Do Corporate Mergers Bring about New Combinations of Knowledge?

- Empirical Evidence from Patent Data -

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Abstract. The aftereffects of corporate mergers, particularly whether corporate mergers facilitate new combinations of knowledge, were investigated using patent application data for two corporate mergers in the Japanese chemical industry. The results show that new combinations are more likely to occur after mergers and that the choice of a "new combinations" strategy can differ between companies. This strategic choice has an impact on the aftereffects of corporate mergers, and the difference in strategic choice might depend on whether power and initiative reside in the same premerger firm.

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1. INTRODUCTION

Recent literature on the role of firm-specific resources has indicated that knowledge is the most strategically significant resource of a firm. A particular view of a firm, namely, the knowledge-based view, emphasizes the capacity of a firm to integrate tacit knowledge (Nonaka, 1994; Grant, 1996; Conner and Prahalad, 1996). As this resource is usually difficult to imitate and is socially complex, heterogeneous knowledge bases comprise the major determinants of sustained competitive advantage and performance. However, as Grant (1996) and other researchers have shown, the "knowledge-based view" is not yet a theory of a firm at some respects.

If knowledge and its management are of such great importance, knowledge strategies should play a critical role in a firm's strategic planning. Of the numerous strategic choices that a firm can make, one of the most drastic ones is whether to merge with another firm. However, a corporate merger can be likened to a double-edged sword. If it is carried out successfully, a firm can gain access to new resources and, by the redeployment of resources, increase its revenue and reduce costs, which will result in its performance improving significantly. However, as a worst case, a corporate merger simply creates turmoil and results in poor performance. In fact, many empirical studies have shown that there is no guarantee that the aftereffects of a corporate merger will be positive (Lubatkin, 1983; Mueller, 1997).

From a knowledge-based perspective, mergers can be viewed as combinations that broaden a firm's knowledge base. A broader knowledge base may provide many opportunities for recombining the existing elements of knowledge into new syntheses. In other words, the emergence of new combinations of knowledge that lead to innovation is one of the important motives for suffering the stress of a corporate merger. However, empirical findings suggested that the impact of mergers depends on the characteristics of the knowledge of the merger and merged firms (Ahuja and Katila, 2001; Mowery, Oxley, and Silverman, 1996, 2002; Sampson, 2004). If the merger is successful, the firm should be able to generate new knowledge that could not have been generated in its absence. If it is unsuccessful, the firm's knowledge base could be ruined. Although knowledge is seen as the most important asset of a firm, until now, hardly any research from the knowledge-based view has been conducted on how the aftereffects of corporate mergers have been successfully achieved, especially at the micro level. It is possible that the lack of empirical work documenting the aftereffects of mergers is partly due to the difficulty of measuring the technological and other capabilities of firms (Mowery, Oxley, and Silverman, 1996).

Owing to the difficulty involved in measuring firms' technological capability, this paper focuses on the usefulness of patent application data. Patents have three particular advantages: they are systematically compiled, they have detailed information, and they are

available continuously across time (Almeida, 1996) [1]. Considering these advantages, many scholars have obtained useful results about firms' innovative activities by using patent data (Pavitt, 1985). Patents, because of their nature, represent technological advances and include speculations about how a particular technology may be applied. Therefore, parents enable a detailed understanding of how and to what extent each technology was used before and after a corporate merger. Therefore, I investigated the aftereffects of corporate mergers, using patent data, and put forth two questions: (1) Do corporate mergers facilitate new combinations of knowledge? (2) If they do, how and why does a firm choose a "new combination" strategy? To answer these questions, I created a new measure for evaluating new combinations of knowledge and tested three hypotheses.

The remainder of this paper is organized as follows. In the next section, I briefly survey the academic contributions with respect to this issue and present the three hypotheses. The following section describes the analytical procedure and the variables used for testing the hypotheses. The results are presented and discussed in the next two sections. The last section summarizes the key points, describes several limitations, and provides directions for future research.

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[1] It should be noted that patents are not perfect indicators of firms' innovative activity. However, they may serve as an interesting monitoring device to identify the main lines and trends, and even under specific conditions, enables us to analyze R&D processes in greater detail (Engelsman and Raan, 1992). Three potential limitations of patents were pointed out by Patel and Pavitt (1997): (1) patents do not measure the extent of the firm's external technological linkages, (2) patents measure only codified knowledge, and (3) patenting does not fully measure competencies in software technology.

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2. BACKGROUND

New Combinations Evidenced by Patent Data

Perhaps the most significant contribution of Schumpeter was to define innovation as "new combination" (Schumpeter, 1934). Innovation is considered to be accomplished by creatively combining two (or more) previously unrelated pieces of knowledge to form a qualitatively new piece of knowledge. For a new idea to come into existence, different pieces of knowledge have to come together. This implies personal interaction between individuals because most knowledge is held within them.

In this respect, a corporate merger provides many new opportunities for different pieces of knowledge to come together. It is expected to reduce the psychological and/or economic cost of interaction between the members of the two formerly separate firms. Additionally, as each merging firm has a specific technological portfolio, the merger should facilitate diversification and the filling of gaps between the portfolios. This implies that the possibility of new combinations occurring in a firm should be higher after the merger.

H1: Corporate mergers facilitate new combinations of knowledge.

To test this hypothesis empirically, a reliable measure for new combinations of knowledge is required. If a narrow definition of knowledge is permitted, patent statistics provide a proxy for knowledge and are a good resource for investigating this problem[2]. The patent systems of major countries use the International Patent Classification (IPC) code, which had its origins in the Council of Europe's 1954 European Convention on the International Classification of Patents for Invention. Under this scheme, each patent is assigned one or more IPC codes corresponding to the patent's contents. Since the codes correspond to technology areas, the relatedness between fields of technology can be estimated by analyzing the co-occurrences of the codes assigned to each patent (Jaffe, 1986; 1989; Engelsman and van Raan, 1992; Breschi, Lissoni, and Malerba; 2003, 2004). For example, if two codes co-occur frequently, the combination of the two corresponding technology fields is probably not new (i.e., the combination is central in the firm's total portfolio). Similarly, if they co-occur infrequently, their combination is thought to be new (i.e., the combination is marginal in the firm's total portfolio). We can thus estimate the extent of newness of a combination of knowledge on the basis of the frequency of the IPC code pairs assigned to

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[2] There is a discussion that patent statistics show different aspects of industrial innovation (Pavitt, 1982).

patents.

New Combinations as a Strategic Choice

A firm's strategic choices strongly affect the behaviors of the inventors it employs; therefore, focusing on the inventors is a reasonable way to assess the effects of a strategic choice. Jaffe, Trejtenberg, and Henderson (1993), for example, analyzed patent citation data by the U. S. patent office and found that citations were more likely to occur among patents invented by persons from the same region. Such a localization effect of knowledge was also confirmed by many scholars (Almeida, 1996; Almeida and Kogut, 1999; Stolpe, 2002; Song, Almeida, and Wu, 2003; Thompson and Fox-Keanm, 2004).

Narin and Breitzman (1995) and Ernst, Leptien, and Vitt (2000) used patent data to verify Lotka (1926)'s law, i.e., the number of highly productive scientists is a relatively small fraction of all scientists. In a firm, there is a relatively small number of higher-performance inventors and a large number of lower-performance inventors. The higher-performance inventors are assumed to be the key person in the firm's research activities. Besides developing new inventions, they also interact with each other to find promising combinations of the knowledge that they are creating. Since their role includes developing a large number of inventions as well as those that are unique (pursuing unique combinations of knowledge), we are led to the following hypothesis.

> *H2: Inventors pursuing new combinations of knowledge are characterized as higher performers.*

However, the pursuit of new combinations involves greater risks. First of all, a firm confronts higher uncertainty because the probability of the occurrence of new combinations is relatively low. In other words, new combinations generally do not occur in the core area but in the fringe areas of the firm. Since new combinations are unexpected, the probability of commercial success would be lower. Due to this low probability, a firm will encourage its inventors to develop many inventions regardless of the probability of their success. This can be designated as a "he who shoots often, hits at last" policy that compensates for lower effectiveness. This discussion leads to the following hypothesis.

> *H3: A firm pursuing new combinations of knowledge as a strategic choice after a merger can be characterized as having higher efficiency but lower effectiveness.*

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3. ANALYTICAL PROCEDURE

Case Selection

The three hypotheses posited above were tested using data on patents filed at the Japanese Patent Office (JPO). Although Japanese patent data may be biased, they have some advantages that permit valid analyses. First and foremost, the Japanese two-step procedure for granting patents enables a reasonable assessment of an inventor's performance. Additionally, owing to the detailed and integrated system, they are very helpful for a long-term analysis (both characteristics are fully described in later). Owing to these reasons, the Japanese patenting system provides extensive and reasonable data for the following analysis.

The cases for the testing of the hypotheses were systematically selected. First, the total number of patent applications filed during the five years prior to the merger was extracted of all horizontal M&As (a type of merger of two companies that are in direct competition and share almost the same product lines and markets) from 1988 to 2002, summarized in the "Databook of M&As in Japanese Firms" by RECOF Co. Ltd., in the Tokyo Stock Exchange Market. The identification and patent data used hereafter was taken from the PATOLIS database. The database contains extensive information about patent applications filed in Japan, e.g., (a) the name and address of the applying firm and inventors, (b) the date on which the application was filed at the JPO and information on its after status, and (c) the IPC/FI code(s) assigned by the patent examiner.

After identifying the number of patent applications of each corporate merger, the cases were selected as follows. Considering this paper's purpose, corporate mergers that are not in technological areas, for example, retail or the banking sector are not considered appropriate for the case. Also, in order to obtain accurate results, the case should have many patents filed by the merger and merged firms, and their proportion should preferably be close to equal. Therefore, I set three criteria for case selection: (1) the total number of patent applications filed by both firms during the five years prior to the merger should be more than 5000, (2) the ratio of the number of applications filed between the two firms should not exceed 1:2, and (3) the name of the inventor's firm was mostly confirmed on the patent documents (described below). Two cases met all the three criteria: Mitsubishi Chemicals and Mitsui Chemicals (Table 1). Both cases were in the same chemical industry. Fortunately, this enables a comparative analysis based on almost the same conditions. Although both cases occurred in large Japanese business groups, the merger and merged firms did not have a strong business relationship prior to the merger. In fact, they were rivals with a contentious relationship.

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Table 1. Cases for analysis

firm name (after merger)	merger-side firm	merged-side firm	date of merger	number of patents filed during the five years prior to the merger	number of patents filed during the five years after the merger
Mitsubishi Chemicals	Mitsubishi Kasei Kogyo	Mitsubishi Yuka	1994/10/1	7654 (1989/10/1−1994/9/30)	6650 (1994/10/1−1999/9/30)
Mitsui Chemicals	Mitsui Sekiyu Kagaku Kogyo	Mitsui Toatsu Kagaku	1997/10/1	6072 (1992/10/1−1997/9/30)	4981 (1997/10/1−2002/9/30)

Identifying Inventors

Under the patent filing system in Japan, applications are published in a patent publication bulletin (a patent journal) without a search report 18 months after the date of filing the application. The patent journal contains information about inventors, as shown in Figure 1. From the example, we can determine that inventor[3] Taro Suzuki worked for firm X and that Hanako Tanaka worked for firm Y on the date of filing the application.

(71) applicant(s) 000123456

X-company

1-2-3 Shinjyuku-ku, Tokyo.

(72) inventor(s) Taro Suzuki

In X-company, 1-2-3 Shinjyuku-ku, Tokyo.

Hanako Tanaka

In Y-company, 4-5-6 Shibuya-ku, Tokyo.

Figure 1. Example of patent information in Japanese patent journal

Using this information, I identified which of the firms (merger firm or merged firm) each inventor worked at before the merger. Hereafter, I will use "A" to represent the merger firm and "B" to represent the merged firm (i.e., Mitsubishi Kasei Kogyo and Mitsubishi Yuka are referred to as firm A and firm B, respectively). I examined all the patent documents filed by both the firms during the five years *before* the merger and listed the inventors who could be linked to either of the firms. Two lists were created. One was created for the merger firm (list A) and the other, for the merged firm (list B). I excluded the inventors who had provided information other than the firm's name in the address field (the cases where the addresses of inventor's home, affiliate firm, joint research firms, university, etc. were mentioned).

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[3] In Japanese patent law, inventors are defined as the person(s) who practically contributed to the invention, excluding just managers, assistants, and sponsors.

However, the inventors whom I could link to any one firm through one or more patents and not by other patents, were regarded as having worked for that firm and their names were added to the list[4].

Thereafter, using the same data, I checked whether each person on list A and each person on list B had filed at least one patent application during the five years *after* the merger and eliminated those who had not filed any patent application. The lists, then, contained only those inventors who had filed one or more patent applications during the five years both before and after the merger. The following analysis uses the patent applications filed by the inventors on the two lists.

Variables of Inventors

I introduced six variables to designate inventors' characteristics. Hereafter, S is the set of patent applications filed during the target period (five years before or after the merger). Further, P, belonging to set S, is the set of patent applications on which inventor p is named.

(1) New combinations index for each inventor (new combinations)

Since the "newness" of combinations corresponds to a lower probability of co-occurrence between the technology fields, the degree of innovativeness is considered to be the inverse of the number of combination occurrences. The assumption made is that the frequency with which two classification codes are jointly assigned to the same patent document corresponds to the strength of the knowledge relationship (Breschi, Lissoni, and Malerba, 2003). As described above, IPC codes, which are assigned to patent documents by patent examiners, are useful for estimating this frequency. However, since the codes are reviewed periodically (modified slightly every five years), they are not suitable for long-term studies. Therefore, I used the FI code, which is the Japanese original code having its origin in the IPC, and having almost the same classifications as the IPC, as an alternative. The main difference between IPC and FI code is that the latter is updated frequently by the JPO in order to be consistent with other patent codes to enable long-term searches. Therefore, the FI is more suitable for tracing firms' technological areas over the long term.

The FI has the same hierarchical structure as the IPC, i.e., class, subclass, main group,

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[4] This procedure has certain limitations. First, if there were inventors with the same family and personal names in both firms A and B, I could not strictly identify which firm the inventors belonged to. This problem was almost negligible because there was only one instance for each case (the inventor was eliminated from both the lists). However, it is possible that one inventor had been listed twice because the inventor might have changed his or her family name due to marriage during the target period.

and subgroup. I used the higher level, which is represented by an alphabetical "section symbol" followed by a two-digit "class symbol" number (e.g., "C07" corresponds to "organic chemistry"). Using this classification, I first estimated the degree of "newness" by the frequency of co-occurrence between the FI class codes for the patent applications filed during the target period. The formula used for the calculation is derived from Shannon's information theory, according to which, the less likely the event (i.e., co-occurrence) is to occur, the greater the value. The degree of "newness" between FI classes j and k and the one of FI class j are estimated by the following equation.

$$newness(j,k) = -\ln \frac{\sum_{i \in S} fi(j,k)_i / ficount_i (ficount_i - 1)}{\sum_{i \in S} 1}$$

$$if \quad ficount_i = 1, \quad newness(j) = -\ln \frac{\sum_{i \in S} fi(j)_i}{\sum_{i \in S} 1},$$

where $ficount_i$ represents the number of unique FI classes for patent i. fi(j,k)$_i$, and

fi(j)$_i$ takes binary values: 1 means co-occurrence between FI class j and k ($ficount_i > 1$) and

occurrence of FI class j ($ficount_i = 1$) for patent-i.: 0 means no (co-)occurrence.

After calculating the "newness" between the FI classes, I assigned a new combination index to each inventor. It is a weighted average that accounts for "exam ratio" (described below). The index is larger for inventors with patent applications in technological fields with a low probability of (co-)occurrence. In other words, the less the probability of (co-)occurrence in technological areas in which the inventor generates patents, the larger is the index for him or her.

$$new\_combinations_p =$$

$$\frac{\sum_j \sum_{k,j \neq k} \left[newness(j,k) \bullet \sum_{i \in P} fi(j,k)_i / \{n_i \bullet ficount_i (ficount_i - 1)\} \right] + \sum_l \left[newness(l) \bullet \sum_{i \in P} fi(l)_i / n_i \right]}{\sum_{i \in P} 1/n_i},$$

where n$_i$ represents the number of unique inventors for patent-i.

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(2) Inventors' performance (patents, partial patents, exam ratio)

Inventors' performance is measured in terms of efficiency and effectiveness.

Efficiency is related to the number of patent applications for the inventor. Credit is assigned in two ways: An inventor gets full credit (a "patent") for an application and gets partial credit (a "partial patent") for an application if more than one inventor is named; for example, if three inventors are named, each is credited for one-third of the patent (Narin and Breitzman, 1995).

Effectiveness is related to the patent examination ratio for the inventor ("exam ratio"). In Japan, a request for examination must be made to the JPO (the request must be made before three years have passed since the application filing date[5]). Such a request is not made for all applications for several reasons. It may be decided that the patent is not important after the application is filed, or that disclosing the patent's contents is sufficient for budding the novelty of related patents to be granted. This judgment process by a firm implies that the ratio of patents for which a request is made can be used as a measure of an inventor's performance on the basis of quality. Hence, I considered this ratio for each inventor as a proxy of his or her effectiveness and calculated it in terms of a weighted average of the number of co-inventors. For example, suppose an inventor has one patent application for which a request has been made along with one other person and another patent application for which a request has not been made along with two other people. In this case, the exam ratio for the inventor is calculated as a weighted average: $(1/2 + 0/3) / (1/2 + 1/3) = 0.6$, not simply 0.5.

Although some might argue that the ratio of patent registrations is a better indicator of an inventor's performance, because registering of a patent takes many years after the application is filed (e.g., Jaffe, et al., 1993; Hall, 2002), most of the patents in the two cases mentioned here still have their examinations pending. Similarly, many researchers have pointed out that a patent's strength is best measured by the number of patent citations to it (e.g., Narin, Carpenter, and Woolf, 1984; Albert et al., 1991), however, it also takes considerable amount of time to measure the number of targeted patent citations. Therefore, I used only exam ratio as the metric for an inventor's effectiveness.

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[5] The period was changed from seven to three years as of 2001/10/1. Since I am interested in applications filed from 1992/10/1 to 2002/9/30 in the Mitsui Chemicals case, some of them might not have had a request for registration by the firm.

$$patents_p = \sum_{i \in P} 1$$

$$partial\ patent\ s_p = \sum_{i \in P} 1/n_i$$

$$exam\ ratio_p = \frac{\sum_{i \in P} d_i/n_i}{\sum_{i \in P} 1/n_i}$$

(3) Average number of co-inventors per patent for each inventor (co-inventors)

I calculated the average number of co-inventors (including the targeted inventor) for each patent by inventor p, using the following equation.

$$co\_inventors_p = \frac{\sum_{i \in P} n_i}{\sum_{i \in P} 1}$$

(4) Weighted average number of FI classes per patent for each inventor (weighted FIs)

Similar to Lerner's (1994) work, I calculated the weighted average number of different FI classes—which is weighted by the number of co-inventors—per patent using the following equations:

$$weighted\ FIs_p = \frac{\sum_{i \in P} ficount_i/n_i}{\sum_{i \in P} 1/n_i}$$

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4. RESULTS

Aftereffects of a Corporate Merger

The average of (partial) patents and the exam ratio of an inventor during the five years before and the five years after a merger, and the difference between them with t-statistics[6] are summarized in Table 2. The table also shows the index of new combinations and weighted FIs. The latter two are higher for after the merger than before the merger in both cases, implying that a corporate merger tends to broaden the perspective of research activity. In both cases, the merger appears to have played a positive role in promoting the encountering of new knowledge within the company, which can lead to innovation. This supports H1. It implies that mergers increase the probability of encountering people within the firm who have knowledge of different technologies or different ways of thinking. Consequently, inventors are more likely to find new ways of coordinating or combining technologies.

In terms of inventor performances, the number of (partial) patents declines significantly after a merger (Mitsui Chemicals case is not significant but at the level $p < .1$) probably due to the reassignment of technology areas for researchers after the merger as a part of the restructuring. In contrast, inventors' effectiveness (exam ratio) improves significantly for Mitsubishi Chemicals as shown by the higher exam ratio, while it declines slightly for Mitsui Chemicals.

Table 2. Characteristics of inventors

firm name	period patents filed	patents	partial patents	exam ratio	new combinations	co-inventors	weighted FIs
Mitsubishi Chemicals (N=1522)	5 years before merger	9.597	3.334	0.539	4.621	3.445	1.591
	5 years after merger	8.131	3.051	0.584	4.855	3.455	1.666
	difference (after-before)	−1.466 ***	−0.283 *	0.045 ***	0.235 ***	0.010	0.075 ***
Mitsui Chemicals (N=1306)	5 years before merger	11.867	3.348	0.607	4.490	4.173	1.668
	5 years after merger	10.969	3.078	0.577	4.702	4.279	1.757
	difference (after-before)	−0.898	−0.270	−0.029 *	0.212 ***	0.106 *	0.089 ***

Note : A paired sample t-test is used (* p < .05, *** p < .001).

Effect of New Combinations as a Strategic Choice

I used three regression models to estimate whether the difference in the inventor's

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[6] Owing to the large sample, the average of paired difference for the exam ratio is also regarded as t distributed.

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effectiveness (exam ratio) between the two firms could be confirmed after controlling the effects of other variables and determine the extent to which these characteristics affect the inventors' performance. The first model defines three characteristics as independent variables: new combinations, co-inventors, and weighted FIs. The second and third regression models have one or two dummy variable(s), respectively for inventor classification.

The classification of inventors was carried out by the following procedure. Using list A and list B, which I had prepared, I checked each patent application filed during the five years *after* the merger to see whether it named inventors from firm-A and firm-B. Then, inventors who shared at least one patent application with someone from the other firm were classified as *collaborators*; the remaining inventors, as *non-collaborators*. On the basis of this classification, the dummy variable in model 2 was set to 1 for non-collaborators and to 0 for collaborators. In Model 3, "dummy A" was set to 1 for non-collaborators from the merger firm, and "dummy B" was set to 1 for non-collaborators from the merged firm, and both were set to 0 for collaborators. I used the ordinary least squares (OLS) regression for partial patents as the dependent variable (I took the natural log of the number of partial patents because the distribution of partial patents was highly skewed) and used the probit regression for exam ratio as the dependent variable. The results are summarized in Tables 3 and 4.

Table 3. Results of regression analysis (Mitsubishi Chemicals)

dependent variable	*ln* partial patents (5 years before merger)			*ln* partial patents (5 years after merger)			exam ratio (5 years before merger)			exam ratio (5 years after merger)		
independent variable	model 1	model 2	model 3	model 1	model 2	model 3	model 1	model 2	model 3	model 1	model 2	model 3
new combinations	−0.147 ***	−0.119 ***	−0.098 **	−0.169 ***	−0.104 ***	−0.112 ***	−1.247	−1.282	−2.051 *	−4.710 ***	−4.615 ***	−4.990 ***
co-inventors	−0.312 ***	−0.315 ***	−0.325 ***	−0.425 ***	−0.428 ***	−0.422 ***	−0.640	−0.634	−0.123	−0.060	−0.060	0.372
weighted FIs	0.111 ***	0.093 **	0.091 **	0.165 ***	0.112 ***	0.117 ***	2.943 **	2.962 **	3.051 **	3.155 **	3.102 **	3.349 ***
dummy A+B	—	−0.175 ***	—	—	−0.300 ***	—	—	0.359	—	—	−0.123	—
dummy A	—	—	−0.248 ***	—	—	−0.358 ***	—	—	1.521	—	—	0.650
dummy B	—	—	−0.114 ***	—	—	−0.336 ***	—	—	−2.175 *	—	—	−1.692
intercept	1.775 ***	2.192 ***	2.179 ***	1.733 ***	2.444 ***	2.433 ***	−0.457	−0.562	−0.473	2.988 **	2.748 **	2.620 **
R²	0.105	0.135	0.142	0.192	0.279	0.281	—	—	—	—	—	—
F / χ²	59.1 ***	59.1 ***	50.2 ***	120.2 ***	146.8 ***	118.2 ***	838.5	838.5	830.9	892.6	892.4	889.6

Note : N=1522. Numerical variable represents standarized coefficient estimated by OLS regression analysis / probit analysis (* p < .05, ** p < .01, *** p < .001).

Table 4. Results of regression analysis (Mitsui Chemicals)

dependent variable	*ln* partial patents (5 years before merger)			*ln* partial patents (5 years after merger)			exam ratio (5 years before merger)			exam ratio (5 years after merger)		
independent variable	model 1	model 2	model 3	model 1	model 2	model 3	model 1	model 2	model 3	model 1	model 2	model 3
new combinations	−0.202 ***	−0.178 ***	−0.186 ***	−0.211 ***	−0.148 ***	−0.156 ***	−5.186 ***	−5.166 ***	−5.083 ***	−2.305 *	−2.667 **	−2.206 *
co-inventors	−0.244 ***	−0.227 ***	−0.265 ***	−0.217 ***	−0.223 ***	−0.243 ***	1.278	1.263	1.733	3.645 ***	3.694 ***	4.630 ***
weighted FIs	0.254 ***	0.227 ***	0.230 ***	0.157 ***	0.079 **	0.086 **	4.640 ***	4.619 ***	4.577 ***	2.464 *	2.895 **	2.551 *
dummy A+B	—	−0.182 ***	—	—	−0.413 ***	—	—	0.087	—	—	2.968 **	—
dummy A	—	—	−0.239 ***	—	—	−0.401 ***	—	—	1.098	—	—	4.354 ***
dummy B	—	—	−0.145 ***	—	—	−0.419 ***	—	—	−0.562	—	—	1.445
intercept	1.132 ***	1.402 ***	1.552 ***	1.316 ***	2.157 ***	2.233 ***	0.214	0.185	−0.203	−1.368	−2.292 *	−3.043 **
R²	0.092	0.124	0.135	0.073	0.239	0.241	—	—	—	—	—	—
F / χ²	43.7 ***	46.1 ***	40.5 ***	34.0 ***	101.9 ***	82.5 ***	576.6	576.6	575.8	618.7	617.8	611.7

Note : N=1306. Numerical variable represents standarized coefficient estimated by OLS regression analysis / probit analysis (* p < .05, ** p < .01, *** p < .001).

The results indicate that new combinations and co-inventors had a significantly negative effect on inventors' efficiency (i.e., partial patents), while weighted FIs had a significantly positive effect both before and after the merger. This implies that inventors who work relatively independently and cover many but related technological areas are likely to be more efficient. All the results show that new combinations negatively affect inventors' efficiency, which contradicts H2. Furthermore, the negative signs for the dummy variables mean that non-collaborators are less efficient than collaborators. In other words, collaborators are more efficient than non-collaborators, which imply that collaborators must play key roles in developing innovation. Moreover, the increase in the absolute values of the dummy variables after the merger means that collaborators play an even more important role after the merger.

The results for effectiveness (i.e., exam ratio) differ somewhat between the two cases. For example, the sign for co-inventor is negative for Mitsubishi Chemicals, while it is positive for Mitsui Chemicals. Moreover, for Mitsui Chemicals, the coefficients for co-inventors are significantly greater after the merger. This suggests that Mitsui Chemicals emphasized more on collaborative work among researchers after the merger. More importantly, the values of dummy variables (non-collaborators) for Mitsui Chemicals were significantly greater after the merger, which is in contrast to for the case of Mitsubishi Chemicals. This indicates that technological collaboration between the merger and merged firms was less successful after the merger for Mitsui Chemicals than for Mitsubishi Chemicals.

The signs of the new combinations are all negative, which means that pursuing new combinations does not result in effective inventions. This, together with the results described above, leads to the conclusion that H2 is not supported in terms of both efficiency and effectiveness. In addition, careful analyses of the results confirm the differences between the two cases. In the Mitsubishi Chemicals case, the values for new combinations are lower after the merger, while in the Mitsui Chemicals case they are higher. This indicates that Mitsubishi Chemicals followed a "selection and concentration of technology" strategy after the merger in terms of effectiveness. In contrast, Mitsui Chemicals emphasized "new combinations" rather than "selection and concentration" of technology.

This strategic contrast affects the roles of collaborators as well as non-collaborators. From Table 3, the effectiveness of Mitsubishi Chemicals' collaborators and non-collaborators did not change much after the merger. In contrast, as shown in Table 4, the collaborators of Mitsui Chemicals worked less effectively than the non-collaborators after the merger. These cases imply that if a firm makes "new combinations" its strategic choice, effective inventions might not be expected for collaborative work. Also, the results shown on the left side of Table 4 imply that the aftereffect for collaborators in terms of efficiency is higher after the merger (the values for non-collaborators significantly decline after the merger), showing that collaborators are likely to produce more inventions than non-collaborators after a merger. In short, Mitsui Chemicals apparently adapted a "he who shoots often, hits at last" policy for collaborators to compensate for their lower effectiveness, which supports H3.

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5. DISCUSSION

Thus far, I have discussed the aftereffects of corporate mergers, using patent application data. The findings show that Mitsubishi Chemicals and Mitsui Chemicals made different strategic choices for filing patent applications. In this section, I consider how their technology areas affected their strategic choices because this choice is strictly rooted in the technology area in which a firm stands.

Although new combinations after a merger demand a certain level of technological change, in general, such changes cannot be easily realized. In fact, there is considerable evidence that a firm's innovative activities are cumulative in the sense that its technological specialization tends to remain stable over lengthy periods of time (Cantwell and Anderson, 1996; Malerba, Orsenigo, and Peretto, 1997; Malerba and Orsenigo, 1999; Cefis and Orsenigo, 2001; Cefis, 2003; Breschi, Lissoni, and Malerba, 2003). This is because there is inertia that reinforces specialization and technical interdependence (Dosi, 1982; Patel and Pavitt, 1997); thus a firm's technology area generally changes gradually over time. This means that people must take strong initiative for new combinations to occur.

I used a technology map to identify who took the initiative that led to new combinations. I created the map, using correspondence analysis, a method of factoring categorical variables and displaying them in a feature space. First, I determined the total number of patent applications[7] in each FI class for each filing year, using the formula given below (I counted the number of partial patents for each FI class for each filing year). Subsequently, correspondence analysis was conducted with FI class as a row category and the classification of inventor (list A, list B, or both) for each filing year for both cases as a column category. Figure 2 shows a scatter plot of points for each FI class. The distance between FI classes is shorter when they have relatively the same ratio of patent applications among column categories. It must be emphasized that the axes do not represent specific parameters; the relative positioning itself is essential.

$$contribute \ number \ of \ patents(j,t) = \sum_{i \in P(t)} fi(j)_i \big/ \big(n_i \bullet ficount_i \big)$$

$P(t)$: Set of patent applications filed by target inventors in period t

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[7] Since the purpose is to analyze the properties of patent data as a proxy of the firm's innovative activities, patent applications were chosen instead of registered patents.

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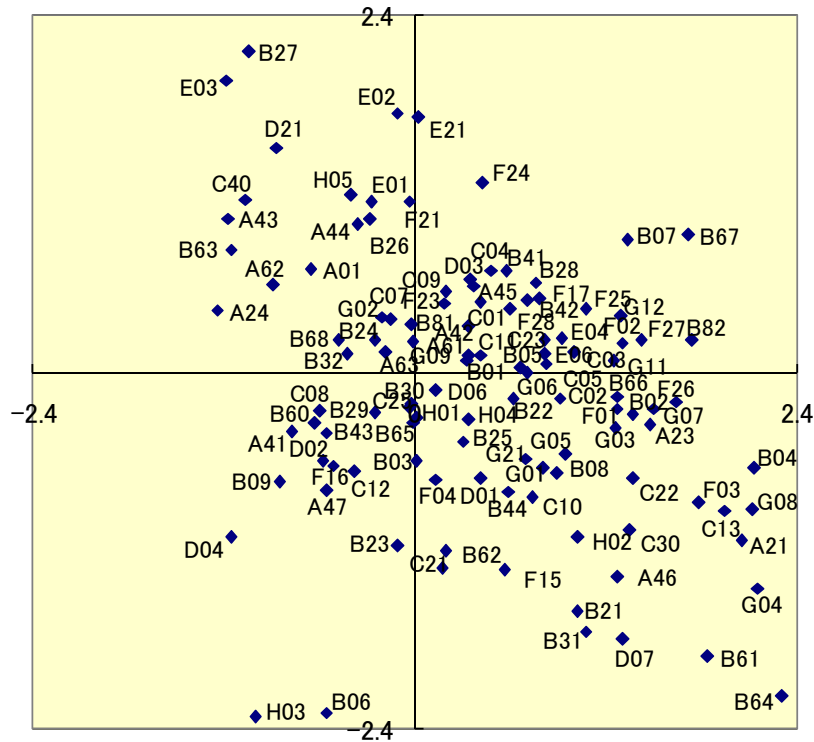

Figure 2. Technology space

Next, I plotted the inventors' technological centroid positions in the same technology space (Figures 3 and 4). The patent applications filed *before* the merger by inventors for file A (merger firm) and file B (merged firm) are labeled A and B, respectively. The applications filed *after* the merger by inventors for both file A and file B are labeled C. The numbers in parentheses indicate the filing period, i.e., (–1) implies filing in the year prior to the merger, and (1) implies filing in the year after the merger. I added ellipses to cover all the filing periods for the inventors' classification.
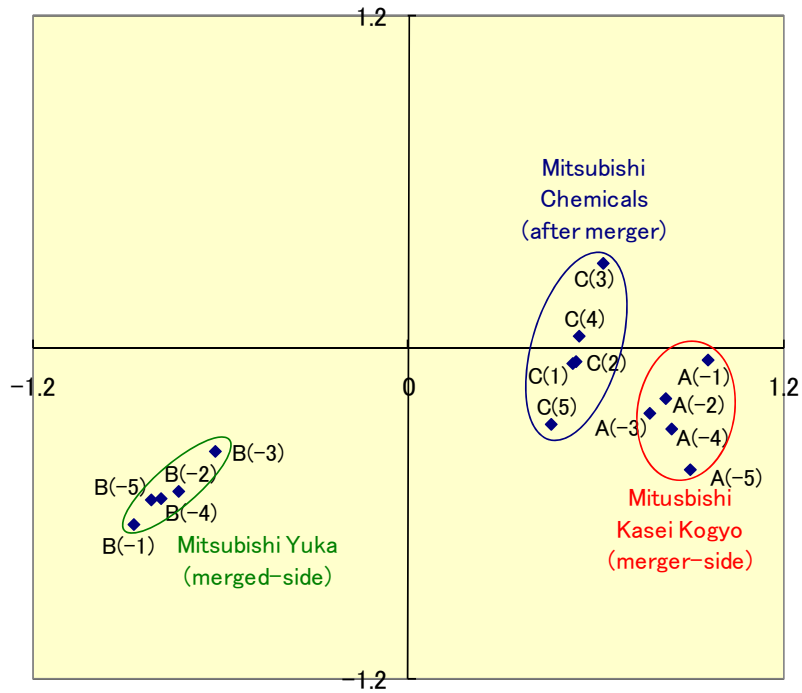
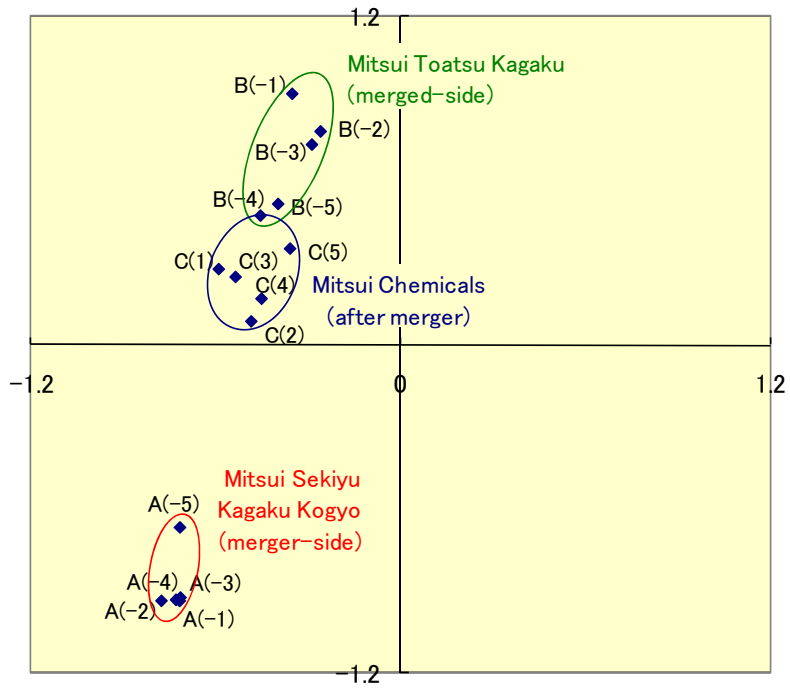Figure 3. Technological position (Mitsubishi Chemicals)

Figure 4. Technological position (Mitsui Chemicals)

Using these figures, we can estimate the firm that took the initiative in terms of collaboration after the merger. For example, Figure 3 shows that patent applications from the merger firm (A), are located in the area plotted in the fourth quadrants, and those from the merged firm (B) are located in the third quadrant. The applications filed by inventors from both firms after the merger (C) are located in the first and fourth quadrant and closer to those from the merger firm (A) than those from the merged firm (B). This implies that the initiative after the merger was taken mainly by the inventors from the merger firm in the Mitsubishi Chemicals case. In contrast, in the Mitsui Chemicals case (Figure 4), the positions of the applications for the merged firm (B) and for both firms after the merger (C) partly overlap, indicating that the initiative was taken mainly by the inventors from the merged firm. Supporting this, the famous Japanese business newspaper, Nikkei, reported the following on the day of the merger, "producing a cash flow by the stable petro-chemical business of Mitsui Sekiyu Kagaku Kogyo (the merger firm), and investing it in Mitsui Toatsu Kagaku (the merged firm)'s fine-chemical business that has high growth potential — the newly formed Mitsui Chemicals develops such a scenario."

This finding provides one explanation for making a different strategic choice for new combinations. Usually, the merger firm has much strong power than the merged firm. Therefore, the results for the Mitsubishi Chemicals case imply that a merger firm can adopt a top-down approach to implement a "selection and concentration" strategy because the merger firm is more powerful and takes strong initiative. On the other hand, the results for the Mitsui Chemicals case indicate that if initiative is lacking in the merger firm, the resulting maldistribution of power and initiative can make the adoption of a top-down approach difficult. This forces the firm to choose a "new combinations" strategy instead of a "selection and concentration" one. These cases imply that if the "selection and concentration" strategy is to be applied, both power and initiative should reside in the same premerger firm.

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6. CONCLUSION

I began this paper by posing two questions: (1) Are new combinations of knowledge facilitated by corporate mergers? (2) How and why does a company make a strategic choice for new combinations of knowledge? My analysis of the two cases indicated that new combinations were more likely to occur after mergers. However, the focus on the "new combinations" strategy revealed a different story. Mitsubishi Chemicals concentrated on their technology area for filing patent applications after the merger. In contrast, Mitsui Chemicals encouraged its inventors, especially the collaborators, to produce many inventions regardless of their effectiveness. Further analyses revealed that the choice of a "new combination" strategy depends on whether or not power and initiative reside in the same premerger firm. Moreover, strategic choice seems to have a significant impact on the aftereffects of a corporate merger.

These evidences have some managerial implications. First of all, although a corporate merger facilitates new combinations of knowledge, pursuing new combinations in innovative activities does not necessarily result in higher performance. This implies that if a firm considers "new combinations" as the strategic purpose for a merger, the firm must endure low performance for research activities. To compensate for the lower performance, a firm might need some schemes that will encourage research activities, especially in terms of the number of research activities. The second point is that the possibility of choosing an appropriate strategy for a firm depends on the overall portfolio of the firm after the merger. If maldistribution of power and initiative exists, a firm might face the difficulty of following the "selection and concentration" strategy rather than the "new combinations" strategy. Contrary to this, if maldistribution does not exist, the "selection and concentration" strategy might be better because the empirical results exhibit significant improvement in effectiveness after the merger.

From a human resource management perspective, two implications can be drawn. The first is the fact that there is a difference in the conditions with regard to the creation of innovation before and after a merger. Therefore, a firm should create a distinct organizational environment for research activities before and after the merger. Second, the classification of collaborators and non-collaborators implies that effective innovation might occur in the fringe area of a firm's technical portfolio as well as of human resources (although the efficiency of inventions is mainly led by collaborators, it is not always achieved effectively by them). Effective inventions can be developed by "unexpected" inventors of a firm, implying that such people should not be treated casually.

While these findings are insightful, there are several significant limitations of this study that should be noted. Perhaps the greatest one is the limited number of cases and the limited geographical area covered by the study (in Japan). The small number of corporate mergers with a sufficient number of filed patent applications in Japan limited the analysis to

two cases. The limited conditions in Japan as well as in the chemical industry make the generalization of the results too narrow. To develop the theoretical underpinnings of how to develop innovations, more empirical works examining the difference between firms, industries, or countries is required. Thus, so that the cases can be compared on an equal basis, some weights that reflect the technical and/or commercial importance of patents need to be devised because each merger is different in its size, type, purpose, etc.

This study also has limitations that have resulted oeing to the analytical method this paper has taken. For example, this paper measured an inventor's performance by his or her patenting activity, whereas the quality of the resulting patents is not explicitly taken into account (I assumed that each patent has an equal weight). In addition, since patent data is not a perfect indicator of research activities, I neglected many other aspects that are important for generating innovation.

This study is just an initial step. The following questions could be investigated in future studies.

(a) Who are the real contributors in a corporate merger? This paper classified inventors as collaborators or non-collaborators, and assumed that collaborators took an initiative for the collaborated work. However, the real contributors could exist in both the categories. More meaningful classification should be devised for detailed analyses.

(b) What kind of organizational environments can a firm offer to achieve the purpose of a merger? Since this paper focused only on the variables of inventors' activities, the variables at the organizational (team, division, etc.) level were neglected. Including these variables provides a clearer list of condition that a firm should prepare in order to merge successfully.

(c) How are internal research activities related to a firm's outcome? There is a missing link between each inventor's performances and his/her real contributions to a firm. An endeavor for bringing together many measures relating to an inventor's activities in a firm will provide us with a more detailed understanding of real contributions of patenting activities.

Despite several limitations, I believe that this study might be the first empirical test of the effects of corporate mergers at the micro level with the purpose of identifying the conditions that may affect the success of corporate mergers. As the analyses revealed, the aftereffects of corporate mergers did not occur in a void. It should be stressed that they depended largely on the firms' strategic choices.

Acknowledgement

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