人材移動に伴う技術流出の実証分析

The effect of researcher mobility on organizational R&D performance: researcher mobility and innovation

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人材移動に伴う技術流出の実証分析

～国際間の人材移動がイノベーションに及ぼす影響～

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概要

日本経済は、1990 年代初めのバブル崩壊以降、長期的な低迷を続けてきた。2000 年代に入ると、BRICS が目覚ましい成長を遂げ、とりわけ中国が急速に台頭し、コスト競争が激化する等市場に大きな変化が生じた。このように日本経済を取り巻く環境に大きな変化がある一方、日本は未だ低迷状況から脱却できず、ますます世界での存在感を失いつつある。その典型例がエレクトロニクス産業である。1980 年代には、日本の製品は、高い技術力で世界から注目され、日本のものづくりは、プロダクトのみならずプロセスまでも研究の対象とされた。しかし、1990 年代以降、日本の産業は世界での競争力を失い、代わりに韓国や台湾等の新興国の企業が台頭してきた。2000 年代に入ると、日本の電機メーカーは大規模なリストラ等により立て直しを図ったが、未だに回復の兆しは見えない。

日本のエレクトロニクス産業が産業競争力を失った一因として、研究開発が事業や収益に結びついていないことが考えられる。例えば、売上高研究開発費率が、収益性に対して負の影響があるとする研究結果がある（玄場公規『製造企業のサービス化の定量分析』、2012)。このことは、研究開発の成果を企業の収益に結び付ける過程、すなわち、イノベーションの効率性に重大な問題が生じていることを示唆しているものと考えられる。なぜ、日本企業は、莫大な研究開発費を投じてもイノベーションにつなげることができなかった一方で、韓国や台湾企業はこの 10 年で急成長を遂げることができたのであろうか。その一因として、日本企業から優秀な人材が流出し、韓国、中国等のアジア企業へと移動したことがあるのではないかと考えられる。すなわち、日本企業ではリストラの過程で、優秀な研究者も同時に流出させる一方、アジア企業ではそのような日本企業出身の優秀な研究者を採用することで、自社の研究開発に活かしていった可能性について検証を試みた。

そこで、本研究においては、二つの仮説を設定し、分析を行った。第一の仮説では、日本から新興国へ移動した人材に着目し、どのような日本人研究者が韓国や台湾等の企業に移動したのかについて分析を行った。日本企業から韓国等のアジア企業へ移動した研究者と、彼らと同じ企業に所属しながら移動しなかった研究者を比較することで、韓国、中国等の企業は、どのような日本人研究者を採用する傾向にあるのかということが

分析可能であるからである。第二の仮説では、日本企業からアジア企業へ移動した研究者の中で、どのような人材が移動先企業でのイノベーションに貢献してきたのかについて分析を行った。イノベーションに貢献し得る研究者の特性を把握することにより、流出させるべきではない人材、企業のイノベーションにとって必要な人材について分析可能であると考えられるからである。

具体的な研究手法としては、日本の電機メーカーが出願した米国特許約 27 万件と、韓国の特許約 7 万件、中国の特許約 5 万件、台湾の特許約 5 万件のデータを対象とし、特許上の発明者名をすべて抽出し、日本企業から韓国企業、中国企業、台湾企業へ移動したと考えられる人物名を特定した。さらに、すべての発明者について、それまでに関わったすべての特許についての被引用回数合計、引用回数合計、IPC 番号の集中度を示す HHI 指数、初出願年からの経過年数等を算出した。また、特許の出願人名から各研究者の出身企業を特定し、その企業規模を売上高で分類し、各人の特性を示す指標の一つとした。さらに、本研究では、発明者が出身企業において社内でどのようなポジションにあったのかを示す指標を算出し、発明者の特性を示す指標として用いた。これは、個人同士の繋がりの関係性を示す代表的な研究である社会ネットワーク理論を用いたものである。社会ネットワーク理論の中心性指標には、次数中心性、近接中心性、媒介中心性、固有ベクトル中心性という代表的な 4 つの指標があるが、本研究ではアジア企業が日本人研究者を採用する際、技術に関する専門的な知識を有するだけではなく、社内で様々な情報が集積するような立場にある研究者を選択的に採用しているのではないかという仮説に基づき、ネットワーク内での影響力や情報集積度を示す固有ベクトル中心性を用いることとした。

第一の仮説に関しては、日本人発明者を対象にして、移動した場合と移動した場合の二値のプロビット分析を行い、各発明者の持つ特性のうち、どの要素がアジア企業への移動に大きな影響を与えているのかについて分析を行った。また、第二の仮説に関しては、パネルデータを用い、固定効果モデルとランダム効果モデルにより知識生産関数の推計を行った。具体的には、アジア企業のイノベーションの成功度を特許の数および特許の質で測り、それについて移動した日本人研究者のうち、どのような特性が貢献したのかを分析した。

日本から韓国、台湾、中国へ移動した発明者に関するデータ分析の結果、日本企業からサムスンへ移動した研究者は 2004 年をピークに減少傾向にあること、またサムスン以外の韓国企業へ移動した研究者は 2003 年をピークに減少傾向にあることが明らかになった。一方で、台湾企業への移動は若干の増減はあるものの一定数の移動が継続していること、中国企業への移動は近年増加傾向にあることが明らかになった。また、移動先企業での特許を詳細に分析すると、韓国企業へ移動した日本人研究者は数人の日本人研究者と同じグループで研究活動に従事している傾向にあるのに対し、台湾企業へ移動した日本人研究者は現地研究者数人とともに研究活動に従事していることが明らかに

なった。このことは、韓国企業は日本人研究者に研究開発結果を求めるのに対し、台湾企業では現地研究者の指導的役割を果たすことを期待している可能性があることを示唆しているのではないかと考えられる。すなわち、韓国企業と台湾企業では、日本人研究者に対して期待していることが異なっており、採用に当たっても異なるタイプの日本人研究者を求める可能性があるものと考えられる。日本からアジア企業へ移動した発明者の基礎データ分析結果に基づき、以下の2つの仮説分析を行った。

第一の仮説に関しては、アジア企業へ移動する人材について、人材の質やインフォーマルなネットワークという観点から実証的に分析を行うため、移動した場合を1、移動しなかった場合0とする二値のプロビット分析を行った。これは、日本企業から韓国企業等へ移動した研究者と移動しなかった研究者の間で、優秀さや経験年数、技術分野の幅、社内でのポジション等に違いがあるかを分析するものである。分析の結果、サムスン等の韓国企業へは、各研究者が関わってきた特許の被引用回数の合計と固有ベクトル中心性が高い日本人研究者が移動する傾向があることが明らかになった。このことは、サムスン等の韓国企業では、日本企業の研究者の中でネットワーク内での影響力が強く、情報が集積する地位にあり、かつ優秀な人材を選択的に採用している可能性があることを示唆している。さらに、サムスンや鴻海では HHI 指数がマイナスであったが、それ以外のアジア企業ではプラスとなった。このことは、サムスンや鴻海のような成長企業では、様々な技術分野での経験を持つ研究者を採用する一方、その他の韓国、台湾企業等では特定の分野に特化した研究者を採用する傾向にあることを示唆している。

第二の仮説では、日本企業から韓国、台湾企業へと移動した人材の質がイノベーションに与える影響について実証的に分析を行った。その結果、新興国企業のイノベーションについて、特許の数で測った場合には、HHI 指数がプラス、経験年数がマイナスとなった。このことは、日本からアジア企業へ移動した人材のうち、若手の研究者や専門性の高い研究者がアジア企業の数で測ったイノベーションに対する貢献が大きいことを示唆している。また、アジア企業のイノベーションを特許の質で測った場合には、移動した日本人研究者はイノベーションに大きく貢献していること、特に経験年数の長い人材ほどイノベーションに貢献することが明らかになった。このことは、特許出願を増やしたい企業にとっては、若手で特定の技術分野に特化した研究者が向く一方、企業の発明の質を向上させるためには、経験年数の長い研究者が向いていることを示唆している。以上の分析から、サムスンのような急成長企業は、幅広い技術分野の経験を持つ優秀な研究者で、かつ情報が集積する影響力の大きな地位にある日本人研究者を戦略的に採用し、自社の発明の質を向上させてきた可能性があるのではないかと考える。一方で、今後成長が見込まれるアジア企業では、日本企業の中でも比較的若手で、特定の分野に特化した研究者を採用し、まずは多くの発明を行うことに注力しているのではないかと推測される。

キーワード : 人材移動、技術流出、イノベーション、ネットワーク分析、被引用回数、引用回数、中国、韓国

1. Introduction

This study conducted an empirical analysis of the effect of the movement of human resources on innovation (Pakes and Griliches 1984; Griliches, 1990). As the influence of emerging nations on the world economy will increase in the future, it is quite likely that there will also be an increase in the movement of knowledge workers from developed countries to emerging ones. To this end, an empirical analysis performed to study on the types of researchers from developed countries to emerging countries who contributed to innovation in industries there.

So far, several models related to innovation have been presented, including those that use a knowledge production function to analyze the effect on innovation activities produced by human capital and by investment in R&D. Those studies focused on companies providing financial or human capital and obtaining knowledge capital in return. Exogenous business organizations that invested in capital and human resources are, in a way, models showing the creation of innovation initiated by corporations.

To identify the relationship between knowledge workers and innovation, however, this study analyzes the type of contribution to innovation activities at new corporations by migrated knowledge workers, who absorbed technology and knowledge from companies in Japan. A number of indices representing the quality of talent are established herein to analyze the role played by the movement of knowledge workers, which in turn creates the spillover of knowledge by these migrating researchers and influences the innovation and growth of their new companies. One of these indices is the social network index. Social networks are composed of different nodes of individuals and the social relationships that individually connect them. By observing the centrality index of each node, it is possible to analyze the characteristics and roles of each node in the overall network. This analysis is carried out using data about researchers who migrated from Japan to emerging nations to investigate what types of positions at their old companies were held by talent who can contribute to innovation at their new workplace in a different country after their migration. There are few research which focused on the effect of talent migration on knowledge spillover via informal networks. This study reveals that during the process of innovation, the intervening fluidity of talent and informal networks plays an important role.

First, to analyze the characteristics of talent who migrate from Japanese corporations to those of Korea, Taiwan and China, a logistic regression model is used to verify the influence of basic explanatory variables such as inventors' individual social network index, career, and evaluation of their invention. In particular, the corporations that achieved rapid growth by actively recruiting talent from developed countries might selectively employ these researchers. Therefore, this analysis is performed from the viewpoint of Korean and Chinese companies that recruit knowledge workers from Japanese companies based on differences in priority characteristics such as the length of his/her career, expertise, and excellence.

Second, the knowledge production function is applied to analyze what types of knowledge workers are contributing to innovation in emerging nations using panel data. Specifically, an empirical analysis is carried out to analyze the quality of migrated talent who had worked at corporations in Japan and of the contribution to innovation at their new companies in emerging nations. Conventionally, R&D expenditures have been used as indicators to measure innovation. However, in this study, I used the number of patents and the quality of the patents to analyze the influence of the quality of talent, migration, and embodied knowledge-spillover on innovation. In particular, to focus on the role played by a researcher's individual career in innovation at his/her new workplace in a foreign country, an analysis is carried out by establishing indicators to measure the length of his/her career, expertise, and excellence. Then, a calculation is performed using fixed effects model and random effect model to analyze how migrated talent contribute to innovation in emerging nations.

As described above, this study quantitatively analyzes the relationship of social networks and career change of individual researchers, mobility of talent, and innovation.

2. Mobility of knowledge workers and innovation

In previous literature, the influence of investment in R&D and human capital were analyzed (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), and Hall and Ham (1999)). These studies analyze patent data using the knowledge production function, considering the patent propensity in America and Europe and patent productivity of R&D using company-level data.

Figure 1 shows Griliches' (1990) knowledge production function relational diagram. In it, R represents the input factors of knowledge production such as R&D investment and the number of researchers; P represents another index displaying patent or quantity of invention; $\dot{K}$ represents the increase in economically valuable knowledge; Z_i represents profit from increased knowledge; X_i represents Z_i = producing other input factors; u_i and w_i represent the disturbances in the process of creating a knowledge increase, respectively; and v_i represents other factors that determine the quantity of the disturbances and invention.

Conventionally, R&D investment cost have been widely used as surrogate variables for innovation. However, the size of R&D cost is an input index and not an index to measure the output of innovation. In this study, I used the number of patents as an output index of innovation. However, the quality of the patent is also an important question in addition to the number of patents. In this regard, patent quality has been studied and the number of times a patent cited have been proposed as the proxy for the quality of the patent. Trajtenberg (1990), Jaffe et al. (2002), Reitzig (2003), Hall et al. (2005) et al. verified the strong correlation between the number of citations and the quality of patents. In addition, Harhoff et al. analyzed American and German patents and verified the correlation between the number of citations and the duration, the patents that were updated before expiration was greater than the patents that expired earlier (Harhoff et al. 1999). For these reasons, I used the number of citations as an index to measure innovation.

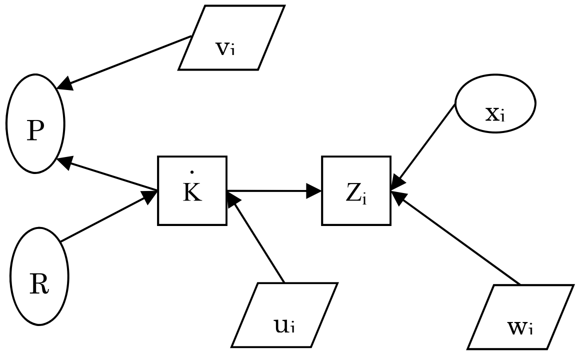

Figure 1 Knowledge production function: a simplified path analysis diagram.

Source: Griliches, Z., Journal of Economic Literature, 28, 1990, P.1661-1797, Figure.13.3

The relationship between the migration of talent and innovation is a less-researched field. However, it is anticipated that from now on, a large number of knowledge workers will migrate from developed countries to emerging nations as the economic importance of the latter increases. Therefore, issues such as how such talent would contribute to innovation in the emerging nations and what type of talent could contribute to that innovation are important. In previous literature, the impact of R&D investment and human capital on innovation has been analyzed using the knowledge production function. However, in this study, the impact of the quality of the talent who migrated from developed countries on innovation will be empirically analyzed. For specific analysis methods, the knowledge production function by Pakes and Griliches (1984) is used; for explained variables, patent citation count is used as a representative index to measure innovation by measuring number and quality of the patents.

3. Hypotheses

In contrast to an analysis of the impact of R&D investment on innovation such as by using the knowledge production function, this study analyzes the impact of the transfer of technology and knowledge on innovation in a corporation caused by the migration of knowledge workers who previously held positions at mature enterprises. For this analysis, first, the type of talent who migrate from developed countries' corporations to emerging nations' enterprises must be analyzed. Hence, the following question and hypothesis was set.

Question 1. What type of talent migrates from developed countries' enterprises to those of emerging nations?

To measure the characteristics of talent, various indices can be considered. However, from the viewpoint of employing a researcher from foreign firm, superiority as a researcher and the position where the researcher was in could be important. Here Question 1 is segmented into the two different hypotheses shown below to empirically analyze the question. In this way, an understanding of the characteristics of talented personnel migrating from developed countries' corporations to emerging nations' enterprises will lead to an analysis of what type of talent is being recruited by emerging nations' companies.

Hypothesis 1-1. Talent migrating from developed countries' corporations to emerging nations' enterprises were excellent personnel.

Hypothesis 1-2. Talent migrating from developed countries' corporations to emerging nations' enterprises used to hold higher positions.

However, from the viewpoint of contribution to innovations measured by the number or quality of patents, to know what type of talent contribute to the innovation could be important. Next, analysis is carried out by using Hypothesis 2 to find out whether talent recruited by emerging nations' corporations from developed countries contribute to innovation in their new host countries.

Question 2. What type of talent contributes to the innovation of emerging nations' enterprises?

As the recruited talent are expected to play leadership roles for local researchers with developing technology and knowledge in emerging nations' corporations, their rich experience and knowledge would have a strong impact. Therefore, the empirical analysis for Question 2 will be carried out on the basis of the two viewpoints shown below.

Hypothesis 2-1. Talent contributing to the innovation of emerging nations' enterprises were highly experienced.

Hypothesis 2-2. Talent contributing to the innovation of emerging nations' enterprises used to research in a specified technical field.

4. Data and variables

4.1 Data

In this study, I identified Japanese electrical equipment manufacturer personnel who had been transferred to Korea, China, and Taiwan, using patent data from the four countries, and performed an analysis of their trends. In this study, to analyze the innovation in the field of electrical appliances, I used patent data (1976–2013) from the H section of the IPC classes. I targeted about 270,000 patents from Japanese electrical manufacturers, about 50,000 Chinese patents, about 70,000 Korean patents, and about 50,000 Taiwanese patents, and pulled out the names of all inventors to appear in them. Excluding the researchers of identical names, inventors belonging to the Japanese companies are approximately 170,000 and inventors of the South Korean company are about 50,000. From the names appearing in these four groups of patents, I pulled out the names of inventors with a possibility of being transferred. Although the same name might appear in both a foreign company's and a Japanese company's patents, it cannot be denied that it is possible these are two different people. Therefore I decided to set a criteria for the degree of similarity between IPC numbers, and only in cases where that criteria was met I judged the persons to be equivalent. In this way, I judged the names of inventors appeared both in Japanese and Asian patents to be equivalent when meeting the requirements for a connection to IPC numbers. And I judged them to have moved between Japanese companies and foreign companies, thus raising the probability that these are actual movements. After identifying the movements of all inventors, I judged whether they had moved from or to a Japanese company. Moreover, using the last patent that was applied by their former company and the first patent that was applied by their destination company, I calculated the probability of the timing of the movement for all transferees.

Figure 2 shows the change in the number of researchers who moved from Japanese companies to Samsung. From the figure it is clearly revealed that the movement of researchers to Samsung peaked in 2004 and then suddenly plummeted. Furthermore, from looking at the details of Samsung patents which Japanese researchers concerned there, it is clear that there are a great many cases of multiple Japanese individuals engaged in research activities in the same group. In addition, I was able to confirm a number of cases in which, even after some of these tracked group members returned to their original Japanese company, they were engaged in the same enterprise and furthermore doing research in the same group. As to their estimated movement period, I was able to confirm a gap of 2-3 years, but the workers conducting research as coworkers at the Japanese company moved to Samsung at almost the same time or one after another, and so I conjecture that they were engaged in cooperative research.

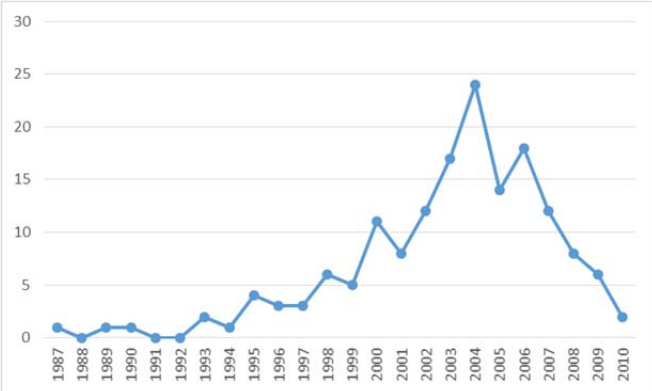

Figure 2 Change in the number of Japanese researchers who moved to Samsung.

Figure 3 shows the change in the number of Japanese researchers who moved to Korean companies except Samsung. There is a small peak around 2000, and the large peak around 2003 may be said to be part of the same movement as the change in the number of researchers who moved to Samsung.

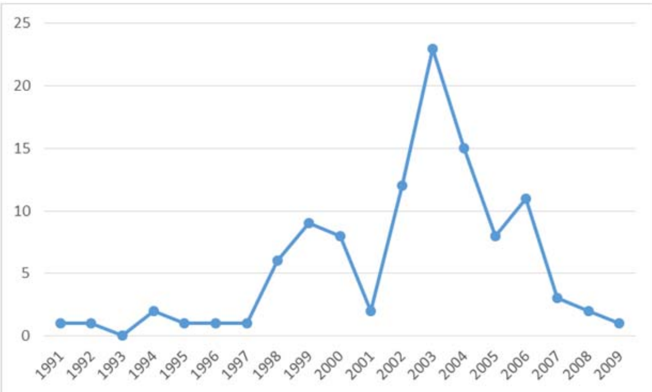

Figure 3 Change in the number of Japanese researchers who moved to Korean companies except Samsung.

Figure 4 shows the change in the number of Japanese researchers who moved to Taiwan. As I described above, Japanese researchers who moved to Korean companies increased suddenly around 2000 and decreased in recent years. Compared to this trend, fluctuations in the number of Japanese workers moving to Taiwan is relatively low. And we know that movements have continued since the nineties constantly. The trend of decreasing numbers around 2007 is thought to be due to a lag, based on an analysis of patents. Based on detailed analysis of the research activities of Japanese researchers at their destination companies in Taiwan, many cases have become clear that Japanese researchers are added to local research groups one at a time, and conducting research in that group. I conjecture that Japanese researchers who move to Taiwan are conducting research while being expected to fulfill a role as leader to these local research groups.

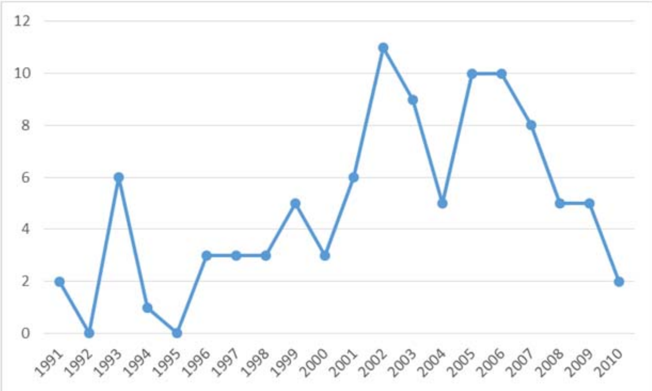

Figure 4 Change in the number of Japanese researchers who moved to Taiwan.

Figure 5 shows the change in the number of Japanese researchers who moved to China. From this figure, we know that the number of Japanese researchers moving to China shows a rising trend. The number of Japanese researchers moving to Samsung and other Korean companies reached a peak in 2003-2004. Compared to Korea's recent declining trend, the number of researchers moving to China is predicted to rise from here on.

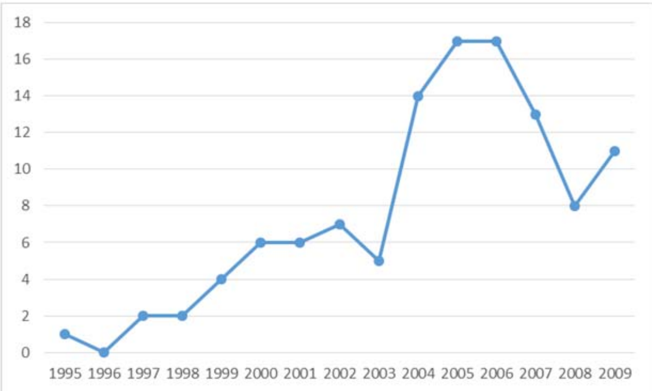

Figure 5 Change in the number of Japanese researchers who moved to China.

As we see above, the numbers of Japanese researchers who moved to Korea have increased sharply since 2000 and settled numbers in recent years. On the other hand, it cannot be denied that the greater number of Japanese researchers may move to China from here on.

In Hypothesis 1, the analysis is based on the hypothesis that the rapidly grown companies are selectively recruiting talent from developed countries. To analyze what type of talent migrate from Japanese firm to Asian companies, the patent data mentioned above are used. The inventors who migrated corporations in Japan to Samsung and the other companies in South Korea and China were identified from the patent data filed by Japanese companies, and the other Asian companies.

In Hypothesis 2, to analyze how developed countries' talent are contributing to the innovation of emerging nations' enterprises, 22-year (1990–2011) patent data and financial data are used to perform an analysis with panel data pertaining to a Chinese corporation (Huawei), a Taiwanese corporation (Hon Hai), and three South Korean companies (Samsung, LG, and Hyundai).

4.2 Explained variable

In Hypothesis 1, from the viewpoint of indicating what type of the knowledge workers will migrate to emerging nations' enterprises, the explained variable can have two values: 1 for migrating to emerging nations' enterprises and 0 for not migrating.

In Hypothesis 2, the number of patents is used as surrogate variables for innovation in this study. To measure the contribution of knowledge workers from developed countries' corporations for the innovation of emerging nations' enterprises, the production function is used in this study. The studies that used the knowledge production function approach (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) are well known.

Furthermore, from the viewpoint of measuring the quality of innovation, the patent citation count is also used as an explained variable. This is because the analysis shows that the citation count of American patents (forward citation) is strongly correlated with the value of the patent in many cases (Trajitenberg 1990; Jaffe et al. 2002; Reitzig 2003; Hall et al. 2005). For example, Hall et al. (2005) demonstrated that the aggregation of the citation count of the patent owned by a corporation is correlated with the company's share price. In this way, citation count can be an excellent index to verify the impact on the quality of the patents.

4.3 Explanatory variable

In this study, to analyze the impact caused by mobility of human resources and talent networks on the innovation of a corporation, a social network index and some indices to measure the features of the talent are used as explanatory variables. Specifically, to measure the features of the migrating talent, variables such as the number of migrated inventors, size of the company of origin, number of career years, citation count, forward citation count, the Herfindahl–Hirschman Index of the IPC number, and eigenvector centrality are used.

In terms of the scale of the company of origin, corporations with $ 100 trillion or greater sales are classified as large, whereas those with less than $100 trillion sales are classified as small. The number of career years is calculated to be the number of years elapsed from the year in which the inventor in question filed his/her first patent application. The patent citation count is used as a representative index for indicating patent quality. The total citation count of a patent in which the inventor has been involved in is used as a surrogate index for his/her excellence. Forward citation count is effective for measuring the quality of patent, this approach has been validated by various studies (Carpenter et al. 1981; Harhoff et al. 1999). And an inventor involved in many high-quality patents can be regarded as excellent. Furthermore, as an index to measure patent quality, apart from the citation count, it has been pointed out that the number of backward citations of the patent correlates with the quality of the patent (Harhoff et al. 1999). From this, the number of times the patent is citied has also been added as a variable to measure the quality of talent. The Herfindahl–Hirschman Index of the IPC number can measure if an inventor has been involved with patents of a specified technical domain or of varied technical domains. That is, a high HHI value indicates that the inventor has specialized in a specified technical field, whereas a low HHI value indicates that the inventor has wide knowledge covering varied technical fields.

In addition, it should be emphasized that the centrality, social network index, is used in this study. Little attention has been given to the correlation between informal networks and the researcher mobility. Therefore, it is important to verify how the network influence the mobility of the knowledge worker. There are four main measures of centrality: degree, betweenness, closeness, and eigenvector. Degree centrality is defined as the number of links incident on a node. Closeness centrality is defined by the length of the shortest paths between all pairs of nodes. Betweenness centrality indicates the number of times a node acts as a bridge along the shortest path between two other nodes. Eigenvector centrality is a measure of the influence of a node in a network. In this study, to measure the influence of the mobility of the knowledge worker, the Eigenvector centrality is used as a measure of influence of the knowledge worker in his network.

Eigenvector centrality is a centrality index proposed by Phillip Bonacich; it evaluates not only high-scoring nodes but also all nodes that are connected to high-scoring nodes. Being related to a node that has many relationships with other nodes implies an important position within the network.

In addition, a factor affecting the quality and quantity of the patent apart from human resources is the increase in the R&D cost. There have been numerous analyses (Pakes and Griliches 1984; Hausman et al. 1984; Hall et al. 1995; Crepon and Duguet 1997) of the cost of R&D and patent applications. In general, the number of patents can increase, and their quality can improve, if the R&D cost is increased, regardless of the quality of researchers. Therefore, in this study, the R&D cost of the current period is also used as a variable.

5. Calculation methods and results

5.1 Testing the first hypothesis: What type of talent migrates from developed countries' enterprises to those of emerging nations?

To verify the characteristics of knowledge workers migrating to emerging nations' enterprises from developed countries' corporations, a logistic model is built for analysis using two-value objective variables. They take the value 1 if the inventor migrated to an emerging nation and 0 if he/she did not. Explanatory variables such as total of number of citings and citations of patents, in which the inventor in the developed country has been involved in his/her career so far, the Herfindahl–Hirschman Index of the IPC classification, and eigenvector centrality are used.

The model formula is as follows.

$$P_i(i=1)=F(C+\sum\alpha_i x_i)$$

$$P_i=\exp(C+\sum\alpha_i x_i)/(1+\exp(C+\sum\alpha_i x_i))$$

P_i represents the probability that knowledge worker *i* takes the value 1, F is the cumulative distribution function, α_i is a coefficient, X_i is an explanatory variable, and C is a constant. The analysis results are shown in Table 1.

From the result, eigenvector centrality is significantly high. It suggests that the emerging nations' companies preferred talent having high eigenvector centrality. The eigenvector centrality shows that they tend to have strong influence and important positions in corporations in developed countries. This means that when emerging nations' companies are recruiting knowledge workers, it is supposed that an evaluation of the positions of the knowledge workers in the developed countries' corporations is conducted as one of the criteria.

In addition, the result indicates that forward citation is significantly high at South Korean company. It suggests there is a high possibility that the emerging nations' companies select new talent considering the number of times the patent in question is cited, as it is the most commonly used index to indicate the importance of a patent.

Regarding the HHI index of the IPC number, albeit not statistically significant, negative values are preferred at a rapid growth company such as Samsung and HonHai. This indicates that there is a possibility that talent involved in patents in varied technical domains are preferred in comparison to researchers with a specified technical domain. On the other hand, the HHI index of the IPC number at the other companies shows positive values. This indicates that specialists in a specified technical field are preferred.

In contrast, the size of the company of origin, which is also statistically insignificant, can be regarded as not very important by recruiters in emerging nations seeking knowledge workers from developed countries.

Among Hypothesis 1, Hyposthesis1-1 and 1-2 are supported.

Table 1 Logistic Regression**:** Knowledge workers migrating from developed countries' corporations to emerging nations' enterprises

Mobility of knowledge workers	*（1）Korean Companies*		*（2）Taiwanese and Chinese companies*	
	Samsung	*Other Companies*	*HonHai Companies*	*Other*
Backward citation per person	0.0002748 (0.72)	0.0006454* (1.93)	0.001248 (0.55)	0.000691* (1.74)
Forward citation per person	0.0013961 *** (3.14)	0.0015431*** (3.00)	-0.000980 (-0.25)	0.001609* (2.46)
Company size	−0.3046282 (−1.1)	−1.323645*** (−4.60)	−1.97259*** (-3.12)	0.650017 (0.90)
Number of years of experience	0.0005447 (0.27)	0.0001832 (0.06)	-0.061929* (-1.91)	-0.000776 (-0.23)
HHI of IPC number	−0.2013988 (−0.62)	0.011731 (0.02)	-0.530932 (-0.76)	0.286130 (0.47)
Eigenvector centrality	2.8292350 *** (6.19)	2.672211*** (3.54)	2.136945* (1.64)	0.212661 (0.12)
cons	−5.6093760*** (−14.39)	−5.7875209*** (−11.05)	−4.401456*** (-4.85)	-7.58929*** (-8.33)
N	108,164	65,242	64,354	44,745

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

5.2 Testing the second hypothesis: What type of talent contributes to the innovation of emerging nations' enterprises?

In this study, to verify the effectiveness of introducing knowledge workers from developed countries by companies in emerging nations such as China and South Korea, the knowledge production function advocated by Griliches and Shankerman (1984) and by Griliches and Regev (1995) is applied. The knowledge production function measures the effectiveness of R&D investment for knowledge increase.

Griliches and Regev (1995) established the following formula to compare labor productivity between companies.

$$Y = Xb + Zc + lm + u$$

Here Y represents the logarithm of the productivity per worker, X is the logarithm of the input variable (intermediate inputs and capital services per person), and Z represents the control variables (e.g., dummy variables for size, age, and location). Griliches set eight variables: 1) intermediate inputs and fixed capital services, 2) R&D capital and labor quality (as a proxy for human capital), 3) size, 4) sector and type of ownership, 5) industry grouping, 6) establishment year, 7) mobility status (entry and withdrawal status), and 8) year dummies.

In this study, the impact due to the migration of knowledge workers from developed countries' corporations on innovation in emerging nations' enterprises is examined by entering the variable related to the characteristics of the knowledge worker. Usually, the number of patents is used as a surrogate variable for productivity. The number of patents used as an explained variable is non-negative numeric data. Hall and Mairesse (1995), Mairesse and Hall (1996), and Harhoff (1998) analyzed French, US, and German manufacturers using the fixed effects model to control the deviation of a company's fixed effect. In this study, the fixed effects model and random effect model are used to perform calculations following the example of Hausman et al. (1984).

The calculation results are shown in Table 2. Formula (1) of Table 2 shows the result calculated using the fixed effects model. From the calculation results, the maximum impact on the innovation of emerging nations' enterprises measured by the number of patents is caused by the number of researchers belonging to the company. The number of migrated talent from developed countries is positive, however small and statistically insignificant. It suggests that the talent from developed countries slightly affects the number of patents. Moreover, the statistically insignificant coefficient of eigenvector centrality is small, demonstrating that important positions held by the migrated talent from developed countries' corporations are irrelevant to the talent's contribution to the innovation of emerging nations' enterprises. On the other hand, the HHI of the IPC number is positive, suggesting a high possibility of contribution to the innovation of emerging nations by talent who have conducted research in a specified technical field.

Formula (2) has been calculated using a random effect model. For the number of patents, the coefficient of local labor number is positive, whereas the number of developed countries' researchers is positive, but small. This demonstrates that an increased number of researchers from developed countries may not necessarily contribute to an increase in the number of patents created by emerging nations' enterprises. On the other hand, the coefficient of the number of years of experience is positive; it suggests that senior researchers from developed countries may be contributing to the increase in the number of patents of emerging nations' enterprises. In addition, the coefficient of HHI of the IPC number is positive; it suggests that the researchers who have worked in a specified technical field contribute more to the increased number of patents than do the talent who worked in varied fields.

Incidentally, two methods, namely the fixed effects model and random effect model, are used in this calculation. The null hypothesis can be dismissed in the Hausman test, pertaining to the selection of two calculation methods. Therefore, as a result, the fixed effect model is preferable.

Reviewing this result, it can be said that the innovation measured by the number of patents filed by Asian companies is highly likely to be contributed by senior researchers or inventors working in a specified field among the talent who migrated from Japanese companies.

Table 2 Impact caused by the migration of knowledge workers from developed countries on the innovation of emerging nations' enterprises

Patent	*(1) Fixed effect*		*(2) Random effect*	
R&D cost	−0.68423***	(−3.76)	0.055439***	(3.16)
Characteristics of knowledge workers from developed countries				
Migrated labor number	0.034616	(0.70)	-0.170241 **	(-2.42)
HHI of IPC number	0.156153	(1.50)	0.37986**	(2.02)
Company size	-0.015197	(0.646)	-0.037986	(-0.64)
Backward citation	-0.013331	(-0.44)	0.016126	(0.30)
Forward citation	0.001636	(0.05)	-0.023300	(-0.41)
Number of years of experience	0.11737	(0.19)	-0.0962001	(-0.84)
Eigenvector centrality	0.011737	(0.19)	−0.002954	(−0.19)
Characteristics of knowledge workers from developing countries				
Labor number	0.9034218 ***	(13.75)	0.667559 ***	(8.63)
Backward citation	0.082151	(1.63)	0.1811539***	(3.06)
Forward citation	0.22882	(0.49)	0.117014***	(2.92)
Scale(ref.=small size)				
Middle size	0.022208	(0.40)	-0.063399	(-0.72)
Large size	0.069359	(0.62)	-0.079676	(-0.52)
Life cycle(ref.=less 20 years)	0.173629**	(2.29)	0.174364	(1.54)
From 20 to 40 years	-0.066178	(-0.61)	0.065237	(0.51)
Over 40 years				

cons	0.18295	(0.47)	−9.1473**	(−2.52)
Year dummy	yes		yes	
Hausman test			0.0000	

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

Next, Table 3 shows the results using the number of cited patents as an index to measure innovation. The number of patents has been used as an index to measure innovation in many studies (Pakes and Griliches 1984). However, it cannot be concluded that only a high number of patents is good for innovation; inventing high-quality patents is also important.

The calculation results are as follows. Formula (1) of Table 3 is the result calculated using the fixed effects model. It suggests that there is a significant contribution from the talent of developed countries to the innovations measured by the quality of patents. The HHI of the IPC number is negative, suggesting a high possibility of contribution to the innovation of emerging nations by talent who have conducted research in varied technical fields. In addition, although not statistically significant, eigenvector centrality is positive. It suggests that talent who used to hold important positions in developed countries' corporations may be contributing to an improvement in the quality of patents.

Furthermore, formula (2) of Table 3 shows the result calculated using the random effect model. Regarding the quality of patents, the number of years of experience in developed countries' corporations shows significant effectiveness in increasing the quality of patents. And the eigenvector centrality is positive. This suggests that the knowledge workers in the important position in the developed countries' corporations contribute to the innovation. Thus, in terms of innovation measured by the quality of patents, the number of researchers and their years of experience from corporations in developed countries evidently show positive effects. The null hypothesis can be dismissed in the Hausman test, pertaining to the selection of two calculation methods. Therefore, the fixed effect model is preferable.

The results of the analysis of innovation measured by the number and quality of patents show that the migrated talent from developed countries contribute to the innovations measured by the quality of patents, rather than the innovations measured by the number of patents. On the other hand, senior researchers contributed to the increase in the number of patents and the quality of patents. Moreover, the statistically insignificant coefficient of former company size is negative for the innovations measured by the quality of patents and for the innovations measured by the number of patents. Among Hypothesis 2, Hyposthesis2-1is supported.

The negative coefficient of R&D costs is probably because the analysis objects of this study are the emerging nations' companies; their R&D investment has not yet been effectively producing innovation.

Table 3 Impact by the migration of knowledge workers from developed countries on the innovation of emerging nations' enterprises

Forward citation	*(1) Fixed effect*		*(2) Random effect*	
R& D cost	0.002772	(0.04)	0.284159***	(5.41)
Characteristics of knowledge workers from developed countries				
Migrated labor number	0.601678 ***	(4.16)	0.409210	(1.52)
HHI of IPC number	-0.10717	(-0.29)	−0.684964	(-0.95)
Company size	-0.003446	(-0.03)	-0.363942	(-1.60)
Backward citation	-0.062008	(-0.57)	-0.280712	(-1.37)
Forward citation	−0.093417	(−0.77)	0.238784	(1.08)
Number of years of experience	0.160971	(0.72)	0.924790 **	(2.17)
Eigenvector centrality	0.027560	(0.86)	0.129107**	(2.24)
Characteristics of knowledge workers from developing countries				
Labor number	0.779671 ***	(3.98)	0.486853*	(1.65)
Backward citation	−0.161082	(-0.90)	0.249539	(1.08)
Scale(ref.=small size)				
Middle size	-0.51931***	(-2.93)	-1.38836***	(-0.52)
Large size	-1.87767***	(-7.56)	-2.69646***	(-6.26)
Life cycle(ref.=less 20 years)	-0.738902***	(-3.05)	-0.231894	(-5.22)
From 20 to 40 years	-1.20232***	(-0.36)	-0.864581*	(-1.78)
Over 40 years				
_cons	5.89562***	(5.86)	-2.19352	(-1.58)
Year dummy	yes		yes	
Hausman test			0.0232	

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

6. Conclusion and implications

As shown above, this study empirically analyzed the relationship between migration of human resources and innovation from the viewpoint of the characteristics of inventors and informal networks. The analysis suggests that in emerging nations that have achieved rapid growth, excellent researchers in important positions from Japanese corporations are selectively recruited.

On the other hand, when the innovation of emerging nations' corporations is measured by number of patents, it becomes clear that senior researchers and highly specialized inventors among the talent from companies in Japanese companies have significantly contributed. In addition, if the innovation of Asian enterprises measured by the quality of their patents, it becomes clear that innovations are better facilitated with higher numbers of talent from developed countries' corporations; specifically, the contribution to innovation by those who have conducted research in varied technical fields and have had a longer career is greater.

Going forward, as emerging nations achieve further economic growth, not only their local companies' size will grow but also their standard of economy will improve; further talent mobility between emerging and developed countries is expected. For emerging nations in Asia or elsewhere, when a company creates innovation, it is essential for it to optimize the technology and knowledge from developed countries' corporations and the knowledge workers who embody them. This time, only the analysis of Chinese and South Korean enterprises was conducted. However, in terms of the relationship between innovation and talent migration, expansion of the scope of analysis to all Asian countries is issue for further study.

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