16 IP System and Corporate R&D Activities
- Empirical Analysis of the Effect of Worker Mobility on Innovation - (*)

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The purpose of this research is to study worker mobility and gain policy implications to create an IP system that can effectively prevent technology leakage caused by worker mobility. Specifically, focusing on the workers who moved from Japanese companies to companies in emerging countries, an analysis was conducted as to what types of researchers tend to move to non-Japanese Asian companies such as Korean companies and Chinese companies from the perspective of career, research field, network index, etc. Furthermore, in order to analyze what types of researchers, among those who moved from Japanese companies to non-Japanese Asian companies, have contributed to innovative activities of non-Japanese Asian companies, an analysis was conducted using panel data. The analysis results have revealed that the Japanese researchers who moved to non-Japanese Asian companies tend to be more competent than those who did not and tend to be in positions where information accumulates. It has also been revealed that, after moving to non-Japanese Asian companies, young researchers with research experience in a specific field have contributed to innovative activities quantitatively, while older researchers with experiences in a wide range of technical fields have contributed to innovative activities qualitatively.

Based on these findings, it may be presumed that among companies in emerging countries such as South Korea and Taiwan that have been strategically recruiting former workers of Japanese companies who can fill those companies' needs, large companies expect these Japanese workers to bring their accumulated information with them, whereas small and midsize companies expect them to bring technology and know-how with them. From the perspective of protecting important technologies owned by Japanese companies, in order to prevent leakage of competent workers, it is necessary to devise measures and systems such as a remuneration system to provide inventors with more incentives. Regarding an IP strategy, since not only the option of seeking patents for R&D results but also the option of keeping their secrecy as know-how will become increasingly important for companies, the policy to protect trade secrets, etc. should be enhanced.

Introduction

Since the burst of the bubble economy at the beginning of the 1990s, the Japanese economy has been sluggish for more than 20 years. In particular, the slowdown of the electronics industry has been obvious. Since the 1990s, the Japanese electronics industry has lost its global competitiveness and seen the rise of new companies in emerging countries such as South Korea and Taiwan.

One of the reasons why the Japanese electronics industry has lost its industrial competitiveness may be the failure to have its R&D activities create new business and increase profits. So far, Japan has been making profits by taking advantage of its technical superiority and exporting sophisticated products mostly to developed countries. However, developed countries, which have been experiencing the rapid aging of population and decline in the birth rate, have recently been replaced by emerging countries in terms of the importance as a market. For this reason, companies in many countries have been focusing on manufacturing products targeted at emerging markets, competing to grasp local needs and release locally customized products in a timely manner. Despite this trend, Japanese companies have often established R&D bases in Japan or other developed countries and have rarely chosen emerging countries as the locations for their R&D bases. In this respect, Japan has been lagging behind other countries in devising effective strategies for conducting business in emerging countries.

However, in the future, as Japanese companies will be more likely to choose emerging countries not only as manufacturing bases or sales bases but also as R&D bases and also to make use of local researchers. If Japanese companies deepen their ties with emerging countries to promote local R&D activities, they will face the following two difficult problems. The first problem is technology leakage due to technology transfer and worker mobility between companies. The second problem is the difficulty in recruiting talented local workers who could make innovations.

(*) This is an English translation of the summary of the report published under the Industrial Property Research Promotion Project FY2013 entrusted by the Japan Patent Office. IIP is entirely responsible for any errors in expression or description of the translation. When any ambiguity is found in the English translation, the original Japanese text shall be prevailing.

In this research, by using patent bibliographic information, an attempt was made to ascertain how many workers moved from Japanese companies to emerging countries and what types of workers moved to those countries. Then, using panel data, an analysis was conducted as to what types of Japanese researchers have contributed to innovative activities of companies in non-Japanese Asian countries. The results of these analyses have revealed the current state and issues related to worker mobility between companies and the types of workers who could contribute to innovative activities.

Ⅰ Background and purpose of this research

1 Background of this research

(1) R&D activities in emerging countries

Since the burst of the bubble economy at the beginning of the 1990s, Japanese companies have seen their business activities slowed down for more than 20 years. While Japanese companies have been restructuring themselves by cutting personnel, costs, etc. in an effort to revitalize their business, they have seen their sales flatten and have been overtaken by Samsung, LG, Hon Hai, and other companies in emerging countries.[1]

In recent years, it has been pointed out that the profitability of the Japanese manufacturing industry has been on the decline. For example, Genba (2012)[2] conducted research and concluded that a higher ratio of the sales to R&D costs has a negative effect on profitability. This suggests that a serious problem exists in the process of turning R&D results into profitable business, or in other words, monetization of innovations. Moreover, it has been pointed out that, while IP strategies play important roles in the process of monetization of R&D results, it has become difficult to identify a clear correlation between patents and enterprise value in recent years (Osaki, 2011). Against this background, there has been an argument that the promotion of R&D activities in emerging countries is an effective innovation strategy. For instance, reverse innovation, which has become famous as a result of its use by GE, has attracted a lot of attention as a growth strategy. Reverse innovation means conducting R&D activities in emerging countries and marketing the resulting products in developed countries as well (Usami, 2011).[3] In this way, an R&D strategy for emerging countries will be an indispensable element of the future revival and growth of Japanese companies.

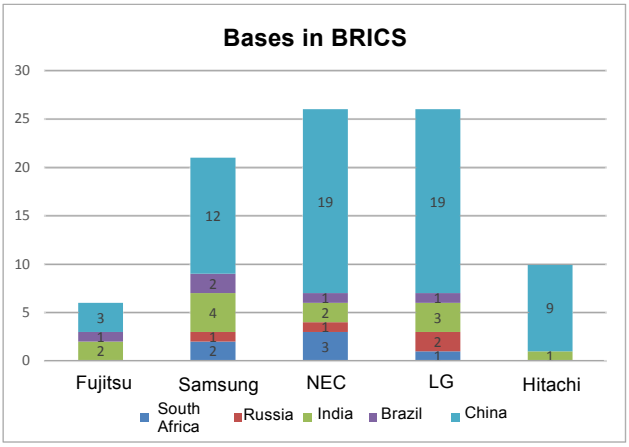
Based on patent data, with a focus on the R&D activities in emerging countries that could contribute to the monetization of R&D results, an analysis was conducted as to how Japanese companies use R&D bases in emerging countries and use researchers and engineers in emerging countries within the framework for their IP strategies (Fujiwara, Watanabe, 2012).4 To conduct this analysis, the first step is to examine the extent to which Japanese companies and Korean companies depend on the bases and workers in Japan or South Korea respectively or use overseas bases and workers when those companies conduct R&D activities and file patent applications. In this analysis, the Herfindahl-Hirschman Index (HHI) was used. This index indicates the level of concentration and makes it possible to conduct a comparison between those companies and examine a strategic difference such as some companies adopting the strategy of concentrating R&D bases and R&D workers in one place, whereas other companies adopted the strategy of pursuing diversification in this respect. Regarding the nationalities of R&D workers, data was collected based on the nationality of each inventor recorded in the U.S. patent registry. Similarly, regarding the addresses of applicants, the nationality of each applicant recorded in the U.S. patent registry was used as a substitute index. The reason for using the number of registered patents is that the registered patents are considered to be the R&D results that are used most frequently as a means for boosting corporate sales. The information registered and publicized by the USPTO as of September 2012 was used as the U.S. registered patent information. The electronics industry was chosen as an industry subject to this research because electronics companies file patent applications most actively.

Next, an examination was conducted as to the extent to which each company uses R&D bases in emerging countries and uses R&D workers in those countries. The five countries subject to this examination are Brazil (the world's 7th largest GDP in 2010), which is the most rapidly growing emerging country and expected to become a great purchasing power, as well as Russia (the world's 11th), India (the world's 10th), China (the world's 2nd), and South Africa (the world's 29th).

(2) Diversification of R&D bases and R&D workers

Since many Japanese companies have developed under the principle that they should be self-reliant, they have been reluctant to use talented researchers overseas (Fukagawa, 2012).[5]

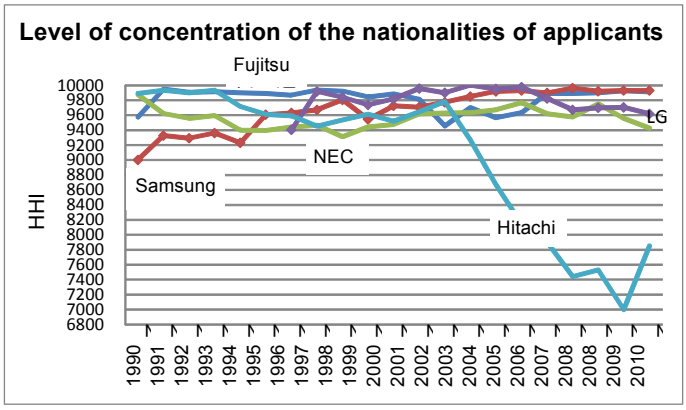
This approach has affected their R&D capabilities, raising three issues as follows. First, although the Japan's R&D level was said to be high, the quality of Japanese researchers has been deteriorating in various fields as pointed out in the research conducted by the National Institute of Science and Technology Policy, etc.[6] In contrast, the quality of researchers in emerging countries has been improving. Japanese companies might have failed to make full use of these R&D human resources in emerging countries. Second, with the globalization of corporate activities, R&D activities are also expected to be globalized and diversified. However, it has been pointed out that the headquarters of Japanese companies are lagging behind overseas companies in fostering workers with a global vision and that in overseas bases, local workers are not given responsible positions in the upstream manufacturing process such as development and designing (Furui, 2010).[7] For example, out of a total of 221,726 employees of Samsung, 119,753 employees are working overseas, accounting for more than 50%[8] of the total (as of 2012).[9] On the other hand, in Fujitsu, out of a total of 173,000 employees, 107,000 employees work in Japan, while the employees working overseas account for less than 40% of the total (FY2011). Third, in global business terms, markets in emerging countries have been increasing their value as consumer markets with a rapidly rising disposable income. This indicates that the promotion of R&D activities in emerging countries has become important as a localization strategy (Kobayashi, 2007).[10] For example, the five countries subject to this research have established bases in BRICS. LG and NEC are ranked top in terms of the number of bases, followed by Samsung (Fig. 1).[11]



[Fig. 1 Bases in BRICS]

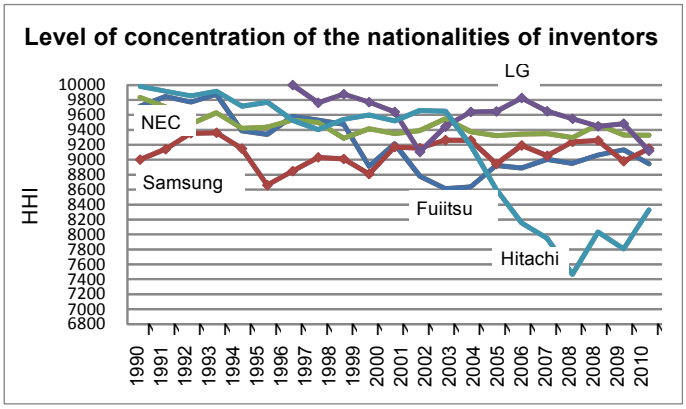
However, the actual contribution of those bases to R&D activities should be measured in consideration of the patents obtained based on the R&D results. Therefore, a comparison was conducted by using the Herfindahl-Hirschman Index (HHI), which indicates the level of concentration, from the perspective of to what extent Japanese companies have used R&D resources in emerging countries. In conducting this comparison, the HHI was determined based on the addresses of applicants and investors. If applicants have foreign nationalities, it indicates the possibility that R&D activities are conducted overseas and that applications were filed by overseas researchers to whom the authority to file patent applications had been delegated. The fact that inventors have foreign nationalities indicates the possibility that overseas researchers are utilized in R&D activities.

Fig. 2 shows the level of concentration of the addresses of applicants. The higher the HHI, the more the nationalities of applicants are concentrated in the home county. This indicates the possibility that R&D activities and the filing of patent applications are not conducted overseas. The lower the HHI, the more the companies have diversified in terms of the countries where they have R&D bases. In short, the HHI determined based on the addresses of applicants shows the level of diversification of the R&D bases and the level of concentration and deconcentration of IP control. As clearly shown in Fig. 2, as far as Samsung and LG in the beginning of the 1990s are concerned, the ratio of applicants with foreign nationalities was relatively high. However, since the 2000s, the nationalities of applicants have been concentrated in South Korea. This suggests that those companies were conducting R&D activities overseas in the 1990s and filed patent applications from those overseas countries based on the R&D results obtained therein whereas, since the 2000s, those companies started to have their headquarters centrally manage patent applications.[12] On the other hand, as far as Japanese companies, namely, Fujitsu, NEC, and Hitachi in the 1990s and the early 2000s, are concerned, the addressees of applicants concentrated in Japan, indicating their strong belief that they should be self-reliant. However, in recent years, the concentration level of all of the five companies has been on the decline, indicating their increasing reliance on overseas bases for patent application filing. In particular, since around 2004, Hitachi has increased the number of applications filed from overseas bases, indicating that it abandoned the self-reliance principle relatively earlier.



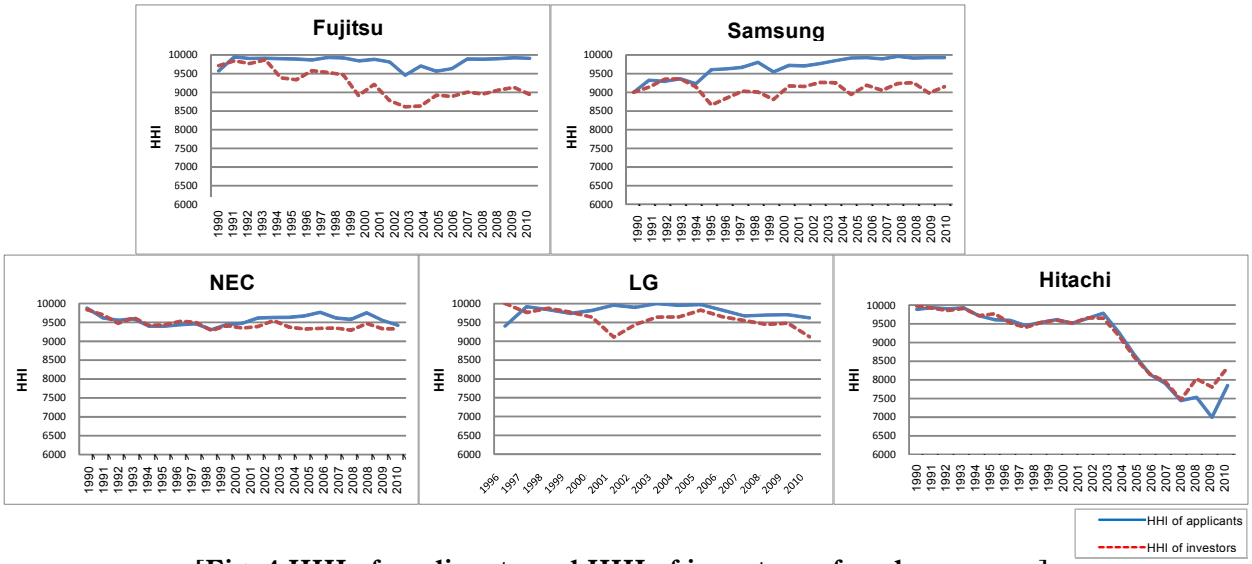
[Fig. 2 Level of concentration of the nationalities of applicants]

Next, with regard to R&D activities, a comparison was made from the perspective of the degree of reliance on the researchers in the home country and in other countries. As shown in Fig. 3, in the 1990s, Samsung was actively using overseas researchers. On the other hand, Fujitsu and Hitachi were actively using overseas researchers in the early 2000s. Since around 2010, Samsung, LG, and NEC have increased their use of researchers with foreign nationalities.



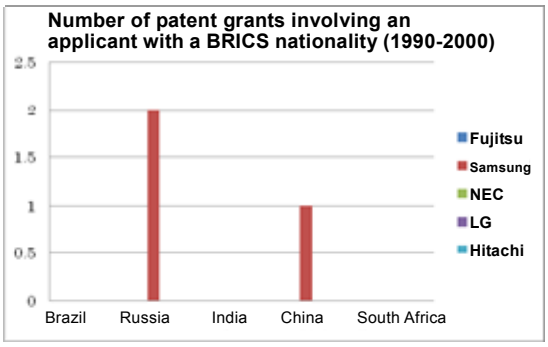
[Fig. 3 Level of concentration of the nationalities of inventors]

Fig. 4 shows the chronological changes in each company's concentration and diversification of R&D bases and R&D workers. As far as the upper two companies are concerned, the HHI determined based on the addresses of applicants and the HHI determined based on the addresses of investors show different chronological changes, whereas the lower three companies show the same chronological changes. This difference may be attributable to the fact that, when using overseas bases and workers, some companies manage human resources separately from intellectual properties, while others do not separate the two. For example, while Samsung has relatively increased concentration in terms of the addressees of applicants, it has consistently been using overseas R&D workers. This suggests that Samsung has introduced stronger headquarters control over intellectual properties since around 2000.[13]

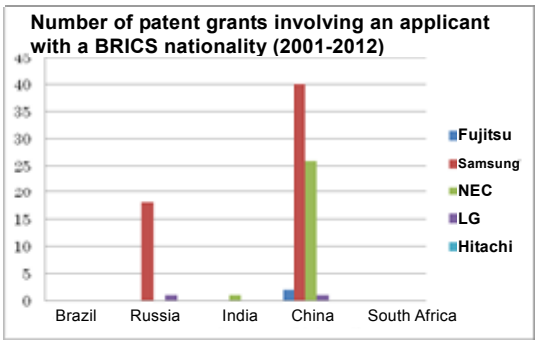


[Fig. 4 HHI of applicants and HHI of investors of each company]

As pointed out above, in recent years, both Japanese companies and Korean companies have increased the use of overseas R&D bases and overseas researchers. Next, regarding BRICS, i.e., the emerging countries that are especially expected to grow in the future, a comparison was made from the perspective of to what extent companies have used those countries as overseas bases and used R&D workers in those countries. Fig. 5 and Fig. 6 show the extent to which each company used BRICS as its bases. As shown in Fig. 5, it was only Samsung that used BRICS as its bases in the 1990s. Samsung continued using Russia and China as its bases even after the 2000s. On the other hand, from the 2000s, NEC, Fujitsu, and LG started using Russia, India, and China as their bases.



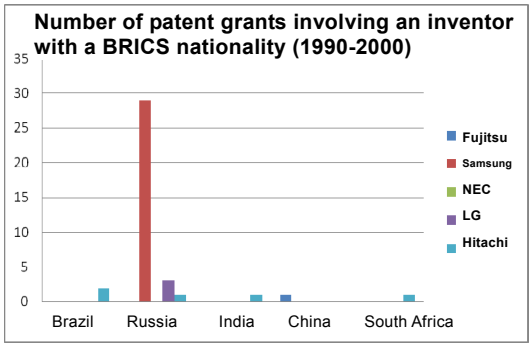
[Fig. 5 Number of patent grants involving an applicant with a BRICS nationality (in the 1990s)]



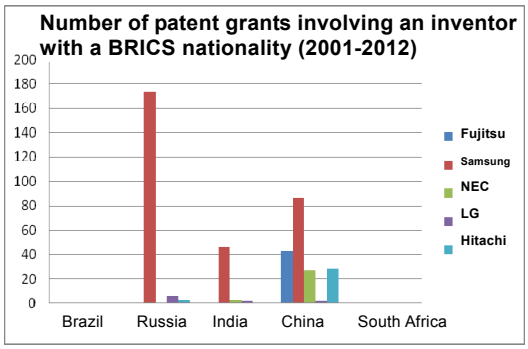
[Fig. 6 Number of patent grants involving an applicant with a BRICS nationality (the 2000s and after)]

Next, an examination was conducted as to the extent to which the researchers in emerging countries have been used. Fig. 7 shows that, in 1990s, Samsung used researchers in Russia, while Hitachi used researchers in Brazil, India, and South Africa. In the 2000s, Samsung greatly increased the use of R&D workers in India and China. From the perspective of the use of workers in China, Fujitsu ranked top, followed by Hitachi and NEC. However, each of them owns only less than half the number of patents owned by Samsung.[14] While both Samsung and Fujitsu have used overseas workers for the R&D activities, Samsung is ahead of Fujitsu especially in terms of the level of utilization of workers in emerging countries. On the other hand, even in the 2000s, no companies have used researchers in Brazil and South Africa. These findings have revealed that Samsung has been unsurpassed when it comes to strategically using overseas workers, especially in emerging

countries.



[Fig. 7 Number of patent grants involving an inventor with a BRICS nationality (in the 1990s)]



[Fig. 8 Number of patent grants involving an inventor with a BRICS nationality (the 2000s and after)]

As described above, the data shows that the Japanese companies have adopted the R&D system of using workers in Japan and conducting R&D activities in Japan. On the other hand, the data shows that, while Samsung has pursued concentration in terms of the R&D bases, it has long used important countries such as BRICS as R&D bases and has long used people with various nationalities including emerging countries as R&D workers. However, as shown by the example of Hitachi, more and more Japanese companies that are hoping to increase their presence in the market of emerging countries are expected to establish R&D bases in emerging countries and increase the use of local workers to conduct R&D activities in those countries.

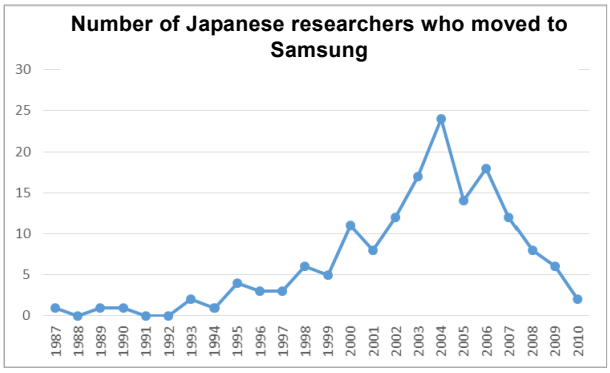
(3) Leakage of workers

Japanese companies have been conducting R&D activities with the belief that they should be self-reliant. As shown by the examples of Hitachi and Samsung, Japanese companies will be expected to abandon the conventional business model where the products developed for the market of the home country are exported to other countries and to adopt a new business model where R&D activities are conducted overseas in collaboration with local researchers in order to produce products customized according to the local needs. For the Japanese companies planning to establish R&D bases and use R&D workers in other countries, their greatest concerns are the risk of leakage of technology and know-how that they have accumulated so far. In general, there are three types of technology leakage.[15] First, technology leakage could occur through "goods" that embody technologies in the form of products, parts, etc. Second, technology leakage could occur through "data" that embody technologies in the form of drawings, documents, and electronic files. Third, technology leakage could occur through "people" who embody technologies in the form of manufacturing know-how of skilled workers, ideas of developers, etc.[16] An example of technology leakage through "goods" is the case where a final product is subject to reverse engineering. An example of technology leakage through "data" is the case where a worker takes a drawing, etc. out of his/her workplace. An example of technology leakage through "people" is the case where an employee or a retiree gives technical guidance or changes jobs, etc. Such technology leakage through "people" is difficult to detect. Furthermore, since the line often blurs between legal job changes and technical guidance and illegal ones, it is extremely difficult to obtain accurate information. In this respect, as mentioned above, Japanese companies have been promoting large-scale downsizing for the last few decades. It has been said that many non-Japanese Asian companies are interested in the victims of the restructuring carried out by Japanese major manufacturers.

Fujiwara & Watanabe (2013)[17] identified the workers who moved from Japanese electric manufacturers to companies in South Korea, China, and Taiwan by using the patent data from Japan, South Korea, China, and Taiwan and analyzed the tendency among those workers. In this research, about 270,000 cases of patent grants to Japanese electronic manufacturers, about 50,000 cases of patent grants in China, about 70,000 cases of patent grants in South Korea, and about 50,000 cases of patent grants in Taiwan were analyzed. The researchers identified the names of all of the inventors involved in those patent grants and then retrieved the inventors whose names appeared in connection with both a patent granted to a Japanese company and a patent granted to a company in South Korea, China, or Taiwan because

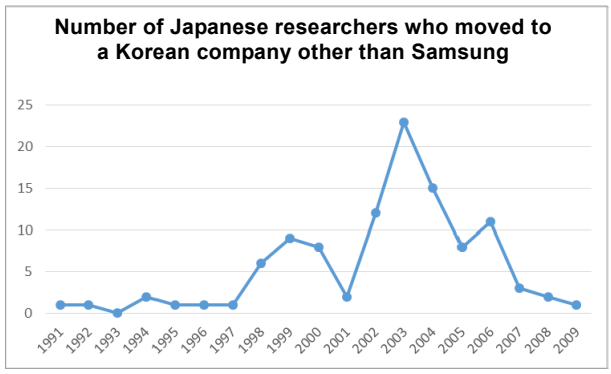
it suggests the possibility that those inventors moved from a Japanese company to a company in any of those countries. However, there is a possibility that, even if the same name appears in connection with two patents, i.e., a patent granted to an overseas company and a patent granted to a Japanese company, it could simply mean that there are two different persons sharing the same name. In order to increase the possibility that there is only one person indicated by that name, the name would be considered to be indicating the same person only if it satisfies the criteria for similarity in IPC numbers. The first step is to identify the inventors whose names appear in connection with both a Japanese company and an overseas company. The second step is to choose from those inventors any inventor who is considered to be an identical person who has moved from a Japanese company to an overseas company because the similarity criteria for IPC numbers is satisfied. In order to determine the direction of the move of each inventor, an analysis was made to identify the company each inventor originally belonged to and the company he/she newly belongs to after the move. In this way, the move of every inventor was tracked. Furthermore, based on the information on the timing of the last patent application filed from the pre-move company and the timing of the first patent application filed from the post-move company, the most probable timing of the move of every inventor was calculated.

Fig. 9 shows the chronological changes in the number of researchers who moved from Japanese companies to Samsung. As shown in the figure, the move to Samsung peaked in 2004 and has rapidly declined since then.[18] A closer examination of the patents that the Japanese researchers obtained after moving to Samsung has revealed that it is extremely common that a few Japanese researchers belong to the same group and engage in R&D activities. The data on the Japanese companies to which those researchers originally belonged show that, in some cases, those members used to belong to the same Japanese company and engage in R&D activities in the same group.[19] While the timing of the move of each researcher varies within a range of 2 to 3 years, it may be presumed that the researchers who had conducted R&D activities as colleagues in a Japanese company moved to Samsung at the same time or with some time lag and jointly conducted R&D activities at Samsung.[20]



[Fig. 9 Number of Japanese researchers who moved to Samsung]

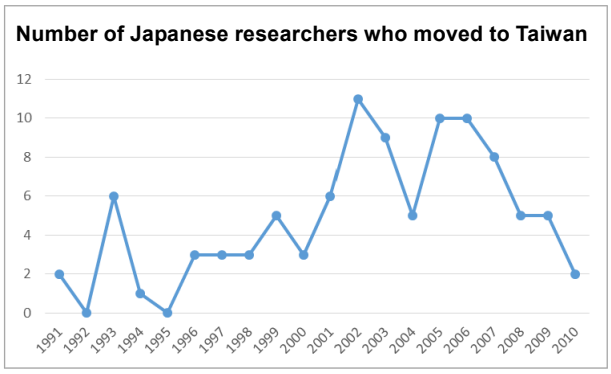
Fig. 10 shows the chronological changes in the number of Japanese researchers who moved to a Korean company other than Samsung. The number reached a small peak in around 2000 and hit the greatest peak in around 2003. This shows the same pattern as the number of inventors who moved to Samsung.



[Fig. 10 Number of Japanese researchers who moved to a Korean company other than Samsung]

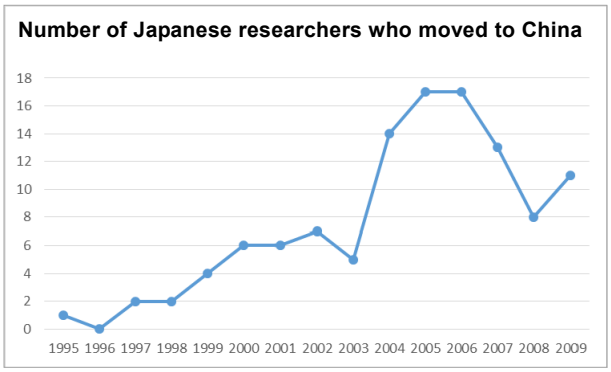
Fig.11 shows the chronological changes in the number of Japanese researchers who moved to Taiwanese companies. While the number of Japanese researchers who moved to Korean companies showed a rapid increase from around 2000 and has been on the decline in recent years, the number of Japanese researchers who moved to Taiwan has shown relatively small changes and stayed almost the same since the 1990s. The decline since around 2007 may be attributable to the time lag that inevitably occurs in this analysis due to the use of patent data. A detailed analysis of the R&D activities conducted by Japanese researchers after moving to Taiwan has revealed that it is very common for Japanese researchers to conduct R&D activities as the only Japanese researcher in a local research group consisting of

several researchers. The Japanese researchers who moved to Taiwan to conduct R&D activities are expected to play a leadership role for local researchers.[21]



[Fig. 11 Number of Japanese researchers who moved to Taiwan]

Fig. 12 shows the chronological changes in the number of Japanese researchers who moved to China. As shown in the figure, the number of Japanese researchers who moved to China has been on the rise. The number of Japanese researchers who moved to Samsung and other Korean companies peaked in 2003 to 2004 and has been on the decline since then. In contrast, the number of Japanese researchers who move to China is expected to further increase in the future.



[Fig. 12 Number of Japanese researchers who moved to China]

As explained above, the number of Japanese researchers who moved to South Korea significantly increased from 2000 and has been on the decline in recent years. On the other hand, the number of Japanese researchers who moved to China could further increase in the future. However, whether or not the number of Japanese researchers who move to Chinese companies increases may depend greatly on the state of the R&D systems of Chinese companies and the treatment of researchers as well as the level of IP protection, etc. in China, etc. The following section will examine the relationship between worker mobility and the IP protection level in each country.

(4) Relationship between worker mobility and the IP protection level

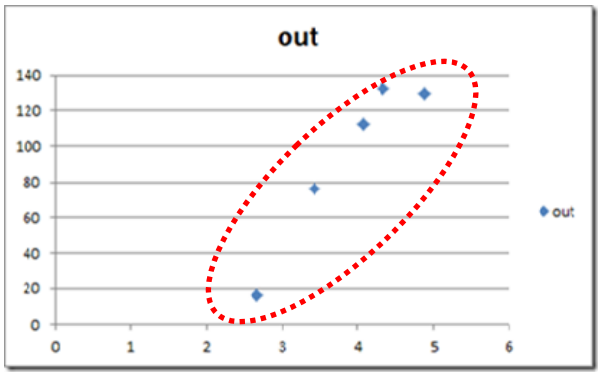
With the globalization of R&D activities, the IP system in each country is an important factor for securing local workers and also for facilitating the move of researchers to that country. However, no specific research has been conducted with regard to the effect of the IP protection level on the securing and mobility of workers.

In this section, patent data was used to analyze the relationship between the changes in the IP protection level in each country and the inflow and outflow of workers to and from that country. This analysis was conducted targeting a total of eight countries that are expected to grow economically in the future, i.e., South Korea, China, India, Brazil, Russia, Thailand, Indonesia, and Vietnam. The U.S. patent data about the patent applications filed by the companies in those eight countries was used. More specifically, I retrieved the inventors' names on all the patents filed by the companies in those eight countries and matched inventors' names in parings of all these countries and extracted the inventors whose names made a perfect match on patents in the parings. Based on the IPC numbers, I considered the matching inventors as identical if they obtained patents in the same technical field and found them to be different persons if they obtained patents in different technical fields. In this way, for each of the aforementioned eight countries, I counted the number of workers secured in other countries (in) and the number of inventors who moved to other countries (out). As the indicator of the IP protection level of each country, I used the Index of Patent Rights (IPR) developed by Park. The IPR is the index publicized by Park every five years based on his research on the following five factors, namely, (i) the scope of patent protection, (ii) accession to international treaties, (iii) whether the country has the legal authority to demand the grant of a compulsory license for a patent or to prevent the non-use of patent rights, (iv) strict punishment for patent infringement, and (v) the guarantee of 20-year patent protection period.

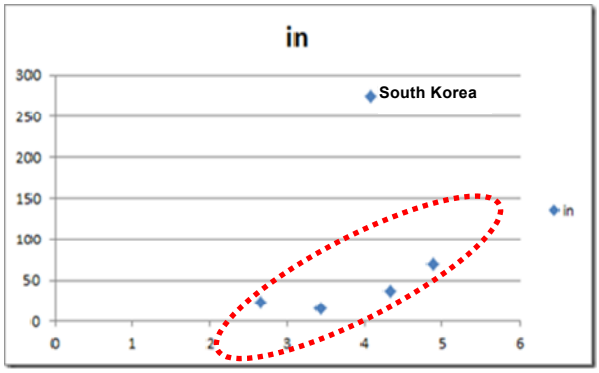
	China	India	Brazil	Russia	Thailand	Indonesia	Vietnam
Average in 1960 to 1990	1.33	1.03	1.22	-	0.95	0	1.38
1995	2.12	1.23	1.48	3.48	2.41	1.56	2.09
2000	3.09	2.27	3.59	3.68	2.53	2.47	2.9
2005	4.08	3.76	3.59	3.68	2.66	2.77	3.03

[Table 1 Index of patent rights of each country[22]]

Fig. 13 shows the relationship between the outflows of workers and the IPR of each country. As shown in Fig. 13, workers tend to move from countries with a high IP protection level. On the other hand, Fig. 14 shows the relationship between the inflow of R&D workers and the IP protection level of each country. This indicates that workers tend to move to countries with a high IP protection level, in other words, the higher the IP protection level is, the easier it would be to attract overseas researchers. While the data shows that South Korea is separated widely from other countries and attracted an extraordinarily large number of workers, this is presumed to be attributable to the fact that South Korea intentionally invited talented workers from other countries.



[Fig. 13 Relationship between the outflow of workers and the IP system of each country]



[Fig. 14 Relationship between the inflow of workers and the IP system of each country]

As described above, in recent years, there has been a drastic increase in the number of workers moving from one country to another. An increasing number of workers are expected to move between emerging countries and developed countries. This has raised two issues in relation to Japanese companies. First, it is important to accurately grasp how many and what types of R&D workers have moved from Japanese companies to which companies. Even though it is impossible for companies to prohibit their employees from moving to other companies, some measures would be necessary to reduce the risk of the outflow of important workers and technologies. Second, for Japanese companies planning to promote the use of overseas workers in the future, it is important to accurately grasp what types of workers they should hire and what types of R&D systems they should build in order to promote corporate growth, in other words, what types of R&D workers will contribute to their innovative activities in emerging countries. This issue is important because companies would be able to increase their market shares in emerging countries by hiring overseas researchers and making effective use of them.

2 Purpose of this research

As described above, many R&D workers have already moved from Japanese companies to other non-Japanese Asian companies. In particular, many workers have moved to Korean companies, which have been growing significantly. However, it is expected that more and more Japanese researchers will move to China, India, Thailand, etc., with the enhancement of the IP systems in those emerging countries in the future.

What Japanese companies must do to become innovative and competitive again is to reconstruct their innovation approach from two aspects, i.e. "leakage" and "acquisition" of technology. More specifically, there is a call for a new strategy with a view to preventing the leakage of technologies that Japanese companies will need to achieve growth, while actively acquiring technologies that they will need to enhance their market shares in emerging

countries in the future.

This research pays attention to the fact that worker mobility has a great impact on technology transfer and innovation, and aims to empirically analyze such impact of worker mobility on innovation. To this end, an attempt was made to first grasp what types of workers move from Japanese companies to non-Japanese Asian companies, and then analyze the difference between those who moved and those who remained among workers of the same company, in terms of factors such as the number of years of career, R&D achievements, and specialized research fields. An empirical analysis was also conducted as to Japanese workers who moved to non-Japanese Asian emerging companies, with a focus on what types of workers contributed to innovative activities of the companies to which they moved.

Thus far, research on innovation results had been conducted using a knowledge production function in order to analyze the impact of R&D investment and human capital on innovative activities of companies (Pakes and Griliches (1984), Griliches (1990)). These earlier research efforts can be evaluated as placing the focus on the extent to which innovation can be created by inputting financial capital or human capital in R&D activities. On the other hand, this research is interested in analyzing how knowledge workers of companies in developed countries would affect the innovation activities of companies to which they moved, with them embodying the technologies and knowledge of their former companies. In order words, the objective of this research is to clarify the impact of knowledge workers on innovation, rather than merely watching the relationship between the financial capital and human capital as an input and the innovation results as an output.

In order to analyze the process wherein the knowledge embodied in knowledge workers spills over to the companies to which they moved and play a role in the innovation and growth of these companies, several indices were used in this research as those representing the quality of workers. One such index is a network index. In this research, an analysis was conducted as to the correlation between the positions that workers held before moving and the contribution that they made at the companies to which they moved, based on the data of workers who moved from companies in developed countries to companies in emerging countries. There are few research results accumulated thus far with regard to such relationship between the in-house network and the spillover of knowledge through worker mobility. This research aims to reveal that human mobility and the existence of an informal network play an important role in the innovation process. More specifically, a quantitative analysis was conducted as to the impact of individual workers' attributes, such as their network index, number of years of career, R&D achievements and specialized research fields, on worker mobility and innovation.

Ⅱ Review of preceding research and setting up hypotheses

1 Review of preceding research

A representative research that was previously conducted to examine the impact of investment in R&D activities and human capital on innovation was Pakes and Griliches (1984), which conducted an analysis of patent data using a knowledge production function.[23]

In the preceding research, the amount of R&D investment and the number of patents obtained were frequently used as a proxy variable to indicate innovation. While an increase in the amount of R&D investment can be understood as the outcome of successful innovation, it is natural to consider the R&D expense as an input. For this reason, patent data was used as a proxy variable to indicate innovation in this research. Furthermore, in addition to the number of patents, the quality of patents was taken into consideration as a proxy variable to measure innovation because, when examining how the movement of workers from developed countries to emerging countries could contribute to innovation, as is attempted in this research, the aspect of improvement of the quality of innovation cannot be ignored.

2 Hypotheses

(1) Hypothesis (i)

As mentioned above, Japanese companies have undergone a major restructuring since around 2000. If all of the engineers laid off by these companies were unnecessary personnel, the companies could have reduced costs by such downsizing and improved their business performance. However, in the past two decades, Japanese electronics manufacturers do not seem to have succeeded in improving their profitability through creating innovation, despite their decision to sell off their unprofitable divisions such as semiconductors. A question that may arise here is whether Japanese companies made a correct

choice regarding workers whom they should have laid off and workers whom they should have retained. In other words, there is a possibility that Japanese companies might have laid off talented workers who could have contributed to creating innovation if they had remained, while retaining common workers without such innovative capability instead.

This research attempts to compare, among researchers who once worked at the same Japanese company, those who moved to non-Japanese Asian companies and those who remained, and analyze the comparison results, using data of the number of years of career, R&D achievements and specialized research fields. For this analysis, the following hypotheses were set up.

Hypothesis (i): Researchers who had achieved superior achievements at Japanese companies moved to non-Japanese Asian companies.

In this research, this hypothesis was tested through the comparison between researchers who moved from Japanese companies to non-Japanese Asian companies and those who remained at Japanese companies.

(2) Hypothesis (ii)

Hypothesis (i) was set up to examine what types of researchers tend to move and what types of researchers tend to remain, on the basis of the difference in quality between, among researchers who once worked at the same Japanese company, those who moved to non-Japanese Asian companies and those who remained at the company. However, whether Japanese researchers would move to non-Japanese Asian companies and whether they would be successful after moving to non-Japanese Asian companies are issues of different levels. Then, another attempt was made to examine what types of Japanese researchers among those who moved would be successful at non-Japanese Asian companies. When Japanese researchers move to non-Japanese Asian companies, they would be expected to develop new fields of research that the non-Japanese Asian companies have not worked in, by making use of the high technological capabilities that they have cultivated at the Japanese companies, rather than being merely expected to serve as part of the workforce. In order to ascertain whether Japanese researchers are successful at the non-Japanese Asian companies to which they moved, the degree of change in the quality or quantity of patents obtained as a result of their involvement would be a more appropriate barometer than the degree of change in the amount of sales. Accordingly, the following two hypotheses were set up.

Hypothesis (ii)-1: Japanese researchers who can contribute to innovative activities of non-Japanese Asian companies on a *quantitative* basis are those who have knowledge in a wide range of technical fields.
Hypothesis (ii)-2: Japanese researchers who can contribute to innovative activities of non-Japanese Asian companies on a *qualitative* basis are those who are young.

Based on Hypotheses (ii)-1 and (ii)-2, the creation of innovation at non-Japanese Asian companies was measured in terms of both quantity and quality and an analysis was attempted to find out what types of Japanese researchers could contribute to such innovation.

Ⅲ Analysis of Hypothesis (i)

1 Data

(1) Data used for analysis

For the analysis in this research, US patent data from 1976 to 2013 was used. Specifically, from among data of US patents held by electronics manufacturers of Japan, South Korea, China and Taiwan, the names of inventors, the number of inventors, the numbers of backward and forward citations of the relevant patent, the IPC number, the year of application and other items were extracted.

Since this research aims to grasp worker mobility accurately, the identity of the inventor was determined by setting a criterion in terms of technical field and confirming the movement of each inventor. Then, for each such identified inventor, factors such as the number of years of the inventor's career, the numbers of backward and forward citations of the relevant patent in which the inventor was involved, the HHI of the IPC number, and the network index were calculated.

Furthermore, based on the assumption that companies that have achieved rapid growth may have preferentially hired workers from developed companies, Samsung (South Korea) and Hon Hai (Taiwan), which are said to have experienced most rapid growth in recent years, were analyzed separately from other non-Japanese Asian companies as the destinations to which Japanese inventors moved.

(2) Explained variable

The explained variable used for analyzing what types of inventors, among those who worked at Japanese companies, tended to move to non-Japanese Asian emerging companies was a binary variable which took on 1 if each inventor moved to a non-Japanese Asian company and 0 if he/she did not move.

(3) Explanatory variable

In order to examine the impact of worker mobility and human network on each company's innovation, the worker quality index and the network index were used as an explanatory variable. For example, in order to measure the quality of each worker who moved to a non-Japanese Asian company, variables such as the numbers of backward and forward citations of the relevant patent in which the worker was involved, the HHI of the IPC number, the size of the Japanese company to which the worker originally belonged, the number of years of the worker's career, and the network index were used.

2 Analysis method

In order to examine the difference in terms of characteristics between, among researchers who worked at the same Japanese company, those who moved to non-Japanese Asian emerging companies and those who remained at the company, a logit model was built using, as an objective variable, a binary variable which took on 1 if each inventor moved to a non-Japanese Asian company and 0 if he/she did not move. The model is expressed by the following formula.

Ⅳ Analysis of Hypothesis (ii)

1 Data

(1) Data used for analysis

In the analysis of Hypothesis (ii) as well, US patent data from 1976 to 2013 was used. As for Japanese companies, the same data as that used for Hypothesis (i) was used. Since Hypothesis (ii) was set up to analyze what elements in Japanese inventors contributed to innovative activities of the non-Japanese Asian companies to which they moved, an attempt was made to track Japanese researchers who moved to five companies in Asia (China, Taiwan, and South Korea). In order to analyze how the inventors who moved from Japanese companies contributed to innovative activities of these five companies, a panel data analysis was conducted using the patent data and financial data on the 22 years from 1990 and 2011.

(2) Explained variable

Regarding the explained variable, patents were used as the index to measure innovation. As mentioned above, the number of patents has been conventionally used as the index to measure innovation.24 In this research, however, in order to take the quality of innovation into consideration, not only the number of patents but also the number of citations of each patent were included as a proxy variable for the quality of innovation.

(3) Explanatory variable

Regarding the explanatory variables, the following indices were used: the R&D costs for each term of each company; the numbers of researchers and Japanese researchers utilized in each term; and indices that indicate the quality of each researcher utilized, such as the numbers of backward and forward citations of the relevant patent in which the researcher was involved, the number of years of the worker's career, the HHI of the IPC number, and the network index.

2 Analysis method

In other to prove the effect of introducing knowledge workers from companies in developed countries to companies in emerging countries such as China and South Korea, a knowledge production function, which was proposed by Griliches and Shankerman (1984) and Griliches and Regev (1995), was used. The knowledge production function is used to measure the effect of R&D investment on knowledge increase.

By using variables relating to the quality of knowledge workers, this research aims to see the impact of Japanese inventors on the innovation at the non-Japanese Asian companies to which they moved.

Regarding an explained variable, the numbers of patents and the number of forward citations were used as a proxy variable to indicate innovation. In order to control the bias due to the effect peculiar to each company,[25] estimations were made based on the fixed effect model and the random effect model in this research.

Ⅴ Analysis results and consideration

1 Analysis of Hypothesis (i)

(1) Analysis results

Table 2 shows the results of a binary logistic analysis regarding Hypothesis (i), in which the case where a researcher moved from a Japanese company to a Korean, Chinese, or Taiwanese company is considered as "1," and the case where a researcher did not move is considered as "0."

The results of this analysis has revealed that the evaluation of research performance of each researcher is positive as far as the researchers who moved to Samsung or any other Korean company are concerned, while the evaluation is negative as far as the researchers who moved to Hon Hai are concerned. Regarding the size of the company a Japanese researcher originally belonged to, the value is significantly negative as far as the Korean companies and Hon Hai are concerned. Regarding the number of years of experience, the value is insignificantly positive as far as Korean companies are concerned, while the value is insignificantly negative as far as Chinese and Taiwanese companies are concerned. Regarding the degree of concentration of technical fields, the value is negative as far as Samsung and Hon Hai are concerned, while it is positive as far as other Korean companies and Chinese companies are concerned. Regarding the eigenvector centrality, the value is significantly positive as far as Korean companies are concerned.

	South Korea				Other non-Japanese Asian countries			
	Researchers who moved to Samsung		Researchers who moved to other Korean companies (e.g. LG)		Researchers who moved to Hon Hai		Researchers who moved to other non-Japanese Asian companies	
Originality	+		+	*	+		+	*
Evaluation of research performance	+	***	+	***	-		+	*
Size of the company a Japanese researcher originally belonged to	-		-	***	-	***	+	
Number of years of experience	+		+		-		-	
Degree of concentration of technical fields	-		+		-		+	
In-house network	+	***	+	***	+	*	+	***

*significant at the 10% level, **significant at the 5% level, ***significant at the 1% level

[Table 2 Logistic regression analysis]

(2) Consideration

With regard to the evaluation of research performance represented by the number of forward citations, the analysis results has revealed that, as far as Korean companies are concerned, the value is significantly positive for both Samsung and other Korean companies, which indicates that only the Japanese researchers who had been involved in obtaining high-quality patents were selected and invited to move from Japanese companies to Korean companies. On the other hand, as far as the Japanese researchers who moved to Hon Hai are concerned, the value is insignificantly negative, which indicates that the researchers who moved to Hon Hai had not necessarily been involved in obtaining high-quality patents. Regarding the number of years of each researcher's experience, the researchers who moved to Korean companies are relatively old, whereas the researchers that move to Taiwanese or Chinese companies are relatively young. Regarding the degree of concentration of technical fields, although the value is insignificant, the analysis results indicate that Samsung and Hon Hai need workers with experience in a wide range of technical fields, whereas other Korean companies and Chinese companies need inventors specialized in a small number of technical fields. Finally, regarding the eigenvector centrality, the value is significantly positive as far as Korean companies and Hon Hai are concerned. This indicates that inventors who were likely to accumulate information thanks to their relatively important position in a company are more likely to move.

2 Analysis of Hypothesis (ii)

(1) Analysis results

The middle column of Table 3 shows the results of estimating a knowledge production function by using the fixed effect model and the random effect model based on Hypothesis (ii). A knowledge production function is determined by using the innovation measured by the number of patents as an explained variable. The results of estimation show that, if the innovation is measured by the number of patents, contribution to innovation is made by researchers who have been engaged in research in specific technical fields.

The right column of Table 3 shows the results of estimation made by using the innovation measured by the quality of patents as an explained variable. The values for the number of years of experience and the eigenvector centrality are positive.

	Innovation measured by the *number* of patents		Innovation measured by the *quality* of patents	
R&D costs	+	***	+	***
Japanese researchers	-	**	+	
Degree of concentration of technical fields	+	**	-	
Size of the company a Japanese researcher originally belonged to	-		-	
Originality	+		-	
Evaluation of research performance	-		+	
Number of years of experience	-		+	**
In-house network	-		+	**

*significant at the 10% level, **significant at the 5% level, ***significant at the 1% level

[Table 3 Panel data analysis regarding innovation measured by the number and quality of patents]

(2) Consideration

Based on Hypothesis (ii) set up to examine the types of researchers who have contributed to innovative activities of non-Japanese Asian companies after moving from Japanese companies to those destination companies, it may be said that the type of researchers who are likely to make such contribution is different depending on whether the innovation is measured by the number of patents or by the quality of patents.

First of all, in the case of innovation measured by the number of patents, the inventors who move from Japanese companies and contribute to innovative activities of non-Japanese Asian companies are likely to be inventors with a high HHI, in other words, those who have been specialized in R&D activities in a small number of technical fields. In the case of innovation measures by the number of patents, the number of years of experience has a negative effect. This suggests that younger researchers are more likely to contribute to obtaining many patents at the destination companies.

On the other hand, in the case of innovation measured by the quality of patents, it is revealed that, among the inventors who moved from Japanese companies to non-Japanese Asian companies, the researchers with rich experiences are more likely to contribute to the improvement of the quality of inventions at the non-Japanese Asian companies.

Ⅵ Summary and policy implications

1 Summary

In this research, empirical analyses were conducted on the relationship between worker mobility and innovation. Research on mobility of Japanese researchers has not been sufficiently accumulated thus far. Furthermore, although innovation has been addressed in earlier research using a knowledge production function, most of the preceding research attempts were made to analyze the impact of R&D investment and human capital on innovation, or in other words, they focused on the number of workers but did not focus on the quality of workers.

In this research, an empirical analysis was made based on Hypothesis (i), from the perspective of the quality of workers who moved from Japanese companies to non-Japanese Asian companies and the informal network they have. The analysis results show that companies in emerging countries which experienced rapid growth preferentially hire, among researchers working at companies in developed countries, those who hold important positions and have high

competency.

Another empirical analysis was made based on Hypotheses (ii) to examine the impact of the quality of Japanese workers on the innovation at the non-Japanese Asian companies to which they moved. The analysis results show that if innovation at companies in emerging countries is measured by the number of patents, young researchers and highly specialized researchers among those from companies in developed countries made greater contribution to innovation. It is also revealed that if innovation is measured by the quality of patents, innovation is promoted at companies which hire more workers from companies in developed countries, and among such workers, those who have longer R&D experience made greater contributions to innovation.

2 Policy implications

As described above, it is revealed that many Japanese researchers have already moved to overseas companies in South Korea, China, Taiwan, etc. and have attained certain R&D goals at the destination companies and that the researchers who moved to overseas companies had attained a much higher level of R&D achievements in the past and had richer experiences in comparison with those who did not move. In the future, the IP systems will be further improved in emerging countries as well such as China, India, and Thailand. As shown in the analysis on the relationship between the inflow and outflow of workers and the level of IP protection offered under the IP system, the improvement of the IP system tends to increase the inflow of workers. Therefore, the number of Japanese researchers who move from Japanese companies to Chinese, Indian, or Thai companies is expected to further increase in the future. Having conducting this research, I would like to make two policy proposals.

First, it will be important to adopt effective policies and systems in order to prevent the leakage of highly skilled workers and secure necessary workers who are essential to Japan. Japanese companies have not taken any action against the leakage of competent researchers to other countries although those researchers would contribute to the innovative activities of Japanese companies. The risk of losing competent Japanese researchers to Chinese and Indian companies, etc. could significantly increase in the future. In order to prevent the leakage of researchers who are essential to Japanese companies and workers, etc. in certain technical fields where the increasing presence of non-Japanese Asian companies would threaten Japanese companies, it is necessary to offer more incentives to inventors by taking such measures as establishing an effective remuneration system.

The second policy proposal would be the early establishment of a system to provide broad protection for trade secrets. Companies are constantly deciding whether they should seek patents for their R&D results or keep their R&D results secret as know-how (Watanabe, 2012). Patents alone would be no longer able to provide sufficient protection for companies. Now, it has become increasingly important to maintain a good balance between seeking a patent and keeping secrecy as know-how. This trend is partially attributable to the fact that the quality of R&D workers in emerging countries has improved to such an extent that they are quite capable of not only understanding patented inventions by simply reading publicized patent applications but also developing improved technologies based thereon. As shown by this research, it is possible to analyze patent data and select competent inventors out of the inventors who belong to Japanese companies. This means that patent data could be used by other companies as the most reliable tool to secure competent workers. In this respect, when the company devises its R&D strategy and IP strategy, the option of not seeking a patent but keeping secrecy as know-how would become more important than before. As a next step, it would be necessary to conduct further discussion on how to protect trade secrets in order to redesign IP systems.

Conclusion

As discussed above, it is revealed that workers who moved from Japanese companies to non-Japanese Asian companies tend to be more competent than those who did not move. This finding suggests that non-Japanese Asian companies hire Japanese researchers strategically, after obtaining an accurate understanding of their abilities and positions, and it also suggests that Japanese companies failed to prevent their competent workers from leaving.

As this research has made clear, since the 2000s, in particular, many Japanese researchers moved to Korean and Taiwanese companies. The significant growth that Korean and Taiwanese companies achieved in the past decade may be

thanks in no small part to the contribution made by the Japanese researchers who moved to these companies. In the coming decade, Chinese and Indian companies will attempt to acquire talented Japanese researchers to attain growth. If Japan maintains the same policies and systems as before, Japanese companies might be overtaken and surpassed by Chinese and Indian companies in the not so distant future, as they had been overtaken and surpassed by Korean and Taiwanese companies.

As proposed in this research, it is hoped that Japanese companies will take measures as soon as possible to prevent the leakage of their competent workers, while the Japanese government will re-design the IP system by introducing a system for protecting technology by means other than patents, such as protection of trade secrets, so that Japanese companies will regain their global competitiveness.

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[1] On the basis of the exchange rate as of December 31, 2011, 1KRW=0.06633JPY, Samsung's sales were approximately 10.9445 trillion yen and LG's sales were approximately 3.5988 trillion yen. Hon Hai's sales also exceeded ten trillion yen.

[2] Kiminori Genba, *Seizō Kigyō no Sābisuka no Teiryō Bunseki* (Quantitative analysis of service industry by manufacturing companies), 2012.

[3] Nobukazu Usami, "BOP Shijō ni okeru Bijinesu Moderu Kōchiku ni kansuru Kōsatsu" "(Study on building business models in the BOP market), *Sangyo Keizai Kenkyu* (journal of Japan Society of Industry and Economy), 2011.

[4] Ayano Fujiwara & Toshiya Watanabe, "Inobēshon no Shūekika ni okeru Chizai no Yakuwari—Nihon Kigyō to Kankoku Kigyō no Sinkōkoku ni okeru Kenkyū Kaihatsu no Hikaku—" (Role of IP in monetization of innovation—Comparison of R&D activities of Japanese companies and those of Korean companies in emerging countries—), *Nihon Chizai Gakkai* (journal of the Intellectual Property Association of Japan), 2012.

[5] Yukiko Fukagawa, *Nihon no Kokusai Kyōsōryoku Saikōchiku to Gurōbaru Jinzai Ikusei* (Reconstructing Japan's international competitiveness and development of human resources with a global vision), 2012.

[6] National Institute of Science and Technology Policy, *Kagaku Gijutsu Bunya no Kadai ni kansuru Daiissen-kyū Kenkyūsha no Ishiki Teiten Chōsa* (Fixed-point survey on first-class researchers' awareness of issues in science and technology), 2010.

[7] Hitoshi Furui, Nihon Takokuseki Kigyō ni okeru Keiei Genchika (Localization of management by multinational corporations originating in Japan), *Kokusai Kankei Kiyo* (*Journal of International Relations*, Asia University), Vol. 19, 2010.

[8] Of a total of 221,726 employees, 54% work overseas and 101,973 employees work in South Korea.

[9] Samsung Electronics Sustainability Report 2012.

[10] Tetsuya Kobayashi, *Nihon Jidōsha Sangyō ni okeru "Kaihatsu no Genchika"* ("Localization of development" in the Japanese automobile industry), 2007.

[11] The number of bases includes the total number of production bases, sales bases, local bases and any other bases of each company publicized in its annual report or website.

[12] How these companies manage their IP is an issue that needs to be investigated separately by holding interviews or other methods in the future.

[13] How this company manages IP is an issue that needs to be investigated by holding interviews or other methods in the future.

[14] The number of patent grants involving an inventor with a Chinese nationality is 86 for Samsung, 43 for Fujitsu, 28 for Hitachi, and 27 for NEC.

[15] Knowledge spillover.

[16] Ministry of Economy, Trade and Industry, *Wagakuni ni okeru Gijutsu Ryūshutsu oyobi Kanri no Jittai ni tsuite* (Actual state of technology leakage and management in Japan), 2007.

[17] Ayano Fujiwara & Toshiya Watanabe, "The effect of researcher mobility on organizational R&D performance: researcher mobility and innovation" The 6th ISPIM Innovation Symposium – Innovation in the Asian Century, in Melbourne, Australia on 8-11 December 2013.

[18] The year of move of inventors was estimated based on patent data. Since some of the inventors who moved to overseas companies quite recently might not have filed a patent application at the destination companies yet, the number of inventors who recently moved could be slightly higher.

[19] Aayano Fujiwara (2013), "Gijutsu Ryūshutsu to Gijutu Kakutoku no Hazama de—Shinkōkoku ni Idō suru Hatsumeisha no Bunseki—" (Between technology leakage and technology acquisition—Analysis of inventors who move to emerging countries) [open seminar at Toshiya Watanabe Laboratory, the Graduate School of Engineering, the University of Tokyo, "IP Management by Innovators" (2013)].

[20] Why these Japanese researchers moved to Samsung is an issue that needs to be investigated separately by holding interviews or other methods in the future.

[21] What activities these Japanese researchers are engaged in after moving to Taiwan is an issue that needs to be investigated separately by holding interviews or other methods in the future.

[22] JC Ginarte, WG Park, "Determinants of patent rights: A cross-national study," Research policy 26 (3), 283-301, WG Park, "International patent protection: 1960–2005," Research policy 37 (4), 761-766.

[23] Source: Griliches (1990), Figure.13.3.

[24] Pakes and Griliches (1984), Hausman, Hall and Griliches (1984), Hall, Griliches and Hausman (1986),Griliches (1990), Kortum and Lerner (1998), Crepon, Duguet and Mairesse (1998),Hall and Ham (1999).

[25] Hall and Mairesse (1995) conducted an analysis of the manufacturing industry in France, using the fixed-effect model. Mairesse and Hall (1996) analyzed the manufacturing industry in the United States and Harhoff (1998) analyzed the manufacturing industry in Germany.