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EMPIRICAL STUDY ON ESSENTIAL PATENTS IN DVD AND MPEG STANDARDS PATENT POOLS

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Abstract

How companies develop inventions which are essential for technical standards? In this paper, utilizing patent data, we empirically investigate what kinds of technological search enables companies to obtain essential patents included in DVD 3C, DVD 6C, MPEG-2, MPEG-4 Visual patent pools. On the basis of previous studies, we adopt three types of technological search: Local Search, Beyond Local Search, and Pioneering Approach to analysis of essential patents in patent pool. Our result shows inventions included in essential patents are developed by Pioneering Approach, where researchers look into roots of technological difficulties, ascertain their bottom lines, and struggle with novel technical solutions. As far as the analysis in a unit of a patent, essential patents are obtained neither by Local Search which explores technological fields which are well experienced in a company nor by Beyond Local Search in which researchers search for technical solutions in technological domains unfamiliar to them.

Kewwords: standard, patent pool, essential patent, technological search, divisional application, regression

1. **Introduction and Background**

Recently, particularly in information technology and electronic industries, it has been strategically inevitable for companies to incorporate their own technology into technical standards. One reason why the importance of technical standards has increased is that the assurance of product compatibility becomes requisite because of development of networked society and internationalization of product markets. The interoperability among products not only increases consumers' benefit (Kats and Shapiro, 1985) but also provides companies the access to large markets. Because of these factors, in formal or informal way, companies often make an arrangement of interface specifications among products ahead of introducing them to the market. Once such standardized products are successfully accepted by consumers, the market stably grows up because of the market-expansion effect and the lock-in effect embedded in standards (Shapiro and Varian, 1999). For example, GSM, one of the communication systems of the second generation cell phones, had been standardized from the latter 1980s to the early 1990s, and prevailed in the world soon until 2006. European companies such as Ericsson and Nokia exercised leadership in the standardization process and then they enjoyed higher business share in cell phone and base station markets. As just described, utilizing technical standards expands a market in information technology and electric industries. Besides, companies can obtain great advantages of market competition if they well incorporate their own technologies into technical standards (Bekkers, Duysters, and Verspagen, 2002).

Today, one of the major problems about technical standards is that huge number of patents owned by many holders is necessary for the implementation of technical standards. Even *de jure* technical standard includes many patented technologies. This is because of the recent technological environment where development period is very short and the demand of cutting-edge technologies which enhance interoperability among products. Besides, more complex and highly-developed technology is, more patent holders appear with segmentalized claims (Shapiro, 2001). As a result, the number of patents relevant to technical standards has radically increased (Figure 1; Simcoe, 2005).

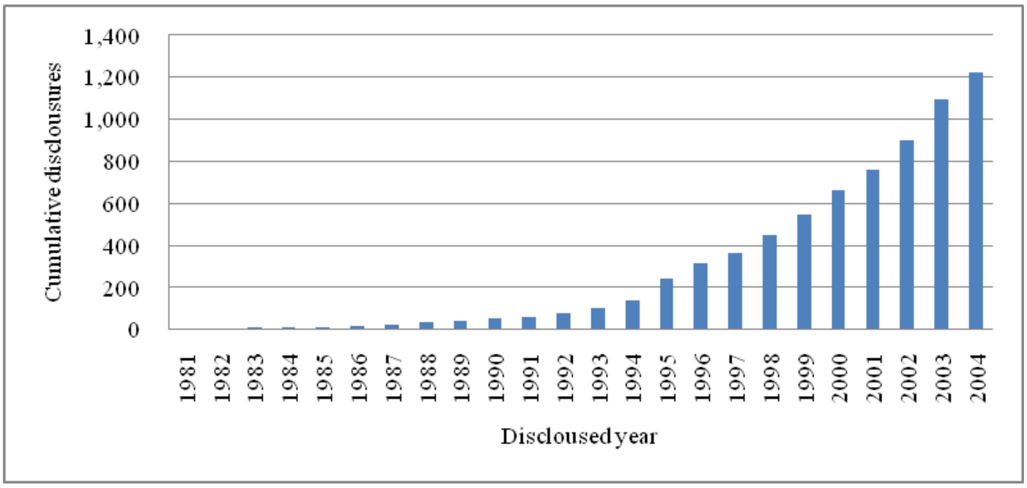

Figure 1. Cumulative number of patents disclosed in standard setting organizations. The author reedited data from Simcoe (2005)

In order to solve the problem, patent pools are established and licensees contact them to acquire patent licensing. They are an effective system to license a bundle of patents necessary for technical standards (Figure 2). Patent pools reduce licensees' transactions cost and block royalty stacking which is caused by licensors' individual collection of royalty (Shapiro, 2001).

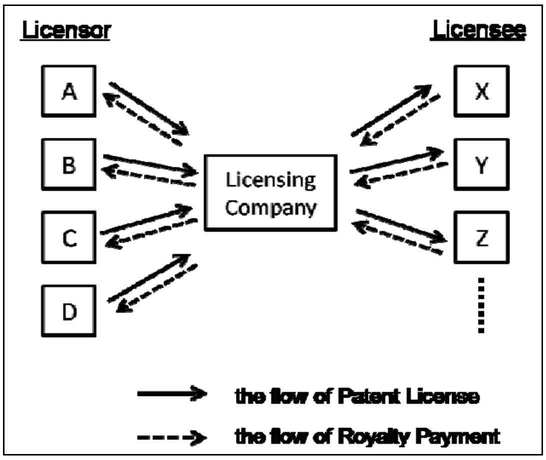

Figure 2. The typical structure of a patent pool

The patents included in patent pools are called "essential patents", and the licensors of essential patents can get royalties according to the number of their licensing essential patents. Patent pools contribute availability of the technical standards and accelerate market expansion of standardized products. As a result, licensors acquire more royalties and it produces huge income. In case of DVD, our estimated income derived from patent royalty relating to DVD products is totally about 7.8 billion US dollars in 2008 (Figure 3). The total royalty revenue is allocated to licensors, basically, according to the *number* of their own essential patents (Kato, 2006).

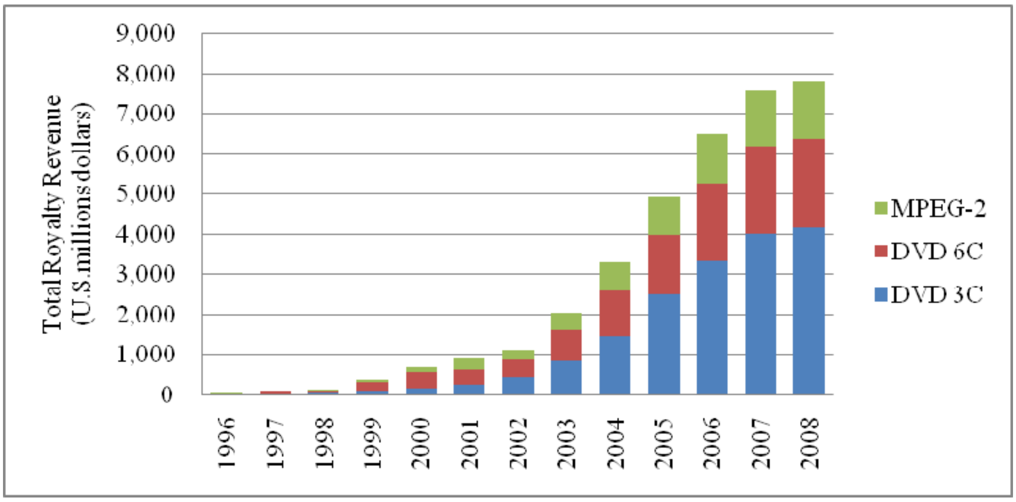

Figure 3. Estimated total royalty revenue of each patent pool related to DVD players, recorders, and drives[1].

It is significant to hold essential patents in order to enhance cost advantage in standardized product market competition. In case of standardized products, a market stably grows up, however, a price continuously drops because standardization degrades the barrier to entry and causes the high competitive market. As the price falls, the ratio of royalty payment to product price relatively becomes higher and it compresses the cost structure of manufacturing companies. However, if they have essential patents included in patent pools, they can get royalty incomes according to the number of their essential patents. Thus, among companies which manufacture the same standardized products, there is a significant gap in perspective of competitive advantage between companies which have essential patents and ones which don't. Again, because the royalty income is basically dependent on the number of licensing essential patents, the question how to gain more essential patents is strategically quite important.

1 The estimated total royalty revenue is calculated from the data: "World-wide electronics market research", 1998-2008, and "Storage devices market research", 2001-2008, Fuji Chimera Research Institute, Inc.

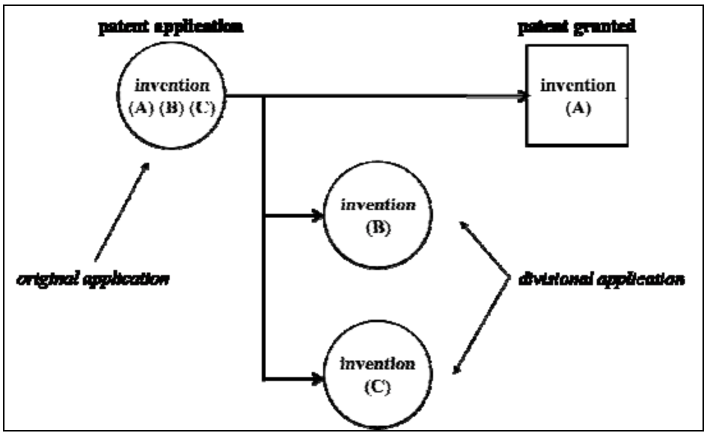

Figure 4. Picture of divisional application

Although previous studies about essential patents are only a few, some literatures point out companies exploit "divisional application system" to gain more essential patents (Nagaoka, Shimbo, and Tsukada 2006; Tsukada, 2008). Utilizing divisional application system, companies can extract some inventions from a patent application which include more than two inventions and file the extracted inventions as new patent applications (Figure 4). It is suggested that companies tend to increase the number of patents by divisional applications which are expected to be regarded as essential patents through standardization process or later. Besides, Nagaoka *et al.* (2006) and Tsukada (2008) argue that the quality of essential patents which are filed by divisional applications is lower than that of non-divisional essential patents. These studies give us the insight for the relationship between essential patents and patent management, however, there has been no previous reports about how essential patents originally are gained as outcomes of research and development (R&D) activity. It is considered that it includes not only patent management but also R&D management to produce more essential patents. Therefore, the goal of our research is revealing what R&D activity brings more essential patents and making the process of gaining essential patents clear.

Our sample of patent pools are DVD 3C, DVD 6C, MPEG-2, and MPEG-4 Visual patent pool. All of them are established in 1990s through standardization process. We adopt a view-point of "technological search" as R&D activity and examine what kinds of technological search tend to create inventions included in essential patents in those patent pools. The following section discusses previous studies in essential patents and technological search and draws hypotheses. The third section discusses our research design, sample data and methodology. The fourth section presents results and discussions. The last section is a conclusion.

2. Previous Study and Hypothesis

In this section, first, previous studies on essential patents are shown and what technological distinction is hold by inventions regarded as essential for technical standards is argued. Then, we organize prior researches suggesting how companies should operate R&D activities in order to develop technologies with the technological features of essential patents. Based on these studies, we propose hypotheses.

2.1 Essential patent

There are only a few researches which empirically consider the matters between patents and standardizations.

Lerner, Strojwas, and Tirole (2003) reviewed the history of patent pools and empirically analyzed features of patent pools with 63 patent pools data which were established from 1885 to 2001. Especially, Lerner *et al.* measured the technological importance of U.S. essential patents in five recent patent pools, including MPEG-2 and DVD, and compared it to that of controlled sample patents. As a result, the technological importance of the essential patents, measured by the number of patent citation (e.g. Albert, Avery, Narin, and McAllister, 1991), is significantly higher than that of the comparative patents even before the essential patents are certified as essential. Furthermore, the essential patents additionally become more important after they come to be included in the patent pools.

As a similar research, Rysman and Simcoe (2008), in a more sophisticated way, examined the difference of technological importance between U.S. patents which are disclosed in standard setting organizations and controlled sample patents. It resulted that the disclosed patents are technologically more important than the controlled patents even earlier than their disclosures. In addition, the technological importance of the disclosed patents is enhanced more after disclosing. Thus, it is shown that patents related to standardization originally possess high technological importance and increase the importance by the announcement effect through standardization process.

On the other hand, focusing on divisional applications frequently utilized in patent pools, Nagaoka *et al.* (2006) and Tsuakda (2008) conducted empirical analyses of a relationship between the quality of essential patents and the frequency of divisional applications. Nagaoka *et al.* analyzed the relationship, in a corporate unit, with data of U.S. essential patents in MPEG-2, DVD 3C, and DVD6C patent pools and argued the frequent usage of divisional applications decreases the quality of essential patents which is measured by patent citation. Also, Tsukada (2008) collected U.S. essential patents in 8 patent pools managed by MPEG LA and made an analysis in a registered patent unit. Tsuakda argues the quality of essential patents is lowered by the times that divisional applications are used in a patent examination process of a focal essential patent although the quality of essential patents is superior to non essential patents. These researches have uncertainty and ambiguity because the number of sample of the former study is only 21 and the latter research inaccurately deals with some of independent variables. However, they are valuable in terms of introducing a structure of divisional applications to an analysis which is discriminative in patent pools that motivate applicants to increase the number of patents.

Essential patents possess higher technological importance than other ones even before they become essential. However, there is a frequent usage of divisional applications among essential patents, which is an outstanding feature of patent pools. These aspects have become clear from previous studies. Next, we review prior studies about the ways of R&D activities how researchers or companies develop inventions with superior technological importance and quality.

2.2 Technological search

There are rich researches considering what sorts of technologies an invention with high technological importance consist of.

It is argued the ultimate source of novelty in inventions is recombination of knowledge (e.g. Fleming, 2001). Inventions come either from combining technological components in a novel manner or through reconfiguring existing combinations. Researchers search for various bits of knowledge when they face technological difficulties. They create novel inventions which solve the technological difficulties by recombining knowledge they searched. It is suggested that the technological importance of created inventions is dependent on the ways of searching, that is, what kinds of knowledge construct the new inventions. According to precious studies, we introduce the three types of searching; Local Search, Beyond Local Search, and Pioneering Approach.

Local search

Corporate R&D activity is not random behavior but it is affected by own past R&D activity (e.g. Nelson and Winter, 1973). It is pointed that companies tend to search for the technical solutions based on a technological field that they have ever experienced when companies meet technological difficulties in R&D and the tendency is called "Local Search" (Helfat, 1994; Stuart and Podolny 1996).

This is understandable in the following way. In an individual level like researchers and managers, when they face technological difficulties, materials or methods that they used in the past make the problem solvers move forward as a guide to avoid compete failures. In that, under the great technological uncertainty, past experiments in own companies become the first beginning step of new experiments. Then, if such a way of decision making is embedded in individuals, it becomes an organizational routine and the tendency of Local Search comes into existence (Stuart and Podolny, 1996; Auja and Lampert, 2001).

Some studies argue that Local Search enhances corporate core technological capabilities and provides inventions with high technological importance. A company which has distinct technological sources compared to other companies and keeps on experiments along its past technological trajectories owns a core technological capability (Barney, 1991; Leonard-Barton, 1992). Leonard-Barton argues core capabilities are knowledge set which consists of four dimensions; skills and knowledge, technical systems, managerial systems, and values and norms, that accumulate through past experiences. The cumulative past developments strengthens skills and knowledge and leads a company to an expert in the relative technological area. Empirically, Stuart and Podolny (1996) showed in a semiconductor industry companies with more Local Search tendency measured by patent citations are likely to have higher business market shares and more frequently cited patents, that is more technologically important inventions. Also, Hall, Jaffe, and Trajtenberg (2000) illustrated companies which invent more based on their own inventions tend to have better market valuation measured by Tobin's q.

Beyond local search

Beyond Local Search is a type of searching behavior that explores unfamiliar technological fields for technical solutions not like Local Search that explores technological fields experienced in past R&D activities (Rosenkopf and Nerkar, 2001).

While Local Search strengthens core technological capabilities in specific technological area, the existing core technological capabilities exert a negative effect to R&D projects where companies attempt to construct new technological capabilities. Leonard-Barton (1992) calls the negative aspect of core capabilities "core rigidities". Also, Levitt and March (1988) names such rigidity of organizational routines "competency traps". As the speed of technological development becomes faster, specific resources and capabilities can provide competitive advantages only for a short while. In such a market, a true source of sustainable competitive advantages is "a dynamic capability", which is a capability to quickly build new technological capabilities corresponding to market changes (Teece, Pisano, and Shuen, 1997). In other words, in order to construct technological competitive advantages, companies need to explore technological fields which have been not experienced before and combine unfamiliar knowledge with own existing knowledge.

Some empirical researches show Beyond Local Search produces inventions with high technological importance. With U.S. patents in an optical disc industry, Rosenkopf and Nerkar (2001) studied how an impact of inventions measured by patent citations is affected by a composition of inventive sources. Rosenkopf and Nerkar introduced two boundaries into inventive sources, an organizational boundary and a technological boundary, and examine the difference of effects between types of boundary-spanning. It results that the impact of inventions built on technologies of other companies is higher and a radical searching way, which is the way that inventive sources span two boundaries at the same time, is most effective when a company tries to develop inventions with high impacts to various technological domains. Miller, Fern, and Cardinal (2007) also made a similar research, in a patent unit, focusing on diversifying corporations and found out that the radical searching way enhances inventive impacts to various technological fields.

Pioneering approach

In corporate R&D activities, both Local Search and Beyond Local Search are types of searching behaviors which look for existing technologies. However, Ahuja and Lampert (2001) empirically illustrated that companies which produces pioneering inventions incline to develop breakthrough inventions which are defined as patents with critically high patent citation. A pioneering invention doesn't build on any existing technology and it is not similar to any prior invention (Nerkar and Shane, 2007).

An approach to develop pioneering inventions is clearly different from Local Search and Beyond Local Search. Ahuja and Lampert mention, "*Instead of trying to modify an available solution, pioneering technologies focus on de novo solutions. Indeed, the directive to researchers from a pioneering technology perspective is often to ignore all available solutions, focus instead on basic problems and their root causes, and step into the complete unknown in search of a fundamental solution.*" (Ahuja and Lampert, 2001, p529). As an example, Brown (1991) points out a director's speech of the Xerox Palo Alto Research (PARC). In fact, Xerox PARC and Bell Laboratories developed technologies with implications far beyond the traditional markets of their parent firms and the technologies affected various technological domains (Rosenkopf and Nerkar, 2001). In this study, we call such a type of searching behaviors "Pioneering Approach", in that companies don't search for any existing technology and struggle with completely new technical solutions.

2.2 Hypothesis

The goal of this study is answering the question what types of technological searches produces inventions included in essential patents. Thus, we don't especially focus on any of previously mentioned technological searches and propose three hypotheses.

Hypothesis 1: Inventions included in essential patents are developed by Local Search.

Hypothesis 2: Inventions included in essential patents are developed by Beyond Local Search.

Hypothesis 3: Inventions included in essential patents are developed by Pioneering Approach.

3. Research Design

3.1 Essential patents extraction

We adopt DVD 3C, DVD 6C, MPEG-2, and MPEG-4 Visual patent pools for our study. This is because, first, they are major patent pools and products applying them have prevailed in the world. Second, essential patents included in them are assured by third-party experts. Third, technologies covered by the four patent pools are related to each other and we can regard them as a certain range of technological field. In fact, DVD products contain DVD and MPEG-2 technologies and also essential patents in MPEG-4 visual overlap with those of MPEG-2.

In this study, Japanese essential patents in the four patent pools are examined. There are two reasons why we select Japanese patents but not American patents. First, Japanese firms give great contributions to the four patent pools. More than half of the members joining each patent pool are Japanese companies and over half of all essential patents included in the each patent pool are also obtained by Japanese firms. Second, an examination of Japanese Patent Office is known as rigid compared to that of U.S. Patent Office, so that Japanese patents have higher integrity in terms of patentability.

We gathered 241 essential patents from DVD 3C, 1181 essential patents from DVD 6C, 116 essential patents from MPEG-2, and 154 essential patents from MPEG-4 Visual. The collection of DVD 6C essential patents was operated in February, MPEG-4 Visual in March, and DVD 3C and MPEG-2 in September 2009. Among collected essential patents, there were overlaps of 1 patent in DVD 6C and MPEG-2 and 28 patents in MPEG-2 and MPEG-4 visual and, besides, 9 patents were not available because of the error of patent numbers. Finally, we extracted 1654 unique essential patents.

3.2 Sample patents extraction

This study focuses on R&D activities and aims to uncover what kind of technological searches provides essential patents. Thus, we have to consider two following points for sound analysis.

One is that we have to distinguish divisional applications among patent applications and exclude them from an analysis. More than half of the collected essential patents are filed as divisional applications as Nagaoka *et al.* (2006) and Tsukada (2008) points the frequent usage of divisional applications in patent pools. It is not adequate to regard divisional applications as outcomes from corporate R&D activities because a divisional application doesn't contain new technological knowledge for its applicant and it is an outcome from patent management (Figure 4). In other words, novel technological knowledge gained through R&D activities are contained only in "an earliest original application", which is filed not utilizing a divisional application. Matters in all divisional applications coming from a single earliest original application must consist in the earliest original application. Thus, we have to adopt only earliest original applications and remove any divisional application from our analysis.

The other is that we have to appropriately define technologies related to standardized technologies. This research should be designed to examine the differences between essential patents and non essential patents so that it is necessary to collect patents whose inventions are technologically as similar to inventions in essential patents as possible. As one of the possible ways, for example, information of patent classifications given to a patent such as IPC is often utilized (e.g. Rosenkopf and Nerkar, 2001; Lerner *et al.*, 2003). However, it is inadequate in this study although it is certainly effective to roughly extract a specific technological area. This is because common patent classifications like IPC cannot define patents possible to become essential for technical standards because a political effect works in a standardization process. For example, in an earlier step of DVD standardization, SD and MMCD technical standards were in confrontation for post CD technical standard but SD finally won MMCD and DVD was mainly constructed on SD. In this case, most of technologies related to MMCD standard lost the rights to become essential for DVD standard although they were optical disc technologies same with SD technologies.

Therefore, in this study, we apply "notices of reasons for refusal" in order to extract patents technologically close to essential patents. In Japanese Patent Law, a patent examiner delivers notices of reasons for refusal to an applicant when his or her patent application is judged not to have patentability. A patent application lacking patentability means an invention in the patent application doesn't hold either novelty or progressivity. An invention without novelty means the invention is already public knowledge and an invention without progressivity means the invention is easily developed by combination of existing knowledge. For instance, a patent application (A) citing a patent application (B) as a reason for rejection means that, *an examiner thinks*, inventions in patent application (A) are already developed in patent application (B) or inventions in patent application (A) are easily conceived through inventions in patent application (B). We interpret this in the way that inventions in patent application (A) and (B) are technologically similar. In view of this, we define patents technologically close to essential patents as patent applications which cite or are cited by essential patents in terms of reasons for rejection.

Based on the two noteworthy points, we extracted sample data in a following way with JP-NET, which is a patent searching service provided by JAPAN PATENT DATA SERVICE Co., Ltd, in October 2009. First, we identified all 2858 patent applications, which are in the same divisional relationship with the essential patents in four patent pools, in which earliest original applications were 693 cases. Then, we collected all patent applications which cited or were cited by the identified patent applications in notices of reasons for refusal. In addition, we again extracted any patent application with the same divisional relationship with the collected patent application. As a result, all extracted patent applications, including essential patens, were 8287 cases and 4703 earliest original applications were observed among them. For an analysis, finally, we adopt 3766 earliest original applications which were filed before this 2000 because most of standardization processes in DVD, MPEG-2, MPEG-4 technical standards were over by the end of 2000.

3.3 Dependent variable

The dependent variable is a dummy variable, *Essential-Dummy*, which is 1 if a focal earliest original application is an essential patent or some of divisional applications deriving from it are essential. Our unit of analysis is “an earliest original application” which is not filed as a divisional application so that divisional applications are eliminated from our sample data. Thus, it is possible that although an earliest original application is not essential, some of its divisional applications are essential patents. In that case, we treat such an earliest original application as an essential patent because we consider, again, an earliest original application includes matters in all divisional applications coming from it.

3.4 Independent variables

To construct independent variables of technological searches, we need information about inventive sources available in a patent data. As such information, we utilize backward citations, which a patent examiner makes to a patent application for reasons of rejection.

Backward citations are regarded as the flow of knowledge in previous researches dealing with U.S. patents (e.g. Coombs and Bierly, 2006). American Patent Law enforces applicants to list relevant prior patents in filing patent applications and the information of citing patents appears in the front page of registered patents even though patent examiners may add to or delete the applicants' citations. Thus, in common researches with data of U.S. patents, it is considered that applicants already know previous patents which they cite in filing patent applications and their inventions construct on the prior arts.

However, under Japanese Patent Law, applicants don't have to list relevant prior patents while patent examiners mainly introduce patent citations. Therefore, it is seemingly difficult to treat patent citations as inventive sources in case of Japanese patents. However, technical solutions are vigorously discussed in a standardization process. Besides, it often occurs that participants actually perform their technical solutions in a standardization process, of course after patented, in order to show their technological advantages. That is, technologies adopted in technical standards are widely known among participators of standardization. As far as technologies involved in standardization, therefore, we can regard their patent citations as the flow of knowledge. Furthermore, not only in case of technologies related to standardization, patent citations based on reasons for refusal may express whether a patent application and its citing ones are in close technological trajectories or not although they don't mean the knowledge flows (Dosi, 1982). If a firm develops inventions along its continuous technological trajectory, the inventions must be technologically close to its past inventions and, therefore, own patent applications are likely to be cited as reasons of rejection. On the other hand, if a firm creates inventions built on ones of another company, the developed inventions must be adjacent to the technological trajectory of the different company and, consequently, its patent applications tend to be cited. Finally, we conclude that backward citations are available as a proxy of inventive sources even in Japanese patents.

Local Search and Beyond Local Search

Following Rosenkopf and Nerkar (2001), we set two boundaries to inventive sources. One is an organizational boundary which distinguishes own technologies from technologies of other companies and the other is a technological boundary which defines whether inventive sources of a focal patent are technologies essential for technical standards or non-essential technologies. Then, we calculate four variables; *Cit_Self-Ess, Cit_Self-nonESS, Cit_Other-Ess, and Cit_Other-nonESS*. Among patent citations which a focal patent makes for reasons of refusal, *Cit_Self-Ess* is the number of own and essential patent applications, *Cit_Self-nonESS* is the number of own and non-essential patent applications, *Cit_Other-Ess* is the number of essential patent applications hold by other companies, and *Cit_Other-nonESS* is the number of non-essential patent applications hold by other companies. As a proxy of Local Search, we adopt *Cit_Self-Ess*. Also, we select a radical searching behavior, *Cit_Other_nonESS*, as a measurement of Beyond Local Search (Figure 5).

Pioneering Approach

According to Ahuja and Lampert (2001), we define a pioneering invention as a patent which doesn't cite any prior art. Thus, we introduce a dummy variable, *No_Cit_dummy*, which becomes 1 if a focal patent doesn't cite any patent application as reasons for rejection. *No_Cit_Dummy* decides if inventions are developed through pioneering approach(Figure 5).

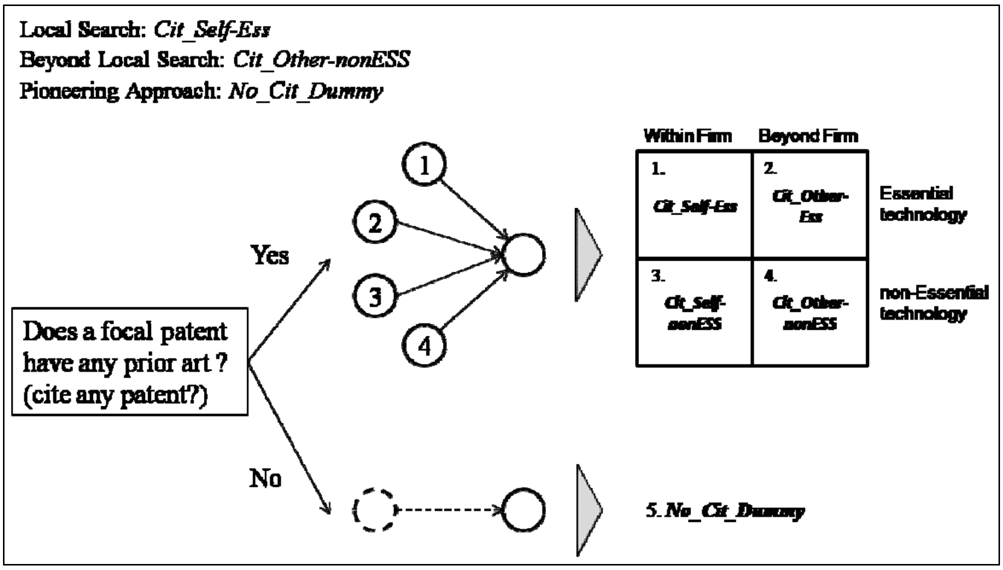

Figure 5. Proxies of independent variables: Local Search, Beyond Local Search, and Pioneering Approach

3.5 Control variables

In this research, we have to control other factors which affect "essentiality" which is the possibility whether a patent is regarded as essential or not.

It is expected that longer a period of patent revision is, higher essentiality a patent has. This is because companies, taking longer period of patent revisions, can consider progress of standardization and alter claims of a patent application to cover standardized technological scope. *Request Period* is a period from the date of filing a patent application to that of requesting its examination, measured by months.

The essentiality of a patent application can be enhanced if its content is richer and its patented scope is broader. As proxies of such aspects, we introduce *Priorities*, *Pages*, *Claims*, and *Theme Codes*. *Priorities* is the number of based priority applications, *Pages* and *Claims* are the number of page and claim when a patent application is filed, and *Theme Codes* is the number of theme codes which are Japanese original patent classifications given to a patent like IPC.

Working with many inventors may produce a better invention whose essentiality is higher. Thus, to control the factor, we employ *Inventors*, the number of inventors. In a similar way, because joint development with other organizations can affect the essentiality, we apply *Applicants*, the number of applicants where corporations in an affiliated group are counted as one organization. Besides, operating co-development with other companies perhaps provides a special positive effect to the essentiality of a patent such as improvement of political power. Thus, we introduce *Collabo-Dummy*, which is 1 if the figure of *Applicants* is more than two.

An invention attracting more attention from other companies may hold higher essentiality. As its proxy variable, *Access Times*, which is the number of times how frequently detailed information of a patent is referred to Japanese Patent Office, is introduced.

In addition, we utilize various dummy variables. To control the difference of inventions related to DVD from MPEG, *DVD Dummy* is employed, which becomes 1 if a patent application is either an essential patent of DVD 3C or DVD 6C patent pool or is connected to them in terms of citations as reasons of rejection. Furthermore, we introduce such dummy variables as *Technological Area* categorized by one-digit theme code, *Application Year* through 1981 to 2000, and *Company* consisting of Canon, Fujitsu, Hitachi, IBM, JVC, LG, Mitsubishi, NTT, Panasonic, Philips, Pioneer, Samsung, Sanyo, Sharp, Sony, Thomson, and Toshiba, whose patent applications account for most of our sample data.

Utilizing the variables given above, we conduct a logistic regression analysis to explain the essentiality of a patent, *Essential Dummy*.

4. Results and Discussion

4.1 Results

In Table 1, we show descriptive statistics and correlation matrix of scaling variables. Also, results of logistic regression are exhibited in Table 2 and Table 3. We conduct two kinds of logistic regression with different units of analysis in order to check robustness. One applies a unit of *patent application* showed in Table 2 and the other applies a unit of *registered patent* showed in Table 3. In the former analysis, we have 3207 operative patent applications all of whose variables are available and there are 679 essential patents among them. On the other hand, 1938 registered patents are used in the latter analysis, in which 616 are essential patents. Note, again, we eliminate any divisional application from all analyses and only earliest original applications are utilized.

Table 1. Descriptive statistics and correlation matrix (n=3207)

	Variable	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11
1	Request Period	55.38	27.67	0	85											
2	Priorities	0.40	0.78	0	12	-0.12*										
3	Pages	17.71	21.14	2	307	-0.05*	0.39*									
4	Claims	10.61	13.60	1	216	-0.12*	0.46*	0.45*								
5	Theme Codes	3.05	1.54	1	13	0.01	0.06*	0.12*	0.10*							
6	Inventors	2.46	1.68	1	13	-0.03	0.17*	0.25*	0.20*	0.07*						
7	Applicants	1.02	0.19	1	6	-0.02	-0.01	0.01	0.01	0.01	0.13*					
8	Access Times	0.37	1.61	0	46	-0.08*	0.05*	0.01	0.05*	0.02	0.02	0.09*				
9	Cit_Self-Ess	0.09	0.34	0	5	-0.08*	0.05*	0.05*	0.03	-0.01	0.04*	0.01	-0.02			
10	Cit_Self-nonESS	0.56	0.69	0	6	-0.06*	0.03	-0.01	0.10*	-0.03	-0.04*	0.00	-0.04*	-0.10*		
11	Cit_Other-Ess	0.28	0.67	0	9	0.06*	-0.02	0.01	0.06*	-0.03	0.06*	0.01	-0.03	0.10*	0.05*	
12	Cit_Other-nonESS	2.23	2.34	0	22	0.00	0.04*	0.02	0.09*	0.02	0.03	-0.02	-0.01	0.02	0.18*	0.15*

*p<0.05

Table 2. The result of logistic regression for the probability becoming essential patents in DVD 3C, DVD 6C, MPEG-2, and MPEG-4 Visual patent pools. The unit of analysis is *patent application.*

		Model 1			Model 2			Model 3			Model 4		
		Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.
Request Period		-0.026	***	(0.003)	-0.024	***	(0.003)	-0.025	***	(0.003)	-0.013	***	(0.002)
Priorities		0.285	***	(0.075)	0.262	***	(0.080)	0.260	***	(0.080)	0.226	***	(0.069)
Pages		0.010	***	(0.003)	0.006	**	(0.003)	0.005	**	(0.003)	0.007	***	(0.003)
Claims		0.009	*	(0.005)	0.016	***	(0.005)	0.016	***	(0.005)	0.005		(0.005)
Theme Codes		0.091	***	(0.034)	0.086	**	(0.037)	0.092	**	(0.037)	0.094	***	(0.033)
Inventors		0.141	***	(0.031)	0.160	***	(0.035)	0.163	***	(0.034)	0.207	***	(0.030)
Appliacants		0.106		(0.451)	0.134		(0.464)	0.194		(0.462)	-0.397		(0.288)
Collabo-Dummy		1.274	*	(0.682)	1.211	*	(0.714)	1.172		(0.716)			
Access Times		0.186	***	(0.038)	0.185	***	(0.036)	0.188	***	(0.037)	0.167	***	(0.033)
Cit_Self-Ess	(Local Search)				-0.657	***	(0.154)	-0.542	***	(0.154)	-0.232		(0.144)
Cit_Self-nonESS					-1.193	***	(0.108)	-1.047	***	(0.112)	-1.162	***	(0.110)
Cit_Other-Ess					-0.430	***	(0.114)	-0.366	***	(0.113)	-0.446	***	(0.106)
Cit_Other-nonESS	(Beyond Local Search)				-0.217	***	(0.030)	-0.160	***	(0.032)	-0.155	***	(0.030)
No-Cit Dummy	(Pioneering Approach)							0.706	***	(0.172)	0.508	***	(0.153)
DVD Dummy		-0.390	***	(0.146)	-0.467	***	(0.156)	-0.448	***	(0.157)	-0.022		(0.137)
Technology Area		3 Dummies			3 Dummies			3 Dummies			3 Dummies		
Company		17 Dummies			17 Dummies			17 Dummies					
Application Year		19 Dummies			19 Dummies			19 Dummies			19 Dummies		
Constant		-4.059	***	(0.566)	-2.715	***	(0.596)	-3.142	***	(0.606)	-1.046	**	(0.426)
Cox-Snell R2		0.242			0.303			0.307			0.219		
Nagelkerke R2		0.376			0.471			0.477			0.340		
N (Patent Application)		3207			3207			3207			3207		

Dependent Valiable: *Essential Dummy*
***p<0.01, **p<0.05, *p<0.1

Table 3. The result of logistic regression for the probability becoming essential patents in DVD 3C, DVD 6C, MPEG-2, and MPEG-4 Visual patent pools. The unit of analysis is *registered patent.*

		Model 1		Model 2		Model 3		Model 4	
		Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Request Period		-0.027 ***	(0.003)	-0.027 ***	(0.003)	-0.027 ***	(0.003)	-0.017 ***	(0.002)
Priorities		0.222 **	(0.090)	0.233 **	(0.094)	0.227 **	(0.094)	0.234 ***	(0.083)
Pages		0.005 *	(0.003)	0.003	(0.003)	0.002	(0.003)	0.002	(0.003)
Claims		0.008	(0.005)	0.014 **	(0.006)	0.014 **	(0.006)	0.006	(0.005)
Theme Codes		0.038	(0.039)	0.048	(0.041)	0.054	(0.042)	0.067 *	(0.038)
Inventors		0.172 ***	(0.039)	0.181 ***	(0.041)	0.182 ***	(0.041)	0.229 ***	(0.035)
Appliacants		0.567	(0.787)	0.758	(0.801)	0.783	(0.808)	-0.464	(0.319)
Collabo-Dummy		0.674	(0.988)	0.368	(1.007)	0.363	(1.013)		
Access Times		0.109 ***	(0.036)	0.130 ***	(0.034)	0.131 ***	(0.035)	0.118 ***	(0.030)
Cit_Self-Ess	(Local Search)			-0.563 ***	(0.173)	-0.497 ***	(0.173)	-0.176	(0.162)
Cit_Self-nonESS				-1.029 ***	(0.118)	-0.932 ***	(0.123)	-1.035 ***	(0.119)
Cit_Other-Ess				-0.405 ***	(0.132)	-0.355 ***	(0.132)	-0.449 ***	(0.120)
Cit_Other-nonESS	(Beyond Local Search)			-0.144 ***	(0.032)	-0.107 ***	(0.034)	-0.102 ***	(0.032)
No-Cit Dummy	(Pioneering Approach)					0.452 **	(0.183)	0.291 *	(0.165)
DVD Dummy		-0.447 ***	(0.162)	-0.471 ***	(0.170)	-0.462 ***	(0.170)	-0.017	(0.147)
Technology Area		3 Dummies		3 Dummies		3 Dummies		3 Dummies	
Company		17 Dummies		17 Dummies		17 Dummies			
Application Year		19 Dummies		19 Dummies		19 Dummies		19 Dummies	
Constant		-3.831 ***	(0.878)	-3.029 ***	(0.902)	-3.283 ***	(0.913)	-0.590	(0.480)
Cox-Snell R2		0.279		0.330		0.332		0.232	
Nagelkerke R2		0.390		0.463		0.466		0.325	
N (Registered Patent)		1938		1938		1938		1938	

Dependent Valiable: *Essential Dummy*
***p<0.01, **p<0.05, *p<0.1

In Table 2, Model 1 is a model where only all control variables are inserted. Then, in Model 2, we add four types of backward citation to Model 1. The value of Negelkerke R-squared of Model 2, which is an index of goodness of fit, becomes much higher than that of Model 1, suggesting it is appropriate to insert the four variables. Model 2 results that all types of backward citation exert significantly negative effect to the essentiality of a patent. It indicates companies have less possibility to develop inventions essential for technical standards if created inventions consist on existing technologies and any combination between own technologies, technologies of other companies, essential technologies, and non-essential technologies. Next, in Model 3, we put *No_Cit_Dummy* into Model 2. *No_Cit_Dummy* is significantly positive although all coefficients of the four sorts of backward citation have the same tendencies with those in Model 2. It suggests inventions not based on existing technologies are likely to become essential patents and the backward citations still have negative impacts to the essentiality even after we distinguish pioneering inventions among the sample patents. In addition, Model 4 is a model where we eliminate *Collabo-Dummy* and *Company* dummies so that the differences among companies are not controlled. We set Model 4 for robust check and the independent variables in Model 4 tend to affect the essentiality in the same way with those in Model 3 except for *Cit_Self_Ess*.

The results of Table 3 are almost the same with those of Table 2 as far as the independent variables are concerned. Patent applications which are finally rejected by patent examiners incline to cite more prior arts than registered patents. Therefore, with a data set including only granted patents, backward citations tend to be less frequent than with a sample of patent applications which mix finally rejected ones and registered ones. However, the results of Table 3 suggest the effects of backward citations are significantly negative to the essentiality even among only registered patents. Through the result of Table 2 and Table 3, the coefficients of independent variables are very consistent.

According to those consequences, we support *Hypothesis 3* and conclude inventions included in essential patents are developed by Pioneering Approach. At least, in units of patent application or registered patent, essential patents are gained by neither Local Search nor Beyond Local Search.

Last, we consider effects of control variables to the essentiality of a patent. *Request Period* consistently exerts a significant negative effect to the essentiality through the results of Table 2 and Table 3. Although we assume a longer period of patent revision allows patent applications to capture more scope of technological standards and to advance their essentiality, by contraries, it tends to decrease the essentiality. Indeed, inventions included in essential patents are outcomes from so pioneering R&D activities that a tiny attempt taking longer span of patent revision cannot enhance the essentiality of a patent. Richer matters in a patent positively strengthen its essentiality according to the results of *Priorities*, *Pages*, *Claims*, and *Theme Codes*. As especially, *Priorities* is positively effective to the essentiality giving the robust results in Table 2 and Table 3, companies are likely to have more essential patents by enriching their patent with more priority applications. *Inventors* also affect the essentiality in a robustly and significantly positive way in Table 2 and Table 3. In a development process involving many inventors, the combination of various bits of their knowledge can occur and produce an invention with higher essentiality. From the results of *Applicants* and *Collabo-Dummy*, developing an invention with other companies doesn't give a consistent and significant effect to its essentiality. Finally, a patent attracting more attention from other companies has higher essentiality according to *Access Times*.

4.2 Discussion

Inventions included in essential patents are developed by Pioneering Approach, in which researchers look into roots of technological difficulties, ascertain their bottom lines, and struggle with novel technical solutions to establish pioneer technology. Both types of searching behaviors don't contribute to produce inventions essential for technical standards; Local Search, which explores experienced technological area searching for technical solutions and Beyond Local Search, which explores technological fields unfamiliar to problem-solvers.

We can understand why essential patents are based on pioneering inventions, in the following way. Ahuja and Lampert (2001) argue that, in terms of technological progress and technological trajectories, pioneering inventions are risky attempts to jump from a recent technological trajectory to a distinct one. Researchers try it in hope that the new trajectory yield higher value, however, sometimes fail and jump to a technological trajectory that yields extremely lower value. The evolution of technical standards is not along a continuous trajectory but rather a disruptive trajectory which caused by radical innovations, considering the differences of technical standards such as between the cell phone systems 2G and 3G or between CD and DVD (e.g. Dosi, 1982). Besides, the technological scope of a set of essential patents is regulated and selected to cover only fundamental technologies of technical standards. Therefore, an assemblage of inventions included essential patents is a foundation of a technological standard, which is an edge point of a disruptive technological trajectory, hence, essential patents must be pioneering inventions. Indeed, as the results of our analysis show, inventions based on existing technologies are not likely to become essential patents, which means inventions along a continuous technological trajectory cannot become essential for a new technical standard.

It is presumable that although Pioneering Approach is a challenge that researchers search for technical solutions in extremely high technological uncertainty, their successes partly depend on cumulative knowledge of organizations that they belong to. Nonaka (1994) suggests organizations play a critical role in mobilizing tacit knowledge held by individuals and provide the forum for knowledge creation. Brown and Duguid (1991) argue that a close group of individuals with similar interpretative frameworks can share knowledge and create synergies to increase the overall level of knowledge. Also, as an example of empirical analyses, Quitana-Gracia and Benavides-Velasco (2008) shows companies with higher technological diversification tend to create more inventions which are not dependent to any existing technology. In this research, individual technological searches by inventors were highlighted compared to corporate technological searches because we utilized patents as a unit of analysis but not a firm unit. Thus, according to the prior researches, it is worthy to make a further research about how inventions included in essential patents, which are developed by individual Pioneering Approach, are related to the tendencies of corporate searching behaviors.

We conduct the following analysis to grasp the tendencies of searching behaviors in corporate level. First, we make a factor analysis to all scaling variables of the patent applications which we utilized above in order to contract the information.

Table 4. The result of factor analysis

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Request Period	-0.198	-0.064	0.146	-0.173	**0.732**
Priorities	**0.753**	0.021	-0.053	-0.025	-0.121
Pages	**0.766**	-0.068	0.033	-0.013	0.127
Claims	**0.784**	0.159	0.032	0.016	-0.043
Theme Codes	0.238	-0.042	-0.138	0.111	0.428
Inventors	0.407	-0.122	0.247	0.381	0.256
Applicants	-0.060	-0.016	0.117	**0.782**	0.108
Access Times	0.025	0.019	-0.207	**0.589**	-0.250
Cit_Self-Ess	0.092	-0.414	**0.572**	-0.064	-0.419
Cit_Self-nonESS	-0.016	0.183	**0.735**	0.013	0.078
Cit_Other-Ess	0.035	**0.784**	-0.047	-0.038	-0.099
Cit_Other-nonESS	0.055	**0.602**	0.403	0.009	0.005

As Table 4 shows, it results five factors whose characteristic values surpass one. Then, we focus on Factor 2 and Factor 3, which are related to the variables of backward citation. Because Factor 2 is characterized by *Cit_Other-Ess* and *Cit_Other-nonESS*, it should express how dependent inventive sources are on other companies' technologies. On the other hand, Factor 3 can be the degree of developing inventions built on own technologies because *Cit_Self-Ess* and *Cit_Self-nonESS* feature it. Thus, we can regard Factor 2 as a measure of Beyond Local Search and Factor 3 as a measure of Local Search. We calculate averages of both Factor 2 and Factor 3 with respect to each firm so that a unit is changed from a patent to a company. Then, we create a chart where a longitudinal axis is a measure of Beyond Local Search (Factor 2), a horizontal axis is a measure of Local Search (Factor 3), and the intersectional point is the average values of all companies. Finally, 15 companies which have most essential patents are plotted into the chart with the number of their own essential patents (Figure 6). Note, because patent applications based on here are mainly concerned to MPEG and DVD technologies developed around the 1990s, the computed tendency of each company is available only when we mention such technologies.

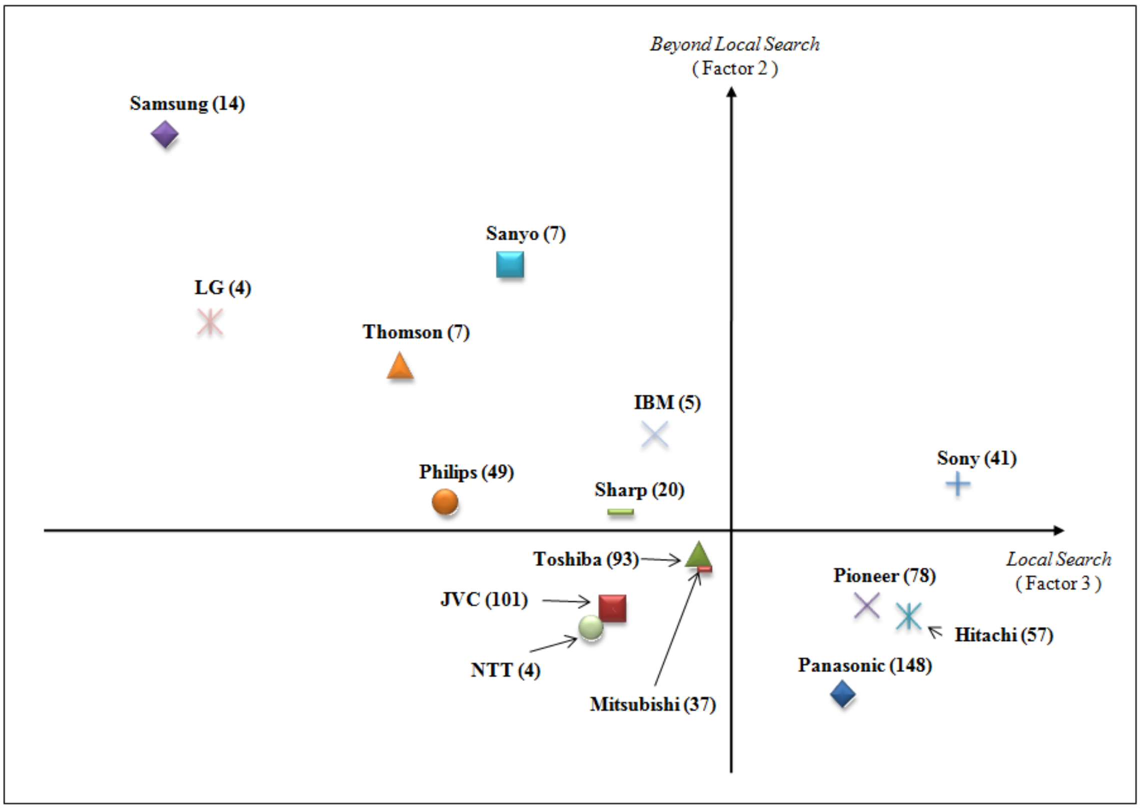

Figure 6. The tendencies of technological search in corporate level

According to Figure 6, some of companies have clear characteristic tendencies of technological searching behaviors. Hitachi, Panasonic, and Pioneer operate R&D activities based on their own technologies and have a trend of Local Search. On the other hand, Samsung, Sanyo, LG, and Thomson have a tendency of Beyond Local Search and positively absorb technological knowledge of other companies. Furthermore, JVC and NTT hold an impulse of neither Local Search nor Beyond Local Search, however, they perform inward R&D activities regarded as Pioneering Approach. Interestingly, Sony has a hybrid technological searching behavior of Local Search and Beyond Local Search.

When we consider the relationship between the number of obtained essential patents and a tendency of corporate searching behaviors, according to Figure 6, it may be said that companies in a tendency of either Local search or Pioneering Approach develop more essential patents although we don't conduct a regression analysis. Especially, firms which operate R&D in Local Search tend to gain more essential patents. That is to say, essential patents are likely developed by companies which accumulate technological knowledge and experiences in specific domains of DVD and MPEG technologies. In fact, for example, DVD-RAM, one of DVD rewritable technical standards, applied "phase-change technology" for recording and erasing data, which was a very unique method at that time. Hitachi was known to have much more technological knowledge about phase-change and developed the most fundamental technology which realized a beam system that enabled to both record and erase data only in one beam. In conclusion, although essential inventions are developed by Pioneering Approach in individual level, it seems to consist on rich knowledge in a specific technological domain accumulated by Local Search in organizational level.

At the end, companies which have strong tendencies of Beyond Local Search such as LG, Samsung, and Sanyo seem to deserve profound considerations. Especially, Samsung intensively gained essential patents in the latter process of DVD standardization through 1998 to 2000 even though Samsung had a disadvantage that it was originally not a member of DVD consortium. An effect of Beyond Local Search exerting to development of essential inventions in corporate level is an open question for future researches.

5. Conclusion

How are inventions essential for technical standards developed in terms of R&D management? This question has not been studied in detail even though the importance of technical standards has increased in perspective to competitive advantages today.

In this study, we empirically verify what kinds of technological searches produce essential patents included in DVD 3C, DVD 6C, MPEG-2, and MPEG-4 Visual patent pools. On the basis of previous studies, we adopt three types of technological searches; Local Search, Beyond Local Search, and Pioneering Approach to study essential patents in the patent pools. Through the analysis of backward citations of each patent, it is revealed that Pioneering Approach produces more inventions which become essential patents. In other words, they are developed through R&D activities in which researchers look into roots of technological difficulties, ascertain their bottom lines, and figure out novel technical solutions. Essential patents are pioneering inventions and don't depend on any existing technology, indeed, as far as on the level of inventors, they are obtained neither by Local Search which explores technological fields which are well experienced in a company, nor by Beyond Local Search in which researchers search for technical solutions in technological domains unfamiliar to them.

Furthermore, this study indicates successes of Pioneering Approach by researchers are affected by types of technological knowledge accumulated by organizations which researchers belong to. That is, types of corporate searching behaviors seem to give an impact to individual Pioneering Approach which provides essential patents. In this study, it is observed that companies with the tendency of Local Search are likely to hold more essential patents. Therefore, organizational knowledge accumulated by corporate Local Search in a technological domain essential for technical standards can support the success of individual Pioneering Approach which tends to provides inventions essential for technical standards.

In standardization process, researches have to realize that inventions possibly regarded as essential for technical standards are developed by jumping into complete technological uncertainty and struggling with roots of technological difficulties. It is almost impossible to develop essential inventions by starting researches based on familiar technologies and searching for existing technical solutions. On the other hand, managers should design R&D projects which enhance core technological capabilities in specific technological domains. This is because accumulating technological knowledge and experiences in specific technologies is likely to support pioneering attempts by researchers, which can produce inventions essential for technical standards.

However, for the sake of gaining essential patents, it is hard to show what kinds of technological domain they should construct their core capabilities on and what technologies they should strengthen. In standardization process, each of participators insists on advantages of their core technologies, but finally they need to reach a consensus about what technology they select. If a researcher who invents an extremely unique and efficient technology fails to win consent from other members, it does not lead to a technical standard. How should companies, in standardization process where political powers work, construct core technological capabilities and embed pioneering inventions deriving from the core technological capabilities into technical standards? This is an issue for future studies.

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