (Nagaoka, Hosono, Akaike & Nishimura, 2013).

D'Este & Perkmann (2011) concluded that if firms attempt to commercialize their knowledge, they tend to earn patents or choose spin-off companies, from a case study in United Kingdom, while if firms attempt to research more, they tend to do joint research, contract research, or consulting. Perkmann et al. (2013) demonstrated that income by collaborative research, contract research, or consulting is higher than income of intellectual property rights, however, the academic engagement such as collaborative

research, contract research, or consulting are not for commercialization. Moreover, informal consulting or advice from universities to industry plays an important role to realize innovation (Cohen et al., 2002). Perkmann & Walsh (2007) illustrated that lower UIC involvement would seek commercialization, while higher UIC involvement would lead to academic engagement and development. These can be summarized in the following figure.

Figure 4: The form and the purpose of UIC



Source : Cohen et al., (2002b), Cohen, Goto, Nagata, Nelson, & Walsh, (2002a), Perkman & Walsh (2007), D'Este & Perkman, (2011), Perkman et al., (2013)

In sum, UIC outcomes differ from universities and firms because its form also differs.

(3) Evaluation method of UIC

MEXT (2005) made use of four criteria to measure the outputs of science technology and innovation, namely input, infrastructure, output, and spillover.

Literature of UIC can be divided into two currents based on the index characteristics. One is output, meaning patents or papers (Agrawal & Henderson, 2002: Tamai & Miyata, 2007: Thursby & Thursby, 2002: Yamaguchi, 2008). The other is spillover as we have mentioned before. It is measured by gross value added, the number of start-up firms, sales to total assets ratio, the number of new drug approvals in medical industry, research productivity, total factors in productivity, and so on. The representative indicators of UIC outputs are patents and papers. Patents indicate the fruits of innovation and productivity (Pavitt, 1985: Zucker & Darby, 1996). The objective of licensing is commercialization, and its benefit exceeds time and money cost (Archibugi, 1992). Also, valuable invention needs to be patented so that technology transfer involving patents can work effectively (Motohashi, 2009). On the other hand, patents do not play an important role in formal knowledge transfer. Thursby & Thursby (2002) verified effects of the pro-patent policy by analyzing universities in the USA. This thesis dissented from the recognition that the importance of patents relies on the attitudes of university and UIC policies such as the Bayh-Dole Act of 1980 facilitated UIC activities for public research institutions and researchers. Agrawal & Henderson (2002) confirmed UIC's actual situation and the research activities of university researchers. They examined the role of

scientific papers and patents in spin-off of intellectual property that universities produce, and they found that influence of papers is much more than that of patents. Papers, however, are quantitative index that is generally used when researchers take bibliometric analysis. Academic papers are important for knowledge transfer as an open path (Cohen et al. 2002a).

The limitations of patents as a means of knowledge transfer are recognized. However, this is caused by the view that industry is the knowledge recipient whereas university professors are the knowledge creators (Agrawal & Henderson, 2002: Cohen et al.,2002). Meyer-Krahmer & Schmoch (1998) note that patents and papers possess co-evolving and co-learning relationships. According to Japan Patent Office (2015), electronic industry (2,603 hundred million yen) costs three times more than chemistry industry (902 hundred million yen). Therefore, it is speculated that patents are significant for industry and it is same in UIC. From the above, we think it is appropriate to employ both patents and papers as quantitative results of UIC. Thus, we will present and summarize a past study on the effects of UIC on industry in the following section.

4. Overview

Following the status quo of electronic industry and the academic overview of UIC, we will reveal how UIC has defined, from the perspective of the theory of innovation, the

characteristics special to industries that are actively involved in UIC.

(1) UIC as an origin of innovation

First of all, the relationship between UIC and innovation stems from the system of national innovation. It refers to the national-level system, which facilitates innovation, as proposed by Freeman (1987) and Nelson (1993). It consists of education systems, the academic level of higher education, the governmental policy, and industrial structure. In 1980s, lots of researchers carried out deep analyses of the role of science as a catalyst to invigorate the economy, in accordance of the progress of electronics technology (Baba & Goto, 2007). In other words, the role of universities as an innovation facilitator came to the forefront both in the academics and in industry.

Also, there is literature concerning policy evaluation, technology knowledge transfer, knowledge spillover and cluster. However, it is inadequate to consider merely these aspects in order to confirm the effects on business, as not all UIC aims to commercialize their outcome.

(2) Biotechnology and pharmaceutics as a subject of study

In UIC study, biotechnology and pharmaceutics have been focused. It is because in the pharmaceutical industry, basic research results can be inevitably associated with

applied research (Mansfield, 1991). Saito & Sumikura (2013) pointed out that UIC and patent application efficiency or new drug approvals have positive correlations. Zucker, Darby & Armstrong (2002) noted that joint research by companies and star scientists has greatly contributed to the market share expansion in biotechnology. Originally, the inclination toward basic research has been justified despite huge costs in time and transaction (Pavitt, 1991). The promotion policies of UIC was then launched to leap over hedge. In fact, however, other industries except biotechnology did not decrease the investment in basic research into applied research (Mowery & Zieodnis, 2001). As things are, we find there would be more research needed on the impacts on the business in other industries.

(3) Overview

UIC is seen as a means of joint research from the industry’ s point of view, while universities concentrate more on how to execute the process. First of all, many studies on benefits of joint research have been qualitative analysis and aimed at formulating theory. Still, there are some quantitative analyses, including Becker & Dietz’s (2004), which substantiated the influence of R&D intensity. With respect to UIC previous studies, Belderbos, Carree & Lokshin (2004) show that joint research with universities can be an effective source of innovation, while it does not positively affect company’s productivity. George, Zahra, & Wood (2002) discussed that companies that actively conducted

collaborative research achieved higher total assets turnover, in spite of less R&D expenses. According to Laursen & Salter (2004), the more ready companies are for open innovation, the more active they are for UIC. Perkmann & Walsh (2007) emphasized group dynamics.

There are less research accumulated focusing on Japanese companies. Ito & Tanaka (2016) identified that external R&D of Japanese firms improves their TFP. However, Motohashi (2003) analyzed the influence of UIC by the amount of value added and concluded that UIC did not directly permeate TFP but contributed to the firm's performance through the increase of elasticity coefficient of R&D outputs. Asakawa, Nakamura & Sawada (2010) elucidated that there is positive correlation between UIC and R&D performance, measured with the 5-stage model. It is not fully objective as there must be response bias, as mentioned by Perkmann et al (2013).

As discussed above, there is no enough research on how UIC influences firms' R&D efficiency. In addition, consensus on the effect of UIC is yet to be reached. In this paper, we examine whether UIC will positively influence R&D efficiency, based on the precondition that the number of joint patents and joint papers by companies and universities is equal to the output index from UIC. Thus we propose hypothesis one below:

Hypothesis 1: UIC between universities and companies will positively influence R&D efficiency.

Furthermore, we formulate Hypothesis two from the current trend on UIC that more and more Japanese companies are collaborating with overseas universities. According to the survey by Nihon Keizai Shimbun in 2015 (N=328), Japanese firms which increased the amount of joint research with overseas universities amounted to 14.6%. In addition, Japanese firms which answered that they are planning to increase the number of collaborative R&Ds reached 31.7%. Moreover, 51.2% of the Japanese electronics firms in this survey answered that they are planning to advance to international UIC. According to the survey (N=681) conducted by MEXT(2015), 53% of the companies answered that the reason Japanese firms conduct joint research is to use the distinguished research capacity, 38% replied that the purpose is to build connections with researchers in overseas universities and 27% said some research that they wanted was not available in local universities. Furthermore, the largest amount of international joint research was done in the engineering field.

They imply that Japanese electronics firms are eager to collaborate with overseas universities to look for the source of innovation. The previous studies also indicate the importance to do joint R&D activities with overseas universities. Song, Asakawa, & Chu (2011) demonstrated that it is indispensable to construct global network in order to achieve world-class innovation. “Global network” refers to not only existing relationship among firms, but also local universities and public research institutes. In addition, Tidd et al. (2005) indicate that companies should make profits from national innovation system in foreign countries.

Researchers have not paid much attention to Japanese firms' international UIC. Nakayama (2013) did a case study of Japanese companies collaborating with British and Swedish universities. It shows the advantages of international UIC: the potential recruitment of foreign students, the acquisition of know-how on human resource management, the establishment of the international collaborative research organizations, and so on. Also, when local R&D carry out exploratory research, companies tend to collaborate with local universities in R&D activities (Asakawa, 2011). Nevertheless, there is almost no evidence that international UIC improves the management index.
From the points mentioned above, we argue for hypothesis 2.

Hypothesis 2: International UIC will positively influence firms' R&D efficiency.

5. Methodology of the analysis

In this section, we explain our method of our analysis.

(1) Sampling

The target of our research is electronic industry. We selected 5 Japanese leading electronics firms and overseas 4 electronics firms which were determined as competitors by the database D&B Hoovers provided by Dun & Bradstreet Inc. (Table1). The number in parenthesis indicate the R&D efficiency of each firms in 2013.

Table 1: Target firms and R&D efficiency of each firms

Japanese Firms		Overseas Firms	
Mitsubishi Electric	1.568	Samsung Electronics	3.470
Hitachi	1.293	Intel	2.044
Panasonic	0.489	Koninklijke Philips	0.892
Sony	0.453	LG Electronics	0.604
Toshiba	0.208		

Source: Capital IQ Income Statement (2016)

(2) Dependent variable: R&D efficiency

In this paper, we adopt the definition of R&D efficiency from Murakami (2005) as the ratio of the sum of expenditures by a firm on research and development in previous five years to the sum of firm's operating income in five years / the ratio of expenditures by a firm on R&D to the firm's sales.

We collected the data of R&D expenditure and operating income from the database Capital IQ. After collecting these data from 2001 to 2016, we calculated the R&D efficiency for eight years.

(3) Independent variable: Joint patents, joint papers

As mentioned above, it is reasonable to use joint patents and joint papers as a proxy for the outcome of UIC. Thus, we use two independent variables in hypothesis 1: the

number of university-firm joint patents and university-firm joint papers. We assembled these data from 2005 to 2016 and smoothed these data to eight years' worth of data by using the method of five-year moving average. We collected university-firm joint papers from the database JDreamⅢ provided by G-search Ltd. and university-firm joint patents from the database Patent scope provided by World Intellectual Property Organization.

In hypothesis 2, we set ratio of the international UIC as an independent variable. We defined the international UIC as the portion of the number of joint patents registered by firms and overseas university and joint papers authored by firms and overseas university out of the number of total joint patents and joint papers. We smoothed the data using the same way as hypothesis 1.

(4) Control variable: GDP growth rate, market capitalization and firm age

We included three variables to control factors that may affect the variation of R&D efficiency. As GDP annual growth rate is indicates the economy of the company, we set GDP annual growth rate of the country which headquarter locates in, as the economy affects the R&D activities of the company. In addition, large enterprises are advantageous to carry out R&D activities (Schumpeter, 1942). Lastly, UIC is influenced by firm age (Motohashi, 2005), we also add the firm age as a control variable.

(5) Method of our study

We accept multiple regression analysis as a method. Since the objective of our research is to measure the correlation between the outcomes of UIC, it is reasonable to select this method. Since the correlation coefficient between the number of joint patents and joint papers was high (R=0.860), we divided this analysis into two models.
As independent variables, we used joint papers in model1, joint patents in model2, the ratio of cross border joint papers in model3, and cross border joint patents in model4

6. Results

(1)Results of hypothesis1

Table 2: Means, Standard Deviation and Correlation of the variables in hypothesis 1 (N=72)

Variables		Mean	S.D.											
				1		2		3		4		5		6
1	R&D efficiency	1.273	1.001	1										
2	Joint paper	173.287	161.430	0.771	***	1								
3	Joint patent	60.440	114.311	0.668	***	0.860	***	1						
4	GDP growth rate	1.344	2.709	0.264	**	0.256	**	0.265	**	1				
5	Market Capitalization	37853.85	37974.759	0.747	***	0.687	***	0.445	***	0.192	*	1		
6	Firm age	92	29.058	-0.452	***	-0.154	***	-0.121		-0.235	**	-0.497	***	1

※ ***Significant at 1%, **significant at 5%, *significant at 10%

Table 3: Results of hypothesis 1

Model1				Model2		
Constant		(4.066)	**	Constant	(2.046)	**
Joint paper	0.572	(6.029)	***	Joint patent	0.434	(1.454)	***
GDP growth rate	0.016	(0.236)		GDP growth rate	0.021	(1.369)	
Market Capitalization	0.228	(2.164)	***	Market Capitalization	0.470	(7.630)	***
Firm age	-0.246	(-3.109)	**	Firm age	-0.160	-0.421)	**
N	72				72		
F-test	44.496	***			42.830	***	
R^2	0.727				0.719		
Adjusted R^2	0.710				0.702		

※ t-value in parenthesis
***Significant at 1%, **significant at 5%, *significant at 10%

The result is illustrated in Table 3. As F-stat was high enough and adjusted R^2 was over 0.7 in both models, this model has considerable validity. The results show positive correlations between independent variable and R&D efficiency in both models. Furthermore, the highest VIF was 3.542 in both models so that we conclude these models are not affected by multicollinearity. Since both models were statistically significant at the p=0.01 level, hypothesis 1 is supported. Our results indicate that collaborating with universities improves R&D efficiency of each corporation.

(2)Results of hypothesis 2

Table 4: Means, Standard Deviation and Correlation of the variables in hypothesis 2

(N=72)

Variables	Mean	S.D.	1	2	3	4	5	6
1 R&D efficiency	1.273	1.001	1					
2 Ratio of international UIC (Joint paper)	0.324	0.126	-0.145	1				
3 Ratio of international UIC (Joint patent)	0.190	0.288	-0.225 *	0.791 ***	1			
4 GDP growth rate	1.344	2.709	0.264 **	-0.202 **	-0.092	1		
5 Market capitalization	37852.847	37974.759	0.747 ***	-0.113	-0.116	0.192 *	1	
6 Firm age	92	29.058	-0.452 ***	0.401 ***	0.342 ***	-0.235 **	-0.497 ***	1

※ ***Significant at 1%, **significant at 5%, *significant at 10%

Table 5: Results of hypothesis 2

Model3	Standard regresstion coefficient	Model4	Standard regression coefficient
Constant	(2.189) **	Constant	(2.046) **
Ratio of International UIC (Joint paper)	-0.012 (-0.139)	Ratio of international UIC (Joint patent)	-0.121 (-1.454)
GDP growth rate	0.111 (1.344)	GDP growth rate	0.11 (1.369)
Market Capitalization	0.684 (7.396) ***	Market Capitalization	0.691 (7.630) ***
Firm age	-0.081 (-0.804)	Firm age	-0.041 (-0.421)
N	72		72
F-test	22.967 ***		24.208 ***
R^2	0.578		0.591
Adjusted R^2	0.553		0.567

※ t-value in parenthesis
***Significant at 1%, **significant at 5%, *significant at 10%

The result is illustrated in Table 5. As F-stat was high enough and adjusted R^2 was over 0.5 in both models, this model has considerable validity. In addition, the highest VIF

was 3.148 in both models, there is no effect by multicollinearity in this analysis. However, the hypothesis 2 was rejected because the results of the test show that it is not statistically significant at the p=0.05 level. In other words, international UIC does not necessarily improve the R&D efficiency of the firms.

7. Discussion

Up to this point, quantitative verification of the hypothesis was carried out with the aim of demonstrating the relationship between UIC and R&D efficiency. This section examines the obtained results. First, hypothesis one was supported because both the number of joint patents applications of universities and firms and the number of co-authored papers have a significant positive influence on the company's R&D efficiency at the p=0.01 level.

Although patents have been told that the role of knowledge transfer as a method of knowledge transfer in the UIC is limited, as a result of the verification, both the joint patents and the joint papers were significantly related to the R&D efficiency at the p=0.01 level. From here, it is presumed that the difference between the roles played by joint patents and the role of joint papers in UIC is small. In addition, since the market capitalization is set as the control variable showed significant results at the p=0.01 level in hypotheses 1 and 2, it is considered that the economy of scale and financial capability are leading to improvement in research and development efficiency.

By implementing UIC, companies can access university research results, solve their own problems, and improve the quality of products and processes.

In addition, it will be easier to conduct research on scales and stages that one company cannot. In Japan, METI and MEXT cooperatively prepare guidelines, and MEXT will start a project to encourage the establishment of an organization promoting industry-academia collaborative research in 2018 (MEXT & METI, 2016: Nihon Keizai Shimbun, 2017). Likewise, both industry and academia have participated in consortiums and university-led organizations. It is suggested that this growing momentum is an appropriate direction and also shows the possibility for the firms of improving R&D efficiency by conducting UIC.

On the other hand, the role of government is considered to be a factor that hypothesis 2 was rejected. "The Triple Helix" is a concept that aims to promote innovation by strengthening collaboration between industry, government and the private sector.

According to Etzkowitz (1993), Etzkowitz & Leydesdorff (1995), at the knowledge society, the potential of innovation and economic development is promoted by the unification of universities, industry, and government. They will play an important role in creating a new social system that enables creation, transfer, and application of knowledge.

We already mentioned that securing research fund is mentioned as an incentive for implementation of UIC.

Debackere & Veugelers (2005) pointed out that universities that are successful in involvement in industry and R&D collaboration are balanced with subsidies from the country, independent of UIC in conducting research. In other words, when policies aimed at creating national innovation are implemented, it is also predicted that there will be concern that the results will be transferred to overseas companies as a result of enhancing university R&D capabilities and UIC. There are differences among countries in terms of the ratio of government burden R&D expenditures to GDP and R&D expenditure by research character, and attracting by policy and regulation are also major decisive factors when companies targeted this time search for partner universities.

In addition, barriers and costs that do not arise in cooperation with domestic industry may also hinder international UIC. Linguistic and religious differences, tacit knowledge among researchers becomes a problem (Hoekman, Frenken, & Tijssen, 2010: Hwang, 2010: Liang, Zhang, Kretschmer, & Scharnhorst, 2006). Nonetheless, it will never be denied that innovation is created by acquiring knowledge through international UIC. Leydesdorff & Sun (2009) showed a decrease in domestic finished co-authored papers, arguing that Japan's innovation system is being opened abroad. Also, as globalization adds, it is pointed out that policies that restrict the international dissemination of university knowledge are invalid (Mowery, 1998b: Park & Leydesdorff, 2008).

Although there are conflicting dynamics in international UIC in this way, the Japanese electronic industry will return to international competitiveness in the future,

and there is great potential for international academic UIC in the future. It is also a fact that it is necessary for us to continue researching this part, and we hope this paper helps the research.

8. Conclusions and implication

In today's hypercompetitive business world, no firm can survive without continuous innovation. It is prerequisite for Japanese electronic industry to identify its cause and take drastic measures. We have proposed that UIC would help Japanese electronics firms improve R&D efficiency, leading to the competitiveness again in the global market. This study shed light on the correlation between UIC and R&D efficiency.

We validated the multiple regression analysis and found that joint patents and papers as an outcome of UIC positively influenced R&D efficiency of electronic firms. It was proved that UIC is likely to improve R&D efficiency, which legitimizes firms' behavior in recent years. Interestingly, there were no significant correlation between international UIC and R&D efficiency. The study raised that the firms and host country of universities effect matter when they collaborate across borders.

This study also showed that corporate-level open innovation is beneficial to not only R&D but also business outcomes. In terms of applications for this work, Japanese firms which need to absorb the external knowledge will make use of it. Our study tried to offer some tips for firms struggling with low R&D efficiency. Hereafter, academic and practical

significances and limitations are described.

The novelty of this paper is as follows. First, we approached R&D activities of electronics firms from the perspective of UIC. Prior studies dealt with the factors and did not scrutinize R&D efficiency verified by operating income. The second main contribution is to focus on electronics industry, which was not paid much attention long in the context of UIC. Third, though most studies pertain to UIC for firms regarded it as merely a part of collaborative R&D, this study is among the first attempt to highlight UIC as a driver of improving R&D efficiency.

Our findings would encourage the Japanese electronics firms which are not necessarily aggressive because they feel that there are many problems in UIC. Looking international UIC in contrast, however, we suggested expanding UIC policy to overseas did not necessarily develop firms' R&D efficiency for about a decade. Nevertheless, we believe that absorbing external knowledge and accepting research outputs from overseas universities does mean a lot for firms seeking for a cue for accelerating innovation.

This study has limitations. There are only nine companies covered and the number of years of data after processing is limited eight years. In hypothesis 2, since the independent variable is set as the international UIC rate and not set as the number of international UIC, which hindered us to distinguish between both domestic and international firms with small and large number of UIC. The value of patents and papers should have been considered, not only the amount. The question remains about the proximity effect, the reason of choice of particular universities by firms, and the balance of

internal R&D. Future study efforts are needed on the appropriate scale and measures.

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