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Determinants of Essential Intellectual Property Rights for Wireless Communications Standards: Manufacturing firms vs. non-manufacturing patentees

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Abstract

Obtaining essential intellectual property rights (IPRs) is important for innovation competition in the network industry, where technical standardization plays a critical role in development. In this study, we empirically investigate the determinants of essential IPRs for wireless communications standards by using the patent database. More specifically, we use the technological capabilities of both the firm and the patent inventor to explain the probability of its selection as an essential IPR. In addition, we compare manufacturing firms' and non-manufacturing patentees' (NMPs) technology strategies for essential IPRs. Our results indicate that manufacturing firms accumulate their technological capability in specific technology fields, whereas NMPs cover broader technology fields to keep their dominant position in the standardization process.

Keywords: Essential IPR, Wireless communications, Technology standard,
Non-manufacturing patentee
JEL Classification: L15, L96, O32

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1. Introduction

Standardization is known to have both positive and negative effects (Tassey, 2000). It facilitates the development of a commonly accepted system, thereby achieving compatibility with complementary systems. At the same time, however, it reduces the variety of choices. When a standard is necessary in business, each company is required to properly and strategically harmonize the contradictory effects: that is, provide differentiated and specialized products while ensuring compatibility with other products. Standardization is especially beneficial for the network industry, where the interconnection of different products and system components is required for reliable services with de-jure standards such as a Global System for Mobile communications (GSM) and a Universal Mobile Telecommunications System (UMTS) in the wireless communications industry.

Once a standard is completed, the related technologies protected by patents become essential intellectual property rights (IPRs). The essential IPR concept is well defined by the European Telecommunications Standards Institute (ETSI) (2011). Essential IPRs are those without which a standardized system cannot operate. Therefore, owners of essential IPRs can take advantage of the relevant patents in their business strategies. First, essential IPRs are important for entering a market. Essential IPRs correlate positively with market power (Bekkers et al., 2002). For example, Motorola conducted exclusive cross-licensing with other parties in the GSM market, selecting only parties with valuable IPRs for Motorola. Consequently, it dominated the market. Second, owners of essential IPRs can demand royalties from use of the patents reflected in the standard. For example, although Qualcomm has a business of chipset developments such as Snapdragon, its royalties represent a considerable portion of its revenue (Mock, 2005).

Studies have identified certain key determinants in obtaining essential IPRs in wireless communications standards. The first determinant is technological advancement (Rysman et al., 2008; Layne-Farrar, 2011; Bekkers et al., 2011). For decades, forward citations have served as a proxy for technological impact (Carpenter et al., 1981; Karki et al., 1997). The interpretation of forward citation is that the more a patent is cited by follow-up patents, the more technologically important it is. Although Rysman, Layne-Farrar, and Bekkers used different data sets, they drew the same conclusion by analyzing forward citations of the given data set. Second, firm-level strategic involvement is important for standardization. Focusing on external alliances among the 3rd Generation Partnership Project (3GPP) members, Leiponen (2008) concluded that firms' external cooperative activities with standard setting organizations (SSOs) and active participation as a core member of technical committees are important for their success in the standardization process. Bekkers et al. (2011) also verified the importance of firms' strategic involvement in the standardization process by analyzing the number of participating work items in one company and voting weights in the standardization process. Third, patent filing behavior has been shown to determine whether a patent becomes essential. Berger et al. (2012) showed that essential patents contain more claims and more frequent amendments than do those that are not targeted for standardization. In addition, Berger determined that essential patents have longer pendency than have other patents. The fourth determinant is that SSOs' members adopt different strategies for standard setting because they have different histories and policies and these differences influence their capabilities (Leiponen, 2006).

Building upon previous research, this study contributes to the probing of additional, previously untested factors. First, it compares essential patent determinants between manufacturing firms and non-manufacturing patentees. The business model of a non-manufacturing patentee (NMP) aims to get their inventions reflected in the standard because licensing royalty is their only revenue source. However, a manufacturer's strategy is not as straightforward because its major revenue comes from sales of goods, which requires product differentiation. Therefore, a manufacturer uses its essential IPRs as a leverage tool for other proprietary IPRs. Second, we investigate the technological capabilities of attendees at standardization meetings and of inventors of the patent to be discussed, as well as firm-level capability. A detailed analysis of the standardization process enables us to separate the contributions of meeting attendees to essential patents from the firm-level capability described in previous research.

The structure of this paper is as follows. First, we discuss the standard setting process in detail. In Section 3, we formulate hypotheses. Section 4 describes the data set used for this analysis. In Section 5, we discuss our analysis results and verify the hypotheses formulated in Section 4.

Section 6 concludes with remarks on the future research agenda and policy implications.

2. The workflow of standardization

The workflow of standardization can be understood as a repeating cycle consisting of four phases: preparing for the up-coming standardization meeting, participating in the meetings, wrapping up the previous meeting, and the interval between two meetings (Figure 1).

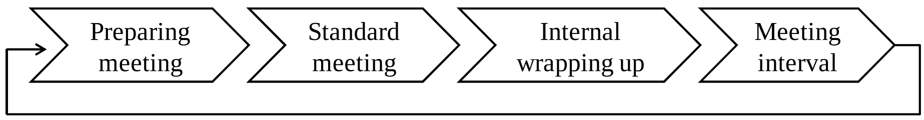


Figure 1. The workflow of standardization

The tasks required in the first phase (preparing for the meeting) include developing strategies for the next meeting, making contributions (a type of report including technical proposals and discussions), and selecting and registering the meeting attendees. Depending on the SSO, contributions for the next standardization meeting may be uploaded in this phase. If they are uploaded, other companies review them in this phase. The second phase is the standardization meeting. The length of this phase is usually one week, during which attendees from various companies/organizations gather at one place for official and unofficial discussions. Unofficial discussions in this phase include technical and strategic negotiations during break times. If necessary, one can change his/her contributions during the meeting. The standard draft is created in this phase by either consensus or voting. The rule to approve the draft varies according to the SSO's policy. In the third phase (internal wrap-up), after the end of the meeting, the meeting attendees review the results and share information with affiliated non-attendees, colleagues, and bosses. The final period—the meeting interval—is when planners develop the agenda for the next standardization meeting and conduct private discussions with other companies and organizations. These discussions can be conducted through e-mails, teleconferences, and other media or by personal visits if the geographic distance is small. The four phases repeat for each round of standardization meetings.

The most important phases for the attendees are the meeting phase and the interval phase. The reason for an attendee's importance in the "Standards meeting" phase is straightforward; the attendee represents his/her affiliation and can have direct technical and strategic discussions with those from other companies and organizations. This idea is supported by Bekkers et al. (2011), who state, "*… but many (smaller) technology decisions are made as a part of continuous negotiation processes in relatively small groups, where the participants usually know and respect each other very well and quite often see each other as friends.*" The attendee is also active in the interval phase, because he/she becomes the contact person for that phase's discussions. Such discussions may occur because attendees from different parties had unfinished discussions during the meeting or simply because the attendees know each other well from the standards meetings and want to share further ideas.

3. Hypotheses

The first hypothesis relates to core technological competencies. Because firms have different business markets, resources, histories, and research policies, they accrue different knowledge and expertise from different R&D and business experiences. Consequently, all firms obtain their core technological competencies in different technological fields. During standardization, firms with different core technological competencies develop a commonly accepted system by adopting technological proposals from each firm. However, these proposals sometimes conflict with each other because owing to their different core technological competencies, each firm wants to develop a standardized system favorable to its core technological competencies. If some standardization meeting members lack the required technology or expertise to develop a standard when that standard is successfully completed, those members must invest in new resources to obtain the required technology and know-how. However, the investment's success is not always guaranteed. From this situation, we derive the first hypothesis as follows:

Hypothesis 1. Each member firm obtains essential IPRs on the basis of its core technological competencies.

However, the wireless communications industry comprises manufacturers and NMPs. Manufacturers participate in the standardization process because they need a standardized system as a basis upon which to develop and market their products. By accumulating experience in product developments and tests, manufacturers can develop specific technological strengths. In contrast, NMPs' business model is to make profit from royalties, and so they derive value from holding economically important patents regardless of the product-market type. Therefore, it is less important for NMPs to accumulate a patent portfolio in a specific technological field than to conduct R&D in mainstream areas of the standardization development process. Consequently, we further develop Hypothesis 1 as follows:

Hypothesis 1-1. The behavior described in Hypothesis 1 is more probable for manufacturers than NMPs.

While testing this hypothesis, we need to numerically measure core technological competency. Many measurement methodologies have previously been proposed, and we use Revealed Technology Advance (RTA) and Patent Share (PS) (Patel and Pavitt, 1997). The RTA is the ratio of a patent's share in related technological fields after determining the technological distribution of all patents for which a firm has applied. A patent with high RTA is understood as highly important within a firm. In contrast, PS is the ratio of a patent's share in related technological fields after determining the technological distribution of all patents reported by the patent office. A patent with high PS is thus understood as highly important compared to other firms' patents in the same technological fields.

The second hypothesis relates to technology strategy. In the wireless communications industry, innovation occurs cumulatively, that is, the following companies enter the wireless communications market on the basis of the technology they learn (or must adopt) from the leading company's patents. For example, He et al. (2006) analyzed the backward citations among Ericsson, Motorola, Nokia, and Samsung Electronics. They found that there was knowledge flow from Motorola to others in the 1980s when Motorola was a dominant player in the market; however, the number of citations of Motorola's patents decreased in the 2000s when Nokia was a dominant player in the market. The authors concluded that the knowledge flow from Motorola to others was the key factor in others' entering the market and catching up. As knowledge spillover is important for market entry, we will test the importance of knowledge acquisition in the standardization process as well.

Hypothesis 2. Knowledge spillover is important in obtaining essential IPRs.

By using backward citations to measure learning, we categorize patents in two dimensions (Figure 2): Self/Non-self backward citations and the number of essential IPRs in the backward citations. First, we consider the knowledge flow from essential IPRs. As previously mentioned, wireless communications technologies in a standardized system have complex interrelations. The standardized system is updated as a result of unexpected technological problems or the need for new functions. When a company has a technology proposal, the proposal must be well connected to the previous version of the standard (i.e., past essential IPRs). Therefore, knowledge of past essential IPRs is expected. Second, we consider the technology strategy, that is, whether the subsequent innovation is based on its own technology or that of others. Here we predict that manufacturers and MNPs apply different strategies. As hypothesized previously, manufacturers are assumed to have greater incentives to create a patent portfolio in a specific technology area. Because their revenue model is based on product sales, even the non-essential patents that are related to essential patents are important. Therefore, it is likely that their technology strategy is to develop subsequent innovations based on their own technologies and also on both essential and non-essential patents. In contrast, NMPs may have greater incentive to maintain their dominant position in the standardization process and develop their technological capabilities in mainstream areas of technology standardization. Therefore, their strategy is to develop subsequent innovations based on essential patents, regardless of whether these are their own patents. Therefore, we have the following hypotheses about technology strategy.

Hypothesis 2-1. Both NMPs and manufacturers develop subsequent innovations based on essential patents.

Hypothesis 2-2. Manufacturers develop their subsequent innovations based on their own technologies.

Hypothesis 2-3. NMPs develop their subsequent innovations based on essential patents, regardless of ownership.

		The number of essential IPRs in backward citations?	
		> 0	= 0
Self citation of Non-self citation in backward citations?	The No. of self citations		
	The No. of non-self citations		

Figure 2. Categorizing patents backward citation category

The final hypothesis is related to inventors who attend standardization meetings. As explained in Section 2, an attendee becomes the center of discussions and negotiations in the standardization whether or not he/she intends to be so. Discussions with other parties provide the attendees with hints of what will appear in the next standardization process; therefore, they can invent whatever is likely to be required in the standard. Further, by being the center of discussions between his own affiliation and other affiliations, an attendee is required to involve his colleagues in the invention process. Our third hypothesis compares attendees and non-attendees.

Hypothesis 3. Inventors who attend the standards meeting will more likely invent a new essential IPR than will non-attendees.

Here, we further develop the discussion about attendees. The first factor considered is whether a patent is invented when its inventor was a meeting attendee. The standardization meetings have several attendees, and their experiences vary. For example, some people may have attended the meetings since the early 2000s, whereas others may have started attending only in the more recent 2000s. Some attendees participate a few times only for some months, while others participate often and for years. We argue that the patent invented by those “attending the standard meetings” has greater probability of being essential than has the patent invented by those “not attending” (Figure 3). Invention activity begins before an inventor first attends a standard meeting and continues even after the inventor stops attending meetings. However, as explained in Section 2, attendees are apt to become the center of discussions and negotiations. Among all the patents sought by an inventor, those sought when the inventor is a meeting attendee (the “attending” phase in Figure 3) reflects the technological needs derived from technological discussions and strategic negotiations. This discussion leads to our in-depth hypothesis as follows.

Hypothesis 3-1. Among all the patents sought by an inventor, those applied for when the inventor attends a meeting have greater likelihood of becoming essential.

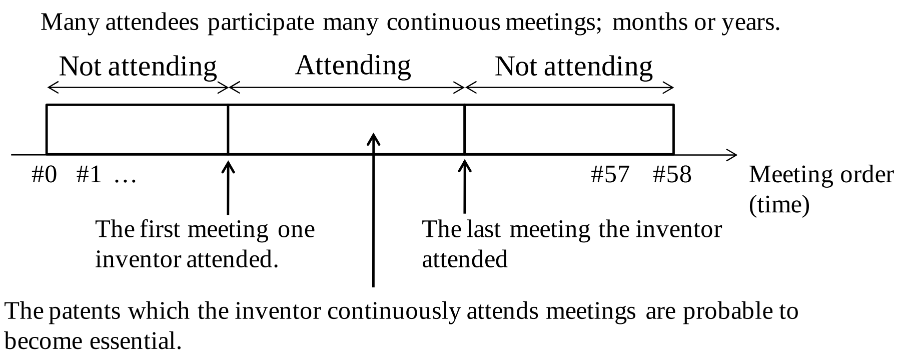


Figure 3. An inventor’s activity as a standardization meeting attendee

Wireless communications includes various technological issues (Goldsmith, 2005; Dalman et al., 2008) such as wireless channels, signal modulations, coding, multiple antenna transmissions, multiple frequency carriers, transmission power, and bandwidth. Although those technologies seem independent of each other from an academic viewpoint, they inter-relate in a complex manner when a system is being designed. Sometimes, proposed schemes in the standardization meetings have contradictory functions. In such cases, attendees must identify technological issues when developing the standard, discuss them from various technological aspects, and resolve them together through a consensus. Therefore, inventors developing a wireless standard require deep understanding of different technological issues.

Given this process that requires a consensus, an attendee must prepare various solutions to a given technological issue. As explained in Section 2, the development of a standard is a complex process of discussions and negotiations. If an attendee prepares only one solution to a technological issue, he might face difficulty in obtaining agreement because of other attendees' personal preferences for technology, operational conflicts with others' proposals, and similar issues. However, if various solutions to a technological issue are prepared, the inventor can flexibly discuss them with other attendees to reach agreement. In this study, the number of inventions within one year before the date when the originating patent was applied for is used as a proxy of the proposals that the inventor can suggest as solutions to a technological issue. Bekkers et al. found that the average delay between the patent application and essential IPR declaration to ETSI has been decreasing (Bekkers et al., 2011). In 2002, the average delay was 2.19 years. We reviewed recent standards meeting minutes of 3GPP (ftp://ftp.3gpp.org/), and confirmed that the discussion agenda changes in every meeting, and as a result few issues are discussed over the course of a year. Therefore, we use the number of inventions within one year before the date when the originating patent is applied. The hypotheses derived from this discussion are as follows.

Hypothesis 3-2. An inventor requires wider technological understanding to obtain an essential IPR.

Hypothesis 3-3. The more solutions an inventor can suggest for a technological issue, the greater probability he has of obtaining an essential IPR.

For Hypothesis 3-2, we use generality (Trajtenberg, et al., 1997) as a proxy of an inventor’s breadth of technological understanding. The authors defined generality as how the follow-up technical inventions spread across different technical fields. If the generality is large, the technical advances from the originating invention are broad and the original invention covers different technological issues. In this study, the average generality of all inventions from an inventor serves as a proxy of the inventor’s breadth of technological understanding. For Hypothesis 3-3, we use the number of inventions within one year before the date when the originating patent was invented as a proxy of the number of solutions that one meeting attendee can propose.

Designing a system is a type of invention. Many inventions in various categories are necessary for a system to operate. Inventors must identify conflicting functions and properly redefine them when developing a system. In this context, a patent is a proxy for technological activities. Patent application for an invention serves to verify the invention's novelty and utility in the US patent law (the industrial applicability in European patent law). If an inventor has applied for more patents than have others, that inventor is considered to have greater ability and expertise to invent useful things. Similarly, a standards meeting attendee with more patent applications is believed to have greater ability and knowledge for developing a wireless communications system. As a person's ability increases with his experience as an inventor, we assume that the attendee's ability and knowledge as an inventor (i.e., a system developer) increases with his inventing experience. We focus on the counting number of patent inventions before the originating patent application that becomes an essential IPR. By using this number as a proxy for an attendee's experience as an inventor, we test whether invention experience affects the attendee's probability of obtaining an essential IPR designation. Consequently, the fourth hypothesis to test in this study is as follows.

Hypothesis 3-4. An attendee with more invention experience has a greater probability of obtaining essential IPRs.

4. Data

To quantitatively test our hypotheses, we use reports from the ETSI, 3GPP, and the European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT). We use the ETSI data for several reasons, the most important and critical reason being that ETSI has constructed a very large and publicly available database for essential IPRs and their policies (ETSI, 2012). Because there are many standard projects and as a result the corresponding patents are numerous, we narrow the project to only UMTS patents.

4.1. Patent dataset

The patent database for this research is taken from the EPO's PATSTAT. We limit the patent dataset applied to the US Patent and Trademark Office (US PTO) for several reasons. The first reason is that in US patent applications, an applicant must provide prior references, either patent or non-patent literature. Alcacer et al. (2009) showed that all citation information is added by examiners in 40% of all patents registered in US. Therefore, the knowledge flow that, unintentionally or not, could not be provided by applicants is added by examiners. The second reason relates to the significance of the US market. Patent applications are subject to a tradeoff between dominance and cost. Because of the US market's global significance, companies doing business in global markets apply for patents in the US, taking the risk of high cost. This situation may lead one to question the proportion of domestic citation. Michel and Bettels (2001) found that more than 90% of patent citations in the Japan Patent Office (JPO) and the US PTO are from domestic references, and more than 90% of patent citations in the EPO are from EP, US, WO, DE, and GB. However, as will be seen, companies selected in this study are highly globalized and would not undervalue the applications in the US PTO, especially when a patent is economically important. Layne-Farrar (2011) confirmed that the number of patents applied to the US PTO is overwhelming compared to that of patents applied to the EPO. For these reasons, we use only patents applied for in the US PTO.

We further narrow the dataset by application years. According to Bekkers (2011), the oldest essential patents were applied for in 1979; therefore, we extract the patent dataset of applications beginning in 1979. Further, the most recent application year available in the version of our patent database is 2009; hence, our dataset contains those patents applied for between 1979 and 2009.

To extract patents relevant to standardization, the dataset is further filtered by the international patent classification (IPC). The UMTS consists of three parts: air interface, radio access network, and core network. We focus on air interface because it has the greatest portion of patents (Goodman and Myers, 2005). We filter our dataset using the following IPCs related to air interface: H1Q, H03M, H04B, H04H, H04J, H04K, H04L, H04N 01, H04Q, and H04W. By using these IPCs, we can narrow the dataset to only air interface-related technologies. We confirmed that nearly 95% of essential IPRs in the UMTS are in these categories. This method has been verified by Bekkers and

West (2009), whose study uses nearly the same IPCs. The difference is that we further narrow our IPCs down only to air interface-related technologies.

Finally, we use only four companies among the 3GPP members. The main reason that we use these four companies is the portion of essential IPRs owned by those companies in our patent dataset. Details will be explained in Section 4.2. The patent searching conditions are summarized in Table 1.

(Table 1)

Through this method, we obtained 30,334 patent applications. The number applications owned by each company is shown in Figure 4. Among these, Samsung Electronics holds the highest number of patent applications (10,571). One reason for this result is that the IPCs used in this study include other wireless communications in addition to cellular systems, such as television. As a consumer electronics company, Samsung Electronics has a broad business area that includes the television market. InterDigital holds the smallest number of patent applications (3,193), which is less than one third of Samsung Electronics' applications. Although it has the smallest number of patent applications, InterDigital is one of the largest essential IPR holders. Their efficiency in obtaining essential IPRs (= the number of essential IPRs/the number of patent applications) is very high. Although the numeric values differ, we find a tendency similar to the analysis shown in Bekkers and West (2009).

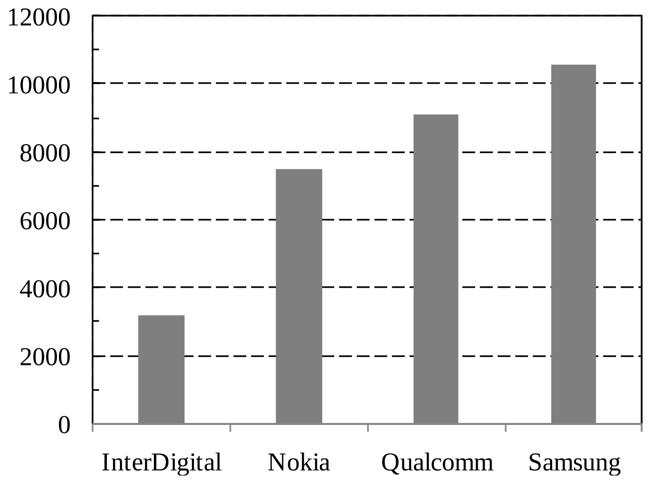


Figure 4. The number of patents owned by the four companies

Figure 5 depicts the four companies' numbers of annual patent applications to the US PTO. Although we took the patent dataset from 1979, the applications of the four companies started in 1988. Nokia and Samsung Electronics show a similar tendency: their peak of patent applications is in 2004 and 2005, after it decreases. However, Qualcomm's patent applications continuously increase through 2009. Compared to Nokia and Samsung Electronics, Qualcomm's applications significantly increase beginning in 2004. InterDigital's patent applications fall slightly in 2009 but gradually increase thereafter. One explanation for InterDigital's and Qualcomm's increase and Nokia's and Samsung Electronics' decrease is our using patent applications to the US PTO. Nokia and Samsung Electronics are Finland- and Korea-based companies, respectively, whereas both InterDigital and Qualcomm are US-based. InterDigital's and Qualcomm's patent applications to the US PTO are domestic, but Nokia's and Samsung Electronics patent applications to the US PTO are foreign. Therefore, there might be uncounted patent applications to the US PTO for Nokia and Samsung Electronics which were applied to in their home country's PTO as the first patent application and therefore not listed in the US PTO. A second explanation for the result seen in Figure 5 relates to the Qualcomm and InterDigital business models. In Qualcomm's success in business, code division multiple access (CDMA)-based technology was very important (Mock, 2005). In broadband CDMA (WCDMA), 15.4% of IPRs essential to WCDMA are CDMA-based technologies (Goodman and Myers, 2005; Lakoff, 2008). Even now, when Qualcomm is developing chipsets such as Snapdragon, its main revenue comes from royalties. InterDigital's business model is also to hold essential IPRs in the standard and license those to other companies without manufacturing any products. This figure supports the idea that success in standardization is crucial for Qualcomm and InterDigital. This fact is further supported when compared to the numbers of essential IPRs and patent applications in Section 4.2. In addition, there are unexpected results. One is that between 2003 and 2007, Samsung Electronics applied for many more patents than did the other three companies. The other surprising result is that Nokia's patenting activity has decreased markedly since 2004. Nokia's patent applications in 2009 are roughly a quarter of its 2004 patent applications. These findings merit further analysis, but that analysis exceeds the scope in this study.

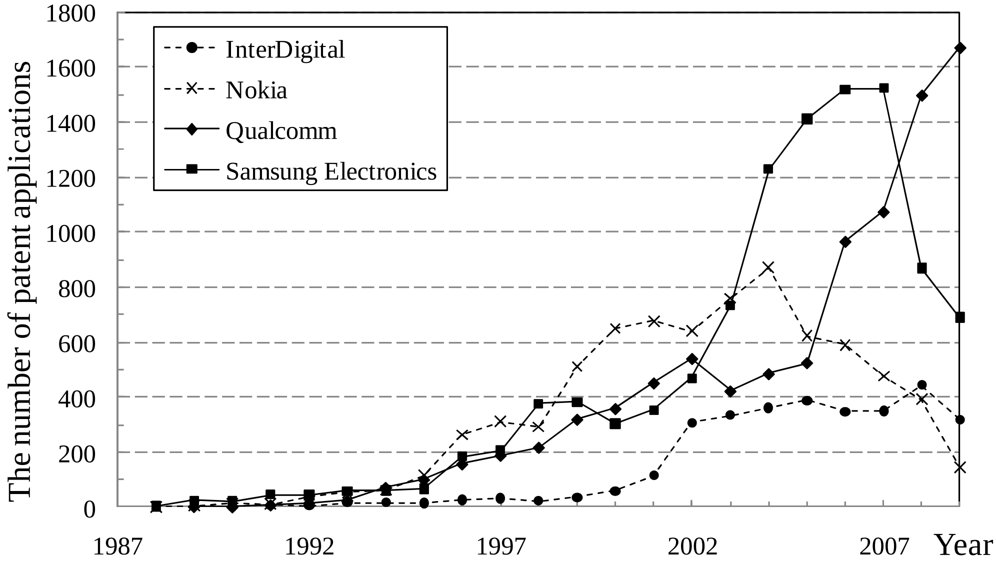
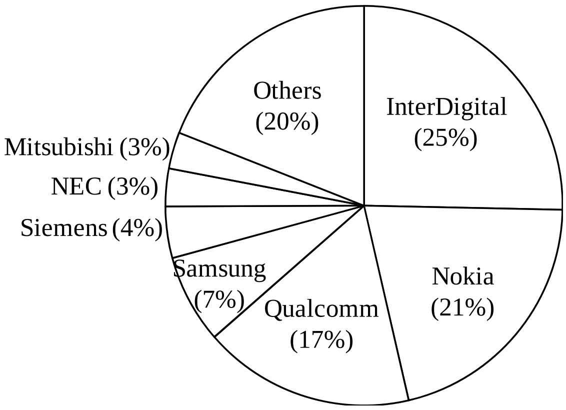


Figure 5. The number of annual patent applications

4.2. Essential IPR

ETSI has defined IPR policy, and it asks its members to inform it of their essential IPRs (ETSI, 2012). Twice a year, ETSI updates and reports the list of essential IPRs in the ETSI Special Report 000314 (ETSI, 2011). ETSI SR 000314 provides information that includes patent application number, patent publication number, patent title, patent office, declaring company, IPR declaration date, and projects to which the essential IPRs belong. We identify essential IPRs in our dataset by matching US publication numbers to those reported to ETSI. Figure 6 depicts the UMTS essential IPRs holders' portions. The latest ETSI SR 000314 (ETSI SR 000314 V2.10.1, published in June 2011) reports 42 companies holding a total of 2749 essential IPRs for UMTS, 1860 of which are included in our dataset. Among the 1860 essential IPRs, InterDigital, Nokia, Qualcomm, and Samsung Electronics hold roughly 70% of essential IPRs.



(Total: 1860)

Figure 6. The portions of essential IPRs in our dataset

Bekkers and West (2009) analyzed the UMTS essential IPR ownership in detail by using the relevant data through 2005. They compared essential IPRs in GSM and UMTS. One of their contributions found that the number of essential IPRs in UMTS increased approximately 8.8 times more than that of GSM. UMTS is known to have its roots in GSM. In fact, Bekkers and West's result implies that many UMTS innovations have achieved higher throughput in UMTS. The authors also identified the concentration of essential IPRs ownership. Although the share of GSM essential IPRs in the top four companies (eight companies) was 52.1% (72.9%), the share of UMTS essential IPRs in the top four companies (eight companies) was 72.4% (90.5%). In Figure 6, the top four companies' share in our dataset is 70%. Thus, the general tendency seen in our dataset is the same as seen in their dataset.

In Section 1, we noted that technological advancement measured by the number of forward citations is a key factor for a patent to be deemed essential. Previous studies by Rysman et al. (2008) and Bekkers et al. (2011) derived this conclusion through analyzing forward citations. However, they do not clearly state whether the forward citation increases after a patent is publicly deemed essential. Jaffe et al. (2000) sent survey questionnaires to inventors to understand the knowledge flow between the inventors of sampled patents and those of the patents cited by the sampled patents. They found that 60% of the inventors were unaware about the patents that they cited before or while working on the invention. One issue is whether the number of forward citations of essential IPRs increases because the essential IPRs are publicly known by their owners' declaration. This issue should be clarified before analyzing forward citations of essential IPRs because if the number of forward citations increases after the originating patent is publicly known as essential, using the forward citations as an indicator of technological significance may be controversial.

Figure 7 presents the comparison of the annual number of forward citations. We searched all the forward citations of all essential IPRs. In Figure 7, we set the date when a patent is declared essential as Year = 0 and then recalculated the application date when the forward citations occurred. Figure 7 shows that more than 70% of forward citation occurred before essential IPRs were publicly known as essential. Many forward citations cited these patents 2–4 years earlier than they were declared essential. The earliest forward citation occurred nearly 15 years before its cited patent was declared essential. The application date used in Figure 7 is the US application date. Considering that the actual priority date is earlier than or equal to US application date, the ratio of forward citations before publicly declared essential IPRs is expected to be higher. Therefore, we can infer that the number of forward citations does not increase because the patent is officially known as essential.

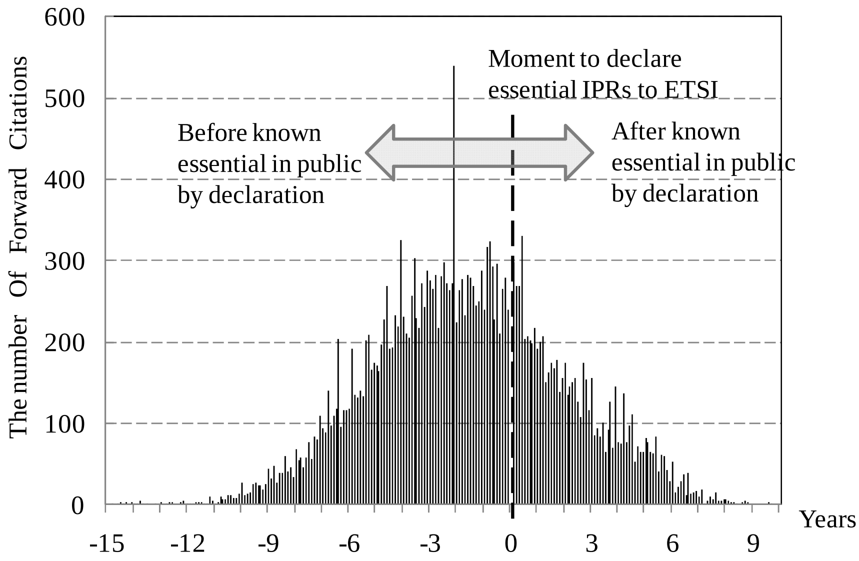


Figure 7. The number of essential patents' forward citations before and after the declaration of essential IPRs to ETSI.

4.3. Meeting attendees

Like the ETSI database, the 3GPP database is also publicly available (ftp://ftp.3gpp.org/). In the 3GPP database, we can find not only specifications for all 3GPP communications standards but also meeting information such as technical contributions, meeting minutes, and attendee information. We extracted all the attendee information in the 3GPP Radio Access Network Working Group 1 (RAN1).

Before describing the attendee information, we explain the 3GPP organization structure to improve the understanding of this research. The 3GPP comprises three levels of decision bodies. The highest of these is the Project Coordination Group (PCC), which meets once every six months to decide on the final adoption of 3GPP Technical Specification Group work items, ratify election results, and determine the resources committed to 3GPP. Under the PCC, there are Technical Specification Groups (TSGs) that decide the definition of the functions, requirements, and interfaces. Each TSG has Working Groups (WGs), one of which is RAN1. 3GPP RAN1 is responsible for the specification of the physical layer of the radio interface and is where technological discussions and negotiations between attendees take place.

In this study, we use the meeting attendees' information from 3GPP RAN1's first meeting (January, 1999) through its 58th meeting (August, 2009). We use information through only the 58th meeting, because our patent database covers only to 2009. The attendee information from the 3rd, 4th, and 5th meetings is missing. Figure 8 depicts the number of attendees from the first through 58^{th} meetings. The number of attendees is nearly constant until the 40th meeting and significantly increases thereafter. The 58th meeting had 310 delegates. From this fact, we can assume that the standardization process has become more complex and competitive. The EPO PATSTAT provides inventors' information on patent applications. By manually matching inventor's names with the meeting attendees, we identified the inventors of patents from the meeting attendees' lists. First, EPO PATSTAT, in some cases, allocates different Inventor IDs to the same name because of reasons such as the abbreviations in inventors' names, the difference of capital and small letters in the names, inconsistent inclusion of middle names. Second, the table format for the 3GPP meeting attendees' list is not defined and was especially inconsistent in the early 2000s. After all the manual name-matching tasks, we removed statistical "noise" and obtained about 280 attendees matching our data set described in Section 4.1.

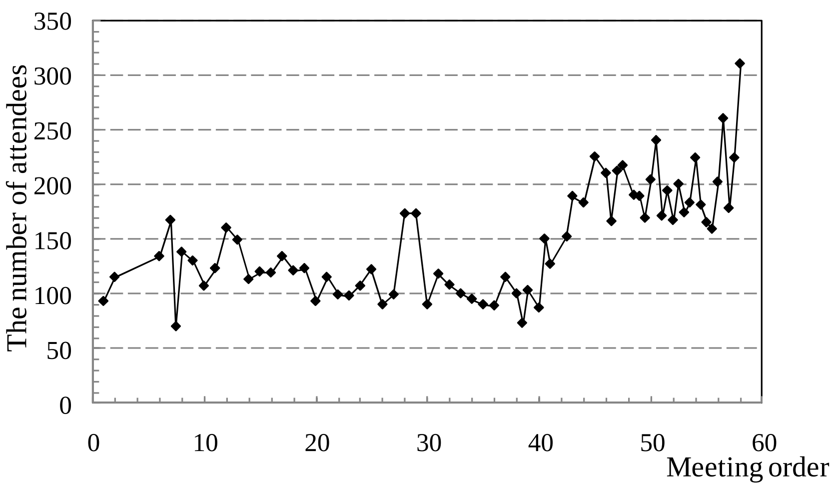


Figure 8. The number of attendees in 3GPP RAN1

Before performing the regression, we compared certain characteristics of attendees and non-attendees. The first comparison is the probability of one patent being essential. We set 1 if a patent was an essential IPR and 0 if not. We averaged all patents by attendees and non-attendees and compared them. The result is shown in Figure 9. The patents invented by attendees are threefold more likely to become essential that those by non-attendees. We also averaged the patents of each company on the same criterion, and that probability differed by company. However, in all cases, inventions by attendees have a higher probability of becoming essential than do those by non-attendees.

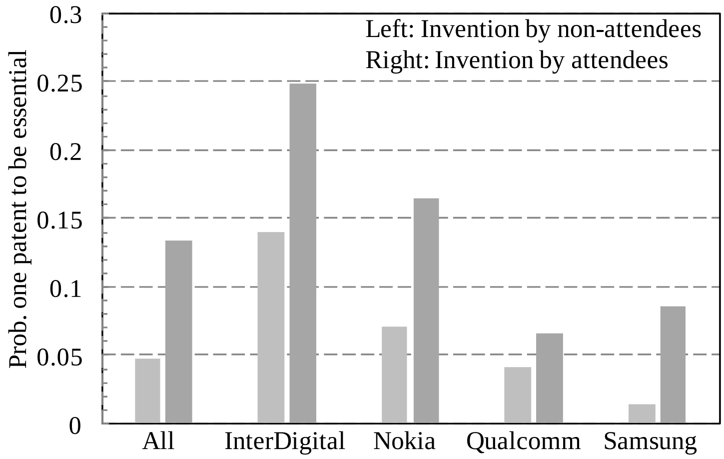


Figure 9. Comparison 1: A patent’s probability of becoming essential

In Figure 10, we compare the number of forward citations between attendees’ and non-attendees’ patent applications. As will be explained in Section 5.1, we must be careful when using the number of forward citations. Older patents tend to have more citations than newer patents. Instead, we use the relative number of forward citations, obtained by dividing the number of forward citations by the average number of forward citations from the same technological categories and the same application year. Figure 10 shows that the number of forward citations is higher for attendees’ patent applications. The gap differs for each company, but all four companies show the same general result. This consistent result suggests that attendees have more technological understanding and more technologically productive inventions than do non-attendees, and as a result they create more technologically important inventions.

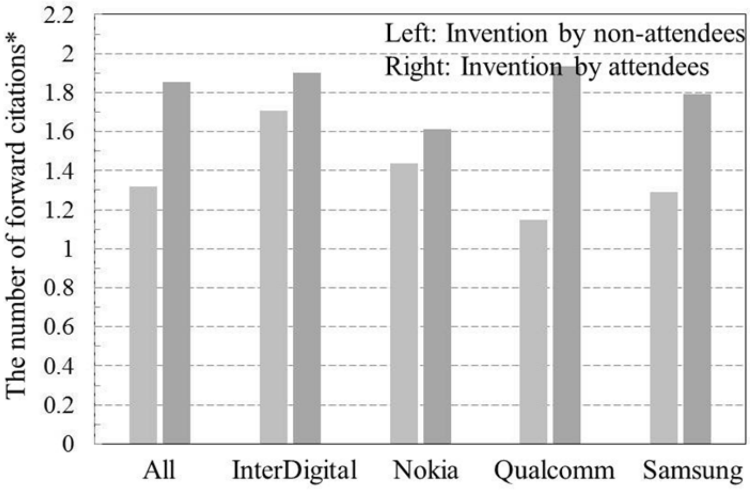


Figure 10. Comparison 2: The number of forward citations* (the number of forward citations divided by the average number of forward citations from the same technological categories and the same application year)

Figures 11 and 12, respectively, compare generality and originality (Trajtenberg et al., 1997). As previously mentioned, generality is defined as how the follow-up technical inventions spread across different technical fields. If one patent is cited in various technological fields (i.e., high generality), the patent's applicability to diverse technological fields indicates that it is fundamental and basic. In contrast, originality is defined as how the back-up technical inventions spread across different technical fields. If a patent cites various technological fields (i.e., high originality), the patent accumulates less specific technology, which indicates that it is "something new." As seen in

Figures 11 and 12, the difference between attendees and non-attendees shows a slight gap (much less than 10%) in generality and originality.

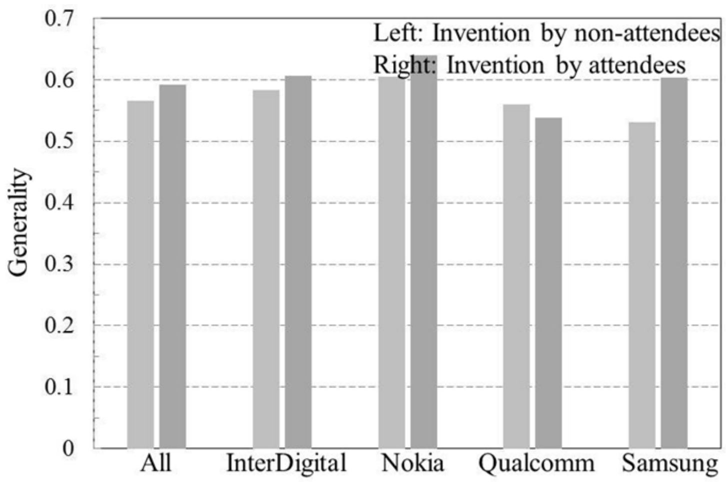


Figure 11. Comparison 3: Generality

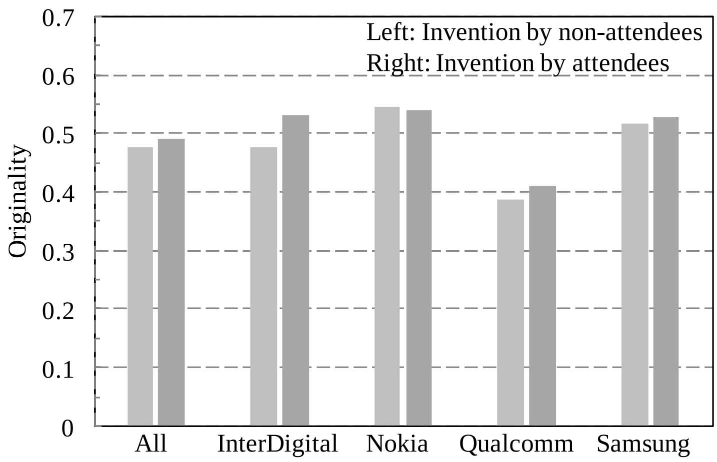


Figure 12. Comparison 4: Originality

5. Results and Discussion

5.1. Regression results

Hypotheses 1, 2, and 3 are tested in this section. The dependent variable is whether a patent application is declared essential. If a yes, the dependent variable equals 1; otherwise, 0. The first independent variables to test Hypothesis 1 are RTA and PS. Both RTA and PS are calculated in the IPC subgroup unit. In most cases, a patent has more than one IPC; and therefore, we calculated the RTA and PS of each patent application in all member IPC subgroups and took the average. We added two interaction terms by multiplying the Manufacturer dummy. The second independent variables to test Hypothesis 2 are the number of essential IPRs in backward self-citations (Back EIPR Self), the number of non-essential IPRs in backward self-citations (Back NonEIPR Self), and the number of essential IPRs in backward non-self-citations (Back EIPR NonSelf). We added the interactions term by multiplying the Manufacturer dummy. The third independent variable to test Hypothesis 3 is "Invention by Attendees," which equals 1 if any meeting attendee is found among the inventors in the patent of interest; otherwise, 0.

This analysis uses several control variables with the independent variables. The first control variable is the number of "Non-essential IPRs in Backward Non-Self citations" (Back NonEIPR NonSelf) together with its interaction term obtained by multiplying the Manufacturer dummy. This term is for the comparison with the other knowledge spillovers mentioned in Hypothesis 2. The second control variable is "The Number of Forward Citations." Several points merit discussion when measuring the technological significance by using the number of forward citations. First, it is now an accepted fact that the number of (either forward or backward) citations varies by technology field and application year (Nagaoka et al., 2010). Second, there is a time effect: newer patents have less probability of being cited by others compared to older patents. To overcome these limitations, we calculated the relative number of forward citations, obtained by dividing the number of forward citations by the average number of forward citations from the same IPCs (H1Q, H03M, H04B, H04H, H04J, H04K, H04L, H04N 01, H04Q, H04W) and the same application year. In addition, for fair comparison, we considered only non-self-citations. The remaining control variables are Originality, the Number of inventors, the Manufacturer dummy, and the Prior Application year dummy (Year dummy in Table 2). The value of the Manufacturer dummy is set to 1 if the inventor's affiliation is either Nokia or Samsung Electronics; otherwise, 0. The value of the Year dummy is set to 1 according to the prior application year of each patent application.

Before moving to analyses, note that the number of observations, N, is less than 30,334. Because we used patents applied for only to the US PTO, certain independent variables (Generality, Originality, Number of essential IPRs in backward citations, and Relative forward citations) are derived from US PTO-to-US PTO patent citations. The patent applications that have citations of non US PTO-to-non US PTO are not used to estimate regression.

Our analysis uses the probit regression model, and the result is shown in Table 2, with the coefficients and t statistics of each independent variable. First, RTA has positive effects and statistical significance at the 1% level in all regression models, whereas PS has the same tendency in only few models. However, the interaction terms with the Manufacturer dummy, “Manufacturer x RTA” and “Manufacturer x PS,” have positive effects and statistical significance at the 1% level in all regression models. The slope shift due to the interaction term is positive, implying that manufacturers’ essential IPRs are influenced by their core technological competencies measured by RTA and PS. As a result, Hypothesis 1 is supported for manufacturers.

Second, we analyze Hypothesis 2. Both “Back EIPR Self” and “Manufacturer x Back EIPR Self” have positive effects and statistical significance at the 1% level in all regression models. Learning from a manufacturer’s own essential IPRs had an effect on obtaining new essential IPRs. Hence Hypothesis 2-1 is supported. “Back NonEIPR Self” has a negative effect and statistical significance at the 1% level. That is, knowledge from the manufacturer’s own non-essential IPRs negatively influenced obtaining new essential IPRs. However, “Manufacturer” = 1, the coefficient of “Manufacturer × Back Non-EIPR Self” is positive and has statistical significance at the 1% level. This result must mean that manufacturers did not develop their subsequent innovations on the basis of their non-essential IPRs but essential IPRs, so that Hypothesis 2-2 is also supported. “Back EIPR NonSelf” has a positive effect and statistical significance at the 1% level whereas “Manufacturer × Back EIPR NonSelf” does not. This result is understood to mean that for NMPs, knowledge from others’ essential IPRs influence obtaining essential IPRs. Thus, Hypothesis 2-3 is supported. Overall, Hypothesis 2 is supported.

		The number of essential IPRs in backward citations?	
		> 0	= 0
Self citation of Non-self citation in backward citations?	The No. of self citations	General: + Manufacturer: +	General: − Manufacturer: +
	The No. of non-self citations	General: + Manufacturer: No statistical significance	General: + Manufacturer: −

Figure 13. Result of knowledge spillovers

Finally, “Invention by delegates” has a positive effect and statistical significance at the 1% level in all regression models. Invention by meeting attendees is found important in obtaining essential IPRs. Therefore, Hypothesis 3 is supported.

Additionally, analysis of several of control variables provided interesting findings. First, we observed that the Manufacturer dummy variable has a negative effect, but this result should not be understood to imply that not manufacturing companies need not hold essential IPRs. The data set used in this regression model has only two types of companies: manufacturing companies and NMPs. If Manufacturer = 0, the dummy variable indicates NMPs. Therefore, this result should be interpreted as implying that it is important for manufacturing companies to hold essential IPRs, but it is more important for NMPs to hold essential IPRs. Second, we need to explain the effect of “Back NonEIPR NonSelf.” “Back NonEIPR NonSelf” has a positive effect and statistical significance at the 1% level (Figure 13). Nevertheless, owing to the negative effect of “Manufacturer × Back NonEIPR NonSelf,” the coefficient becomes negative due to the slope shift under Manufacturer = 1. Therefore, the knowledge spillovers from others’ non-essential IPRs are positively effective for NMPs and negatively effective for manufacturers. On the basis of the conclusions obtained from other parameters of knowledge spillovers, we can infer that knowledge spillover from its own non-essential IPRs is not beneficial for manufacturers in obtaining essential IPRs.

(Table 2)

5.2. In-depth analysis of attendees

Hypotheses 3-1 to 3-4 are tested in this section. We performed analysis from the individual inventor’s viewpoint. The dependent variable is whether a patent application is declared as essential. If yes, then the dependent variable equals 1; otherwise, 0. The first independent variable is “Invention when the inventor acts as a meeting attendee (Hypothesis 3-1),” and is used as a dummy variable. If the patent was applied for when its inventor was a meeting attendee, then this independent variable equals 1; otherwise, 0. Because we are using patents applied for to the US PTO, the application date to the US PTO may not be the original date. Therefore, to have an accurate invention date, we use the priority date only for this independent variable. The second independent variable of interest is the impact of an attendee’s breadth of technological understanding (Hypothesis 3-2). As explained in Section 3, this is proxied by the average generality of all the patents for which each inventor applied. The third independent variable is used to test the number of solutions that an attendee can use for strategic discussions (Hypothesis 3-3). This is proxied by the number of inventions within one year before the date when the originating patent was invented. The last independent variable is an attendee's experience as an inventor (Hypothesis 3-4). The number of patent inventions for the originating patent application serves as a proxy. Other variables are used as control variables.

Our analysis used the probit regression model, and the result is shown in Table 3,with the coefficients and t statistics of each independent variable. As we mentioned earlier, the independent variables of interest are "Invention when an attendee acts an inventor," "Average Generality of an attendee," "the number of patents applied for within one year before the application for the originating patent," and "the number of patents applied for before the originating patent is applied for." Among these four variables, only "Invention when an attendee acts an inventor" is positive and has statistical significance at the 1% level in all regression models. The other independent variables do not have statistical significance in all regression models. Hence, only H3-1 is supported. This implies that the most important factor is the invention for the standard having been created while its inventor is actively participating in the standardization discussion.

(Table 3)

6. Conclusions and policy implications

Interest in essential IPRs has been increasing in the wireless communications industry. Studies have sought the determinants for obtaining essential IPRs. In this study, we focused on previously untested items. First, we tested the effect of core technological competencies on essential IPRs. We measured core technological competencies by introducing RTA and PS. RTA represents core technological competency compared to other technological competencies within a company, and PS represents core technological competency compared to other companies' competencies. We found that these parameters are positively effective, especially for manufacturing companies. As a result, we can conclude that it is important to obtain essential IPRs derived from a company's core technological competency. Second, we analyzed the difference in technology strategy between manufacturers and NMPs. We divided the types of backward citations of patents on two dimensions: whether cited patents are essential IPRs and whether citations are made to a firm's own patents. We found that subsequent innovations by manufacturers are based on their own technologies, regardless of whether they are essential patents. By contrast, those by NMPs are based on essential patents, regardless of whether they are their own patents. Finally, we tested the effect of the inventor's attending a standards meeting on his patent's becoming an essential IPR, which is the core contribution of this study. For the analysis, we used 3GPP RAN1's attendees list from the first through 58th meetings, together with a patent database and essential IPR list. By comparison with the patent statistics of non-attendees, we found that (1) patents invented by attendees are more likely to be essential than those by non-attendees, and (2) patents invented by attendees have more forward citations than do those by non-attendees. The regression analysis proved that inventors' involvement in the standardization process as meeting attendees is the most important factor in obtaining essential IPRs.

This study also suggests that some differences exist between the technology strategies of manufacturers and non-manufacturing patentees. A policy goal of standardization is to stimulate innovations by establishing common technology bases on which firms fairly compete. Both manufacturers and NMPs contribute to this process, but we found that manufacturers focus more on subsequent innovations based on the standards, whereas NMPs contribute more to upgrading the technology standard itself. In this sense, manufacturers and MNPs complement each other. However, to facilitate the process, licensing requirements for essential IPRs, such as the RAND condition, must be implemented strictly. In addition, manufacturers tend to have fewer incentives for listing their patents as essential IPRs than do NMPs because non-essential IPRs that differentiate their products generate significant revenue. Therefore, this study suggests that standards organizations devise a policy providing an appropriate incentive design for manufacturers to contribute to the standardization upgrading process.

Another major contribution of this study is providing evidence of the complementarity between standardization and invention activities, by observing these activities at the inventor level.

Participation in standardization meetings, as well as informal discussions with researchers from other firms (competitors in the product market) serve as an important information channel. A standardization meeting is not only a place for negotiating technology standards but also a forum for open innovation through information exchange among standardization participants. Therefore, this study suggests that such information is highly useful for a firm's technology strategy planning, including external R&D collaborations, as a matter of corporate policy.

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Table 1. Patent searching conditions

Patent Database	EPO PATSTAT (Ver. September 2010)
Patent Office	US PTO
Application Years	1979–2009
IPC	H1Q, H03M, H04B, H04H, H04J, H04K, H04L, H04N 01, H04Q, H04W
Company	InterDigital, Nokia, Qualcomm, Samsung Electronics,

Table 2. Probit Regression 1. Dependent variable: Essential IPR (= 1), Non-Essential IPR (= 0)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
RTA	0.3874			0.1925	0.2293	0.1521	0.1717	0.1614	0.1683	0.2048	0.2011	0.2069
	[24.41]***			[8.53]***	[9.61]***	[5.32]***	[6.00]***	[5.40]***	[5.15]***	[6.19]***	[5.93]***	[6.09]***
PS	0.0133			0.0054	0.0142	0.0011	0.0111	0.0075	0.0106	0.0124	0.0164	0.0153
	[3.47]***			[0.88]	[2.18]**	[0.16]	[1.51]	[0.91]	[1.12]	[1.28]	[1.65]*	[1.54]
Back EIPR Self		0.1359		0.125	0.1361	0.1495	0.1399	0.1249	0.0985	0.0979	0.0917	0.0914
		[10.47]***		[9.28]***	[9.91]***	[9.76]***	[9.00]***	[7.93]***	[6.10]***	[5.99]***	[5.64]***	[5.62]***
Back Non-EIPR Self		-0.0269		-0.0194	-0.0247	-0.1332	-0.1535	-0.1162	-0.1388	-0.151	-0.1746	-0.1723
		[-2.24]**		[-1.62]	[-2.05]**	[-5.33]***	[-6.16]***	[-4.63]***	[-5.38]***	[-5.73]***	[-6.56]***	[-6.49]***
Back EIPR Non-Self		0.2633		0.227	0.2252	0.2179	0.1705	0.1504	0.1593	0.158	0.1487	0.1508
		[25.76]***		[21.56]***	[21.43]***	[17.05]***	[12.41]***	[10.84]***	[10.48]***	[10.46]***	[9.87]***	[9.99]***
Invention by Attendees			0.6901	0.4951	0.5187	0.5426	0.5371	0.5981	0.5647	0.5538	0.5433	0.5195
			[26.11]***	[12.56]***	[12.98]***	[13.26]***	[13.04]***	[13.82]***	[12.31]***	[11.94]***	[11.34]***	[10.60]***
Manufacturer dummy						0.3373	0.318	0.3434	0.3685	0.3299	0.3322	0.3213
x RTA						[6.04]***	[5.70]***	[6.03]***	[6.04]***	[5.33]***	[5.15]***	[4.97]***
Manufacturer dummy						0.1168	0.1059	0.1228	0.1253	0.1194	0.1186	0.1165
x PS						[6.42]***	[5.79]***	[6.49]***	[6.02]***	[5.61]***	[5.41]***	[5.30]***
Manufacturer dummy						0.3345	0.344	0.3758	0.4141	0.4174	0.4223	0.4259
x Back EIPR Self						[5.77]***	[5.93]***	[6.35]***	[6.62]***	[6.61]***	[6.68]***	[6.74]***
Manufacturer dummy						0.1061	0.1289	0.0796	0.0994	0.1079	0.1301	0.1279
x Back NonEIPR Self						[3.69]***	[4.48]***	[2.72]***	[3.30]***	[3.51]***	[4.21]***	[4.15]***
Manufacturer dummy						0.0023	0.0526	0.0412	0.0309	0.0277	0.0382	0.0341
x Back EIPR NonSelf						[0.10]	[2.26]**	[1.75]*	[1.25]	[1.12]	[1.53]	[1.36]
Back NonEIPR NonSelf							0.0144	0.0135	0.012	0.0113	0.0092	0.0089
							[8.36]***	[7.75]***	[6.54]***	[6.14]***	[4.89]***	[4.74]***
Manufacturer dummy							-0.0173	-0.0131	-0.0133	-0.0133	-0.0129	-0.013
x Back NonEIPR NonSelf							[-5.18]***	[-3.87]***	[-3.78]***	[-3.78]***	[-3.57]***	[-3.58]***
Num of Forward Citation									0.0045	0.004	0.004	0.0039
									[2.31]**	[1.97]**	[1.91]*	[1.83]*
Generality										1.0188	0.9913	0.9869
										[9.80]***	[9.17]***	[9.12]***
Originality											0.278	0.2813
											[2.87]***	[2.90]***
Num of Inventors												0.0261
												[2.28]**
Constants	-1.9457	-1.8189	-1.8263	-2.0805	-2.2484	-2.045	-2.213	-7.3198	-7.1981	-7.7859	-7.9155	-7.9293
	[-82.45]***	[-91.09]***	-119.78]**	[-59.35]***	[-42.88]***	[-37.64]***	[-37.26]***	[-1.83]*	[-0.93]	[-1.25]	[-23.44]***	[-0.94]
Manufacturer dummy	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
N	30334	16638	30334	16638	16638	16638	16638	16638	11240	11240	10430	10430

* p<0.1, ** p<0.05, *** p<0.01

Table 3. Probit Regression 2. Dependent variable: Essential IPR (= 1), Non-Essential IPR (= 0)

	1	2	3	4	5	6	7	8	9
Invention when an attendee acts an inventor	0.2349	0.2498	0.2775	0.2907	0.2903	0.3876	0.4191	0.4187	0.3960
	[6.23]***	[6.57]***	[6.63]***	[6.88]***	[6.87]***	[7.52]***	[6.26]***	[6.25]***	[5.75]***
Average Generality of an attendee	0.0152	0.0110	0.0218	0.0200	0.0122	-0.0221	-0.0414	-0.0442	-0.0495
	[1.74]*	[1.18]	[2.41]**	[2.15]**	[1.25]	[-0.95]	[-1.34]	[-1.42]	[-1.55]
The number of patents applied within one past year from the application of the originating patent	-0.0115	-0.0142	-0.0106	-0.0131	-0.0130	-0.0099	-0.0092	-0.0094	-0.0051
	[-7.82]***	[-9.20]***	[-6.68]***	[-7.88]***	[-7.85]***	[-4.39]***	[-2.65]***	[-2.72]***	[-1.43]
The number of patents applied until the originating patent is applied	0.0007	0.0001	0.0028	0.0022	0.0022	0.0019	0.0026	0.0027	0.0007
	[1.86]*	[0.14]	[7.02]***	[5.37]***	[5.35]***	[3.51]***	[3.70]***	[3.76]***	[0.94]
The number of forward citations					0.0078	-0.0200	0.0057	0.0046	-0.0084
					[2.68]***	[-4.34]***	[0.62]	[0.51]	[-0.76]
Generality						1.0586	0.7872	0.7820	0.7378
						[11.2]***	[6.05]***	[6.01]***	[5.49]***
Originality							1.5890	1.5939	1.0119
							[12.10]***	[12.13]***	[7.38]***
The number of inventors								0.0120	0.0171
								[0.90]	[1.25]
The number of essential IPRs in backward citations									0.1079
									[12.22]***
Manufacturer dummy	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.0796	-0.8635	-1.5444	-1.3549	-1.3517	-0.5592	-1.0145	-1.0689	-0.7678
	[-31.37]***	[-20.55]***	[-17.21]***	[-14.51]***	[-14.47]***	[-2.78]***	[-1.91]*	[-2.00]**	[-1.48]
N	7618	7618	7612	7612	7612	3906	2615	2615	2615

* p<0.1, ** p<0.05, *** p<0.01