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Technological importance and breadth of standard essential patents: A comparison between practicing and non-practicing entities for mobile telecommunication technologies

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Using 23 867 standard essential patents claimed for three different wireless telecommunication standards (GSM, WCDMA, and LTE), this research examined the difference in technological importance and breadth of patents between practicing and non-practicing entities. We discovered that compared to manufacturers and service providers, organizations who do not appropriate innovation-derived profits directly from product or service markets tended to have relatively low-quality but broadly scoped technologies for the claimed standard essential patents. These relationships between the characteristics of inventions and the organizational types were consistently held across different generations of wireless standards as indicated by regressions run for each sample split by generation. Furthermore, the theory and policy implications of our results and arguments are presented herein.

KEYWORDS
mobile telecommunication, non-practicing entity, patent assertion entity, standard, standard essential patent

1 | INTRODUCTION

Standard essential patents (SEP), a subset of patents that are indispensable to producing particular standardized goods or services, are distinguishable in several aspects from the "ordinary" patents. They are generally of higher market value [1] and technological importance [1,2] than comparable non-essential patents with long-lasting effects on subsequent technological development [3] and related technologies [4,5]. Competition in technology development and patenting for SEPs is generally more fierce than for non-essential patents [1]; moreover, this competition provides a lens through which we can detect a difference in firms' technology and patenting tendency depending on its product's market position and strategy [6].

The mobile telecommunication industry is one of the most active industries in which a race toward standards appears significant to a firm's competitive advantage. One study shows that about 30% of the consumer price of smartphones transfers to the owners of the relevant SEPs [7]. Therefore, a better understanding of the characteristics and strategies of competitors' technology standards is critical to any significant player in this industry. The race toward technology standards is not run just by the manufacturers of equipment and facilities but is also joined by non-practicing entities (NPEs). The mobile telecommunication industry is one of the most fertile playgrounds for NPEs, according to a study by Bessen and Meurer [8]. While not directly involved in manufacturing, NPEs make their revenue from patent licenses, litigations, or other patent-related intermediary services such as patent aggregating and pooling [9–13]. Albeit differences in individual business models, NPEs share a commonality such that they earn profits from asserting patent rights [11].

A firm's patenting strategy varies by its position in the product market [14,15] as well as its intended uses of the patented technologies [16]. We previously established that firms fell in distinct categories based on the characteristics of their SEPs [17]. Due to their "non-practicing" orientation, NPEs' position in the mobile industry value chain must be distinct from the manufacturers and service providers [18–20]. Hence, we suppose that their patenting strategies should also be distinct.

In this paper, using a magnifying glass of SEPs in mobile telecommunication technologies, we analyze how one very different type of firm in terms of business strategy digresses their patent strategy from the rest of the firms. In particular, we examine differences in both the quality and scope of essential patents between NPEs and the rest. Although a few previous studies addressed a similar issue, they were confined to the litigated patents and, therefore, vulnerable to selection bias. For example, among the litigated patents [10], showed that the quality of the patents owned by NPEs was higher than those owned by others. For a small set of the litigated patents owned by NPEs, Reitzig, Henkel, and others [21] found that litigation strategy depended on the quality of patents. References [19,20] in which the authors discovered that NPEs tended to use different sources of knowledge in developing SEPs from PEs, are likely the closest to this study. We expand the empirical base to non-litigated patents and discuss the relationship between business and patenting strategies in a more general way.

Economic impacts of NPEs on the mobile telecommunication industry are already enormous as revealed by litigation cases [22–24]; however, the impacts must be even more significant if the hidden innovation costs incurred by the litigation cases to the relevant manufacturers and service providers are considered [25]. Those hidden costs include the costs additionally spent by the relevant entities regarding inventing-around, monitoring other's patenting, maintaining litigation, and developing and filing patents for a variety of strategic purposes [26]. Therefore, a better understanding of NPE's patenting strategies in this industry is crucial also for business managers.

This paper is organized as follows: Section 2 explains the theoretical background and the process of establishing the hypotheses based on the previous research on SEPs of mobile telecommunication technology; Section 3 describes the collection and analysis of empirical data; and Section 4 details the examination of the hypotheses established through regression analysis, and examines the SEP strategy of NPE based on the final analysis results.

2 | THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

Mobile handsets and telecommunication equipment require thousands of different component technologies to complete any commercially viable product. Accordingly, the ownership of those component technologies is fragmented among many firms across the mobile telecommunication value chains, including manufacturers, service providers, parts suppliers, and NPEs. Hence, firms can appropriate the benefits from new technologies in a more cooperative and complex way than in a life-or-death kind of standards war [27]. In the winner-take-all type of standards war as shown in such historical examples as a direct current (DC) of electric power vs an alternating current (AC) or DVD vs DivX in the compact disk (CD) technology [27], almost all benefits of new technological standards go to the winning side who has dominated product markets. In the mobile telecommunication industry, technological complexity and widely fragmentary ownership of technologies make it impossible for any single player to win the entire standards race.

Besides evident benefits such as dominance in the product markets or tickets for the market for technology, the benefits from standardization in this technology accrue to the developer in a more subtle and integrated way than in the winner-take-all situation. For example, the in-house integrator of the standardized technology would be able to develop a new product in a better and more cost-effective manner because it might have accumulated better and more detailed knowledge and know-how about the technology than the rivals [28]. Kang and Motohashi [20] reveals that essential patents, compared to non-essential patents, are more likely to be based on "core technological competency" of the inventing firm, as indicated by the citing of own patents (regardless of essentiality) for manufacturers and essential patents (regardless of ownership) for NPEs. It can also save efforts regarding either inventing-around or acquiring an external technology that could occur if the rival technology would have been standardized instead of its own. Therefore, firms participating in the standardization game have incentives to strategize both patenting and standardizing their new technologies.

SEPs are more likely to address important and core technological aspects on a standard trajectory and therefore are more likely to be utilized in a larger number of subsequent inventions than non-essential patents. Empirical studies support these conjectures by showing that the technological value of SEPs were higher than those of non-essential patents. Technological value is measured by such factors as technological utility [2,29], the propensity to be cited by the subsequent essential patents [19], the longevity of citation age [29], the number of claims, and the number of amendments to claims [1]. Partly because of the higher technological importance, SEPs are more useful for a business than non-essential patents, which was indicated by their use as bargaining chips in cross-licensing deals [2,30] or sources of licensing revenues.

While SEPs are a selected subset of patents of higher technological and business value, standardization processes themselves may work as a focusing device for future technological standards to enhance the visibility, adoption, and values of a standard candidate [29]. Firms often take strategic actions to promote their technologies onto standards. The literature reports some social engineering schemes such as collaboration with peer firms, participation in standard-setting organizations and forums, and other activities to enhance the visibility of their technologies [2,5,6,31]. Kang and Bekkers [18] found that patents filed just before the standardization meeting by the meeting participants were more likely to be SEPs but with lower quality (as measured by forward citation counts). To make their patents conformant to upcoming standards, firms also conduct patent engineering to add or amend dependent claims [1].

However, standardization hampers exerting the predatory strategy of patents [13,26] and undermines secrecy benefits [32]. Although not compulsory, once a technology gets on a standard, it is subject to licensing in fair, reasonable, and non-discriminatory (FRAND) terms, which, in some cases, reduces the profit potential that may be realized through predatory pricing or price differentiation. A rational firm would evaluate the benefits and costs involved in patenting and standardizing technology under development to choose the best option available to itself. For the core technologies in mobile telecommunication, secrecy or preemption strategy may not work very well because the technological competition is very fierce and rewarding (especially when one wins standards). The competitors and component developers (who are supposed to have a similar level of interest and knowledge in the target technology) will easily hack secrecy, when time is allowed, and disarm preemption through inventing-around. Hence, hiding technology would not be so lucrative. The benefits of standardization in the mobile industry seem to outweigh the costs as indicated by the fact that firms were so eager to get their technologies standardized to even take strategic actions [2,5,6,18,31].

In summary, SEPs are a particular sort of patents that mingles a firm's core competency, new technological development on a non-peripheral technological trajectory, strategic intentions of the participants, and high economic values and stakes. These features make it possible for us to project a different behavior of the participants better than those noisy and complex features found in general patents. Therefore, we use SEPs as a magnifying glass through which we can discern firms' technological features and strategies.

2.1 | Standard essential patents and non-practicing entities

Bearing in mind the generic benefits and costs associated with SEPs in the mobile telecommunication industry, we now turn to a more specific question about differences in patent quality and scope by types of firms. In particular, we argue that the technological utilities and breadth of an SEP should depend on a firm's position in the product market and its internal capability to some extent. To make an argument more explicit and readily testable empirically, we dichotomize the types of firms into practicing entities (PE) and non-practicing entities, which are supposed to be located on opposite sides of a virtual spectrum constructed from the above two dimensions: product market and internal capability.

PEs such as telecom equipment manufacturers (and parts suppliers or service providers alike) can appropriate additional profits from product markets by enhancing product features or reducing costs and lead times through new technologies. NPEs, in contrast, generally earn profits from new technology through licensing, litigating, or threatening for litigation, all of which are related to asserting patent rights [11]. Despite many variants in NPE business models [33], a lack or shortage of hands-on experience in product markets and manufacturing processes constitutes a set of characterizing features of NPEs.

These features of NPEs (the lack of hands-on experience in manufacturing processes and product markets) work disadvantageously for NPEs in terms of gaining knowledge through learning-by-doing and learning-by-interacting [34,35] to eventually make them positioned disadvantageously in inventing more useful standardizable technologies. The capability-based view of a firm says that the internal synergy of different activities enhances the chances of learning and innovating capabilities [28,36]. Because of their hands-on experience in the manufacturing process, competitive dynamics, and market needs, manufacturers (and PEs in general) are generally better positioned than NPEs in coming up with a high-quality invention.

NPEs' heavy dependence on asserting patent rights as a major revenue source drives them to maintain an expansive portfolio of patents. For example, assume that a firm developed a trivial new invention that is patentable and standardizable. If the firm is a PE and has alternative appropriating mechanisms other than patents such as fast lead time, advantageous marketing and manufacturing capability, it would not be likely to spend extra money on filing and maintaining a patent for it. In highly complex, fragmented, and competitive environments of mobile standard essential technologies, the values of technology are inevitably entwined with other complementary technologies, making a portfolio of patents rather than a single patent more suitable for licensing deals [30,37]. Because NPEs lack another appropriation mechanism than asserting patent rights, they must have stronger incentives toward a strong patent portfolio than PEs, which leads them to include even weak patents in their SEPs. Using a group of European firms, Blind and Thumm [6] revealed that the firms having alternative appropriation mechanisms (in their case, a set of relevant patents) were less likely to participate in the standard-setting processes. Furthermore, according to the theoretical work detailed in Ganglmair and Tarantino [38], lower product market competition leads to ex post disclosure of essential technologies. Subsequently, NPEs who, by definition, do not compete in product markets will disclose their technologies later in the standard-setting processes, which incentivizes them to include lower quality technologies in their portfolio of essential patents.

We summarize the above arguments into the following hypothesis.

Hypothesis 1 *All other things held equal, the technological quality of standard essential patents will be lower for NPEs than for PEs.*

With regard to the technological breadth, from the standpoint of internal capability, we focus on the difference between PEs and NPEs between the structure and organization of technological development. In general, manufacturers and service providers (PEs) have a highly functional organizational structure incorporating a high level of internal division of labor. Due to relatively high functional discretion and low central control of this structure, PEs tend to develop technologically more specific inventions than NPEs.

The odds of licensing or infringement are positively associated with the technological breadth of the patent [39,40]. Subsequently, in the same vein of arguments as given above, an NPE, whose financial stakes depend much more heavily on the market for technology than a PE, should manage, if it can, to make its patents as broad as it can. Therefore, we submit the second hypothesis as follows.

Hypothesis 2 *All other things held equal, the technological breadth of standard essential patents will be broader for NPEs than for PEs.*

3 | DATA AND MEASURES

3.1 | Data

Following the literature [1,41,42], we collected information about the essential technologies of mobile telecommunication standards from the IPR Online Database provided by the European Telecommunications Standards Institute (ETSI). ETSI publicizes and maintains the voluntary claims for the standard essential technologies but does not authorize or endorse them. Hence, the list is subject to both false positives (not essential but claimed to be essential) and false negatives (essential but not claimed). This limitation of data casts a caveat in interpreting the results of this research. To be more precise, our results will be about the self-declared standard essential patents, which one may think over-represent the firms of weaker appropriation methods [6]. However, we assume that such biases should not be systematic based on two observations. First, our dataset includes a significant number of patents from all major players. Given the limited and uncertain impacts of a standard declaration on the following standardization and licensing processes, we assume that falsely (un)declared technologies would distribute randomly across different firms. Second, our understandings of SEPs are mostly ascertained through this particular data source, as many previous studies using it. Hence, we can discuss any discrepancies or limitations of data and the underlying phenomena in a more informed way.

To cover the three generations of mobile standards, we downloaded the standard declarations searchable with the following keywords: “GSM” and “GERAN” (which stands for GSM EDGE Radio Access Network) for the second generation (we call them “GSM”), “WCDMA” and “UMTS” (Universal Mobile Telecommunication System) for the third generation (we call them “WCDMA”), and :E-UTRA” (Evolved UMTS Terrestrial Radio Access Network) and “LTE” for the fourth generation (we call them ‘LTE’). The selection of the keywords is consistent with the relevant previous studies [2,42].

We then matched each claimed standard with the US patent data using the Worldwide Patent Statistics Database (PATSTAT) provided by the European Patent Office (EPO). We analyzed the patents from only one patent authority to control for the heterogeneity stemming from different filing authorities. The US patents were a natural choice because they had been most sought after by international firms, and their data quality, including patent citations, was one of the highest. The number of matched standard essential patents in the dataset counted 23 867, including 13 988 patents for GSM and WCDMA and 9878 patents for LTE.

3.2 | Measures

We measured the technological quality of SEPs using the number of citations received (or forward citations count), which is a dependent variable for Hypothesis 1. Forward citations count, although not free from noise, is one of the most widely accepted measures for technological utility, importance, or quality of a patent. To mitigate the bias from the right truncation (ie, the older patents tend to receive more citations), we counted citations from the subsequent patents filed within five years from the application date of the focal patent following the previous studies [43–46]. The average 5-year citation count (*nFC*) in our sample is 14.6, much higher than the count for the ordinary patents (Table 1).

Although the 5-year citation count may mitigate the right truncation, it may still depend on any cohort-specific effects. Therefore, we calculate another measure of forward citation counts by normalizing it by cohort. Given that we work on relatively homogeneous technologies (ie, mobile telecom), we normalized total forward citation

TABLE 1 Description of variables

	Description	Average	SD	Min	Max
Dependent variables					
nFC	The number of citations received from the subsequent patents filed within five years from the filed date of the focal patent	14.603	26.216	0	535
zFC	*z*-score of forward citation normalized by year	0	0.999	−1.606	17.2
nIPC	The number of different 4-digit IPC classes	5.361	5.532	1	114
Independent variables					
npe_all	NPE dummy: 1 for any NPEs; 0 otherwise	0.333	0.471	0	1
npe_Q	NPE dummy: 1 for Qualcomm; 0 otherwise	0.208	0.406	0	1
npe_ID	NPE dummy: 1 for Interdigital (including IPR Licensing); 0 otherwise	0.100	0.301	0	1
npe_pub	NPE dummy: 1 for ETRI or CATT; 0 otherwise	0.011	0.105	0	1
npe_othr	NPE dummy: 1 for Innovative Sonic, SPH America LLC., or VirnetX; 0 otherwise	0.013	0.113	0	1
Control variables					
dGranted	Indication of whether there exists a publication of the grant or not	0.712	0.452	0	1
nInventor	The number of inventors	3.142	1.896	1	15
nApplicant	The number of applicants	2.088	1.906	1	16
lnBC	Ln(1 + the number of backward-cited patents)	1.907	1.404	0	5.407
lnNPL	Ln(1 + the number of cited non-patent literatures)	1.027	1.116	0	4.605
lnFamily	Ln(The number of member patents of INPADOC family)	3.014	1.319	0	7.033
dPCT	Indication of whether a patent was applied for PCT (if applied for PCT, PCT = 1; if not, PCT = 0)	0.419	0.493	0	1
filing_year	The year of patent application	2004.581	4.683	1977	2012
Location	- geo_*na*: location of patent holder (based on headquarters of firms) is US	0.435	0.496	0	1
	- *geo_eu*: location of patent holder (based on headquarters of firms) is Europe	0.243	0.429	0	1
	- *geo_asia*: location of patent holder (based on headquarters of firms) is Asia	0.321	0.467	0	1
Dummies for technology class	- *wipo_digital*	0.387	0.487	0	1
	- *wipo_telecom*	0.435	0.496	0	1
	- *wipo_others*	0.163	0.370	0	1
Generation	- Generation of Mobile telecommunications technologies is GSM	0.198	0.398	0	1
	- Generation of Mobile telecommunications technologies is WCDMA	0.388	0.487	0	1
	- Generation of Mobile telecommunications technologies is LTE	0.414	0.493	0	1

counts received by the focal patent only by year using *z*-score. Hence, for a patent i filed in year t, we calculate the distance, zFC_{it}, from the mean of forward citations of patents filed in the same year, mean$(FC)_t$, as multiples of the standard deviation of forward citations of patents filed in the same year, $sd(FC)_t$, as

$$zFC_{it} = \frac{FC_i - \text{mean}(FC)_t}{sd(FC)_t} \tag{1}$$

Subsequently, we measured the technological breadth regarding Hypothesis 2 using the number of different technology classes. The basic idea is that a patent assigned to multiple technology classes should be applicable to their corresponding technologies. Following the literature [47,48], we counted the number of different International Patent Classification (IPC) classes at their 4-digit level for each patent and made it a variable *nIPC*. It ranges from 1 to 114, with a mean of 5.36 (Table 1).

Key independent variables are indicators for NPEs. Conceptually, NPEs should have earned a significant portion of revenues from asserting patents instead of manufactured goods or services. Checking a variety of references and sources including company homepages, news articles, court orders [49], and research articles [20,50], we identified seven NPEs: Qualcomm,[1] Interdigital, Electronics and Telecommunications Research Institute (ETRI) of Korea, Chinese Academy of Telecommunications Technology (CATT) of China, Innovative Sonic, VirnetX, and SPH America LLC[2] [51]. In the sample, they take 33% of all patents where two dominant NPEs—Qualcomm (21%) and Interdigital (10%)—take the most. We made a dummy variable called *npe_all* that we coded; a value of 1 was used if an applicant was any of these seven entities and 0 otherwise. To examine the heterogeneity by different origins and business models of NPEs, we broke down NPEs into four subgroups and dummy-coded each group. Because of the dominance of Qualcomm and Interdigital, we dedicated two dummies for each of them (*npe_Q* for Qualcomm and *npe_ID* for Interdigital). We then made a dummy, *npe_pub*, for the two public research institutes (ETRI and CATT). We coded the last three NPEs (private but very small) as *npe_othr*. Reference groups for all NPE dummies in the regressions are manufacturing and service firms.

We controlled a wide range of patent-level characteristics known to correlate with the quality and the breadth of patents. We controlled whether or not a patent was granted by including a dummy variable, *dGranted*, that we coded: 1 for a granted patent and 0 otherwise. Granted patents are likely to have broader applications and higher utility than non-granted ones because they should have passed a thorough examination by a patent examiner for commercial applicability and the inventive step. In the sample, 71% of patent applications were granted.

The number of inventors and the number of applicants is also correlated with the quality and the breadth because they represent, to some extent, the resources invested in the invention, the degree of collaborative efforts, or the technological complexity of the invention. In the sample, the average number of inventors is about 3.1 while the average number of applicants is about 2.1.

Both backward citations to patents and non-patent literature (NPL) are known to strongly correlate with the scope and quality of patents [47,52]. Thus, we included in the regressions backward citation counts (*lnBC*) and the count of citations to non-patent literature (*lnNPL*), both of which were log-transformed to mitigate the effects of skewness.

Technologically important (or widely applicable) patents are likely to be economically valuable as well [53]. Following the literature, we controlled this effect using two proxy variables for economic value: family size (*lnFamily*) and a dummy for PCT filings (*dPCT*). We took a logarithm of the family size because there were a small number of large-sized patent families. In the sample, the mean family size is around 20, while the share of PCT filings is about 42%.

We also controlled temporal effects using filing years (*filing_year*) and technological heterogeneity using technology controls (dummies for technology class). The patents in the sample are highly focused, with about 43.5% being 'telecom' class and about 38.7% being 'digital' by 35 WIPO nomenclature [54].

Finally, we controlled the geographic origins of main applicants by including two dummy variables indicating whether the headquarters of an applicant was located in Europe (*geo_eu*) or Asia (*geo_asia*). The reference group was North America.

4 | ANALYSIS AND RESULTS

We estimated parameters using negative binomial regression models (NBRM, henceforth) given that we had count data as our dependent variables, and found significant evidence of overdispersion for both DVs (G2 = 9711.74, $p < 0.001$ for *nFC* and G2 = 12 496.27, $p < 0.001$ for *nIPC*). We also estimated both models using robust standard errors to correct the downward bias of standard errors [55]. For the technological quality, we ran OLS regressions for *zFC*. To check the robustness of estimations against a different grouping of NPEs, we estimated models using

[1]Despite its significant revenue share coming from the sales of equipment and service, we classified Qualcomm into NPEs because of the following three reasons: 1) Its licensing business is incomparably substantial in its firm value as well as among competitors, 2) Qualcomm totally outsourced its manufacturing, and 3) previous studies [20, 50] cited in the texts also put Qualcomm in the NPEs category.

Patent licensing business is one of the prominent and differentiating business models of Qualcomm, making Qualcomm distinct from other manufacturers. Patent licensing explains more than two-thirds of the firm value of Qualcomm (despite its one-third share of revenue) as testified by David Wise, Qualcomm Senior Vice President and Treasurer, in 2015 [49]. Qualcomm's licensing business is substantial (with no comparable player) in the mobile handset industry. Let us present only several stylized facts: Qualcomm's licensing revenue exceeded the combined licensing revenue of 12 others including Ericsson, Nokia, and Interdigital in 2016 and took 25% of mobile handset and 50% of modem chip licensing revenues [49]. Moreover, Qualcomm was known to have required the chip buyers to license its patents, which was permanently injuncted by court order in 2019 [49].

Since its sales of CDMA manufacturing and assembly to Kyocera in 2000, Qualcomm continued to outsource all of its manufacturing to global foundry firms such as IBM, Taiwan Semiconductor Manufacturing Co., and United Microelectronics. This fact is also consistent with our hypothesis and better fits with classifying it as an NPE.

[2]Interdigital is one of the well-known NPEs in the mobile telecommunication industry. Innovative Sonic is a Taiwan-based NPE who sued Research in Motion for patent infringement in 2010. VirnetX and SPH America are small NPEs from Japan and the United States, respectively. We merged IPR Licensing, a subsidiary of Interdigital, with Interdigital in the sample.

TABLE 2 Result of negative binomial regression for forward citations

	DV = nFC. Negative binomial regressions				*DV = zFC*. Ordinary least square regressions			
	(1) NPE all-in-one	(2) NPE subgroups	(3) GSM + WCDMA	(4) LTE	(5) NPE all-in-one	(6) NPE subgroups	(7) GSM + WCDMA	(8) LTE
npe_all	−0.249***	N/A	N/A	N/A	−0.094***	N/A	N/A	N/A
	(0.040)	N/A	N/A	N/A	(0.021)	N/A	N/A	N/A
npe_Q	N/A	−0.232***	−0.034	−0.446***	N/A	−0.030	0.075**	−0.135***
	N/A	(0.048)	(0.063)	(0.076)	N/A	(0.026)	(0.031)	(0.044)
npe_ID	N/A	−0.422***	−0.484***	−0.238***	N/A	−0.231***	−0.285***	−0.059
	N/A	(0.060)	(0.077)	(0.090)	N/A	(0.031)	(0.030)	(0.062)
npe_pub	N/A	−0.186	−0.380	−0.086	N/A	−0.193***	−0.232***	−0.143***
	N/A	(0.123)	(0.260)	(0.126)	N/A	(0.033)	(0.058)	(0.040)
npe_othr	N/A	0.029	−0.075	0.095	N/A	0.022	0.093	−0.059
	N/A	(0.096)	(0.128)	(0.136)	N/A	(0.050)	(0.073)	(0.067)
dPCT	−1.224***	−1.224***	−1.152***	−1.295***	−0.310***	−0.309***	−0.239***	−0.398***
	(0.032)	(0.033)	(0.046)	(0.048)	(0.012)	(0.012)	(0.014)	(0.020)
nInventor	0.006	0.006	0.023**	−0.027	0.027***	0.027***	0.033***	0.013**
	(0.010)	(0.010)	(0.012)	(0.018)	(0.004)	(0.004)	(0.005)	(0.006)
nApplicant	0.170***	0.171***	0.136***	0.213***	0.091***	0.089***	0.062***	0.117***
	(0.010)	(0.010)	(0.013)	(0.017)	(0.006)	(0.006)	(0.007)	(0.011)
lnBC	0.760***	0.759***	0.806***	0.697***	0.151***	0.153***	0.166***	0.137***
	(0.017)	(0.017)	(0.022)	(0.025)	(0.006)	(0.006)	(0.007)	(0.011)
lnNPL	−0.054***	−0.050***	−0.061***	−0.029	0.015*	0.018**	0.022**	0.021
	(0.016)	(0.016)	(0.021)	(0.023)	(0.008)	(0.008)	(0.010)	(0.013)
lnFamily	−0.193***	−0.192***	−0.201***	−0.169***	−0.050***	−0.049***	−0.038***	−0.055***
	(0.013)	(0.013)	(0.016)	(0.019)	(0.005)	(0.005)	(0.006)	(0.008)
dGranted	0.464***	0.453***	0.535***	0.355***	0.140***	0.138***	0.159***	0.103***
	(0.044)	(0.043)	(0.059)	(0.061)	(0.013)	(0.013)	(0.014)	(0.023)
filing_year	−0.042***	−0.040***	−0.040***	−0.058***	−0.002	−0.002	−0.004*	−0.011***
	(0.004)	(0.004)	(0.005)	(0.008)	(0.002)	(0.002)	(0.002)	(0.003)
geo_eu	0.002	−0.020	0.067	−0.091	−0.157***	−0.155***	−0.089***	−0.198***
	(0.044)	(0.045)	(0.059)	(0.070)	(0.021)	(0.023)	(0.026)	(0.039)
geo_asia	−0.022	−0.066	0.055	−0.166***	−0.265***	−0.262***	−0.160***	−0.365***
	(0.039)	(0.042)	(0.060)	(0.057)	(0.019)	(0.022)	(0.026)	(0.036)

(Continues)

TABLE 2 (Continued)

	DV = nFC. Negative binomial regressions				*DV = zFC*. Ordinary least square regressions			
	(1) NPE all-in-one	(2) NPE subgroups	(3) GSM + WCDMA	(4) LTE	(5) NPE all-in-one	(6) NPE subgroups	(7) GSM + WCDMA	(8) LTE
wipo_digital	0.022	0.021	0.034	0.039	0.070***	0.062***	0.038*	0.130***
	(0.043)	(0.043)	(0.056)	(0.066)	(0.018)	(0.018)	(0.021)	(0.033)
wipo_telecom	0.128***	0.131***	0.056	0.253***	0.075***	0.072***	0.013	0.181***
	(0.041)	(0.041)	(0.052)	(0.065)	(0.018)	(0.017)	(0.020)	(0.033)
Constant	84.609***	82.042***	80.910***	118.184***	4.448	4.602	6.597*	21.280***
	(8.490)	(8.382)	(10.271)	(15.247)	(3.269)	(3.259)	(3.647)	(6.659)
Observations	23 867	23 867	13 989	9,878	23 866	23 866	13 988	9,878
Log likelihood	−71 670	−71 653	−41 757	−29 785	N/A	N/A	N/A	N/A
Wald chi2	9,712	9,659	4,676	5,247	N/A	N/A	N/A	N/A
Pseudo R^2	0.0687	0.0689	0.0655	0.0769	N/A	N/A	N/A	N/A
F-stat	N/A	N/A	N/A	N/A	520.8	427.1	240.1	194.9
R-squared	N/A	N/A	N/A	N/A	0.216	0.219	0.215	0.240

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors in parentheses.

two different sets of NPE measures: (i) NPE all-in-one (*npe_all*) and (ii) four subgroups of NPEs. To check the robustness against sample composition and different generations of standards, we also ran split-sample regressions for two different groups of mobile telecommunication technology standards: GSM and WCDMA as one group and LTE as another group. Tables 2 and 3 show the results from the regressions for each dependent variable (*nFC*, *zFC*, and *nIPC*, respectively). Both tables show four models – column (i) for using *npe_all*; column (ii) for breaking down NPEs into four subgroups; column (iii) for GSM and WCDMA split sample; and column (iv) for LTE split sample.

NPEs are likely to have SEPs with less forward citations than PEs, as indicated by the negative and statistically significant coefficient on *npe_all* (−0.249 for *nFC* and − 0.094 for *zFC*, $p < 0.01$) in columns (1) and (5) of Table 2. This finding supports Hypothesis 1.

Drilling down on different types of NPEs and different generations of standards, the results from the regressions are mixed. The regressions results for *nFC* show that the effects are likely to be attributed to two major private NPEs (Qualcomm and Interdigital) as their coefficients, *npe_Q* (−0.232, $p < 0.01$) and *npe_ID* (−0.422, $p < 0.01$) are negative and statistically significant while coefficients on two other NPE subgroup dummies are not statistically significant. In the regression results from *zFC*, the coefficients on the public NPEs (*npe_pub*) are negative and statistically significant.

Two split-sample regressions maintain similar results; however, for GSM + WCDMA, the Qualcomm dummy is either marginally insignificant for *nFC* or even significant and positive (0.075; $p < 0.05$) for *zFC*. The regression coefficients on the Interdigital dummy (*npe_ID*), although negative and significant except for *zFC* and LTE, tend to decrease in their absolute values as generations go forward. Consistent results may be found only for commercial and small NPEs (*npe_othr*) which do not show any significant differences from PEs. Hence, there is both temporal and organizational heterogeneity in NPE's patent quality. The results show that NPEs must not be homogeneous at all. At least we need to differentiate between public and private NPEs or between large and small NPEs in terms of patenting strategies for essential technologies.

Consistent with the previous studies, usual patent value covariates such as backward citations, the number of inventors, the number of applicants, and granting for patents are all positively and statistically significantly associated, mostly, with forward citations. Curiously, we had a negative and significant association of the family size (*lnFamily*) and filing PCT (*dPCT*) with forward citations.[3]

[3]We obtained qualitatively the same results when we regressed the same model except for removing either of the two variables. The covariates are not significantly collinear either as indicated by *VIF* not exceeding 2.0.

TABLE 3 Result of negative binomial regression for *nIPC*

	(1) NPE all-in-one	(2) NPE subgroups	(3) GSM + WCDMA	(4) LTE
npe_all	0.085***	N/A	N/A	N/A
	(0.014)	N/A	N/A	N/A
npe_Q	N/A	0.084***	0.114***	0.080***
	N/A	(0.016)	(0.021)	(0.024)
npe_ID	N/A	0.229***	0.285***	0.157***
	N/A	(0.022)	(0.029)	(0.031)
npe_pub	N/A	−0.076*	−0.225***	0.014
	N/A	(0.042)	(0.055)	(0.055)
npe_othr	N/A	−0.219***	−0.109***	−0.345***
	N/A	(0.027)	(0.033)	(0.045)
dPCT	−0.034***	−0.036***	−0.056***	−0.004
	(0.012)	(0.012)	(0.016)	(0.016)
nInventor	0.013***	0.014***	0.008**	0.022***
	(0.003)	(0.003)	(0.003)	(0.004)
nApplicant	−0.030***	−0.027***	−0.035***	−0.015***
	(0.004)	(0.004)	(0.005)	(0.006)
lnBC	0.059***	0.055***	0.057***	0.047***
	(0.005)	(0.005)	(0.007)	(0.008)
lnNPL	0.020***	0.020***	0.012	0.037***
	(0.006)	(0.006)	(0.008)	(0.009)
lnFamily	0.173***	0.167***	0.177***	0.139***
	(0.005)	(0.005)	(0.006)	(0.007)
dGranted	0.066***	0.067***	0.069***	0.059***
	(0.012)	(0.012)	(0.016)	(0.018)
filing_year	−0.044***	−0.044***	−0.031***	−0.072***
	(0.001)	(0.001)	(0.002)	(0.003)
geo_eu	−0.025*	0.001	0.050**	−0.081***
	(0.015)	(0.015)	(0.019)	(0.024)
geo_asia	0.048***	0.089***	0.089***	0.102***
	(0.014)	(0.015)	(0.021)	(0.022)
wipo_digital	−0.578***	−0.572***	−0.542***	−0.587***
	(0.015)	(0.014)	(0.018)	(0.023)
wipo_telecom	−0.134***	−0.131***	−0.123***	−0.130***
	(0.013)	(0.013)	(0.016)	(0.021)
Constant	89.249***	90.051***	63.503***	145.483***
	(2.962)	(2.919)	(3.501)	(5.079)
Observations	23 867	23 867	13 989	9,878
Log Likelihood	−57 913	−57 826	−34 949	−22 685
Wald chi2	12 496	12 937	6,971	6,388
Pseudo R^2	0.0975	0.0988	0.0892	0.116

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors in parentheses.

Considering geography dummies, we obtained no evidence of geographical influence on the quality of patents overall. However, when we look at the split-sample regressions, the patents from Asian applicants for LTE standards were likely to have lower quality than those from North American applicants as indicated by the negative and significant coefficient on *geo_asia* (−0.166, $p < 0.01$) in the model (5).

In our sample, SEPs falling in the telecommunication technology category is likely to receive more citations than other technology categories as indicated by positive significant coefficients on *wipo_telecom* in the models (1), (2), and (5).

We also found the negative association of filing years, *filing_year*, with forward citations across all models, which might indicate a tendency for progressive fragmentation of SEPs as time went by [37].

As for the number of IPCs whose regression results we presented in Table 3, the coefficient on *npe_all* is positive and statistically significant (0.085, $p < 0.01$) in the model (1). Hence, SEPs from NPEs overall are likely to be broader than those from PEs as predicted by Hypothesis 2. However, these overall NPE effects seem to be attributed to two dominant private NPEs—Qualcomm and Interdigital as indicated by the positive and significant coefficients on their dummies and the even negative (and significant) coefficients on public and other NPEs (*npe_pub* and *npe_othr*, respectively) in the model (2). These results are also maintained qualitatively, in general, for all split-sample regressions. Therefore, although Hypothesis 2 was supported, our findings indicate that we need some modifications to reflect heterogeneity among different types of NPEs.

Furthermore, some of the control variables look interesting. First, the higher the number of applicants, the narrower the technological scope of a SEP as indicated by the negative and significant coefficient on *nApplicant*. Second, the technological breadth is likely to be broader for SEPs from Asian applicants than from North American ones (except for GSM). Hence, North American applicants seem to focus on core technology more strongly than Asian ones, when they go for a SEP. Third, the technological breadth of SEPs tends to have become narrower and narrower as time went by as indicated by the negative and significant coefficient on *filing_year*, which, combined with the above finding for the negative temporal tendency of forward citations, implies increasing fragmentation and incremental improvement of SEPs.

5 | DISCUSSION AND CONCLUSION

Using 23 867 standard essential patents claimed for three different mobile telecommunication standards (ie, GSM, WCDMA, and LTE), this research examined the difference in technological importance and breadth of SEPs between practicing and non-practicing entities. In our sample, NPEs explained about 33.3% of total SEPs. However, most SEPs claimed by NPEs were assigned to two private NPEs: Qualcomm (20.8% of all SEPs) and Interdigital (10.0%). Public research institutes from Korea and China and small private NPEs take the rest. We found that organizations that do not appropriate profits of innovation directly from product or service markets (or NPEs), compared to manufacturers or service providers, tended to have relatively low-quality but broadly scoped technologies for the claimed standard essential patents. These relationships between the characteristics of inventions and the organizational types held across different generations of wireless standards as indicated by regressions run for each sample split by generation. However, the effects are heterogeneous across different types of NPEs. This study implies that large commercial NPEs such as Qualcomm and InterDigital are different from public NPES such as ETRI and CATT or small commercial NPEs.

There had been heated debates about the roles of NPEs in the economy and for innovation, especially in the policy arena [56,57] but also in the scholarly communities [8,10,11,23]. This paper contributes to the literature by presenting empirical evidence of systematic differences between NPEs and PEs in the technological characteristics of important inventions worthy of standards. Distinct from the existing studies focusing on the economic impacts of "big shot" patents bearing litigations, this research examines the technological features of a broader set of patents within a sector over consecutive periods of technological evolution.

This paper contributes to the literature in at least three aspects. First, this study empirically found different characteristics of technological developments between NPEs and PEs. Kang and Motohashi [19,20] revealed that NPEs tended to use different sources of knowledge in developing SEPs by showing a citation tendency to the essential patents in subsequent essential patents being higher for NPEs than PEs. Our study extends this line of inquiry by shedding new light on the differences in two important features of patents (ie, technological quality and breadth) other than knowledge sources between NPEs and PEs.

Second, we provide empirical underpinnings in the necessity of a detailed breakdown of NPEs. It is known in the business sphere that there are scores of conceptually different business models among the NPEs operating in the United States [33]. By showing a heterogeneity among four different types of NPEs, this study calls for scholarly attention to this issue.

Third, we explained how technological orientation and patenting strategy emerge differently by firms depending on their different positions in the product markets and manufacturing capability. The extant literature on this issue delves mostly into better understanding phenomena and their impacts. Therefore, it lacks theoretical explanation behind the phenomena about the reasons why NPEs should behave differently from PEs in terms of technology and patent strategy. We presented our arguments using two theoretical constructs: 1) the commandability of appropriating mechanisms other than patent rights assertion and 2) the organizational effects of the presence of internal capability related to manufacturing or direct customer services. However, in the paper, we only gave broad arguments associated with these constructs and did not examine each mechanism separately and precisely. We wish future studies overcome these weaknesses and further develop this line of arguments.

There are several managerial and policy implications. As suspected by many, NPEs may increase the transaction costs in accessing and utilizing SEPs. Combining the result from [18] that "just-in-time" patents are generally of low quality, we can conjecture that SEPs from NPEs are more on the rent-seeking side than on deepening technological content. Lower-quality patents held by NPEs are less likely to be settled, resulting in higher litigation costs [21]. This study does not involve any normative appraisal of NPEs, that is, we do not claim that NPEs are bad because their average technological quality of SEPs is lower than PEs, and technological breadth is wider than PEs.

Nevertheless, the results of this study imply that NPEs' contribution to developing mobile telecommunication standards might be associated with a higher probability of relatively dubious (or low quality) and ambiguous (or broader in scope) patents. This implication is partly consistent with the finding in [10] that the range of forward citations for the litigated patents is larger for NPEs than for the corresponding peers (hence, higher uncertainty in ex ante projection of litigation propensity). Inclusion of these dubious and ambiguous patents in a patent pool for cross-licensing, for example, raises monitoring and evaluation costs of the potential licensees resulting in additional transaction costs.

This study does not say that every patent from NPEs is lower in quality and broader in scope than every patent from PEs. We only examined average and aggregate tendencies between two broad groups of organizations. Therefore, as shown in [10], NPEs may have strong and sharp patents in their arsenals for litigation.

In theoretical consideration, we pointed out that the resulting patterns in technological aspects of SEPs were not solely attributable to the distinctive business and patenting strategy of NPEs. We argued that different innovation processes associated with different organizational structures should also contribute to shaping the quality and breadth of innovation outputs. Therefore, a better understanding of the difference between NPEs and PEs requires both strategic and organizational-level factors.

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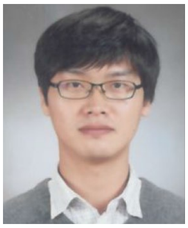

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APPENDIX A

TABLE A1 Correlation table of variables

	nFC	*nr_IPC*	*npe_all*	*npe_Q*	*npe_ID*	*npe_pub*	*npe_othr*	*dPCT*	*nInventor*	*nApplicant*	*nBC*	*nNPL*	*lnFamily*	*dGranted*	*Filing_ year*	*geo_na*	*geo_eu*	*geo_asia*
nIPC	0.064*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npe_all	0.070*	0.188*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npe_Q	0.088*	0.076*	0.7252*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npe_ID	–0.002	0.213*	0.475*	–0.171*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npe_pub	–0.032*	–0.037*	0.151*	–0.054*	–0.037*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
npe_othr	0.009	–0.023*	0.162*	–0.056*	–0.038*	–0.012	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
dPCT	–0.294*	–0.192*	–0.204*	–0.124*	–0.145*	0.073*	–0.085*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
nInventor	0.082*	–0.010	0.031*	0.049*	–0.035*	0.096*	–0.042*	0.073*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
nApplicant	0.271*	–0.064*	0.019*	0.040*	–0.033*	0.056*	–0.029*	–0.127*	0.401*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
nBC	0.380*	0.215*	0.116*	0.063*	0.108*	–0.031*	–0.003	–0.446*	0.022*	0.492*	1.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
nNPL	0.228*	0.124*	0.046*	–0.019*	0.076*	0.000	0.059*	–0.226*	0.050*	0.397*	0.578*	1.000	N/A	N/A	N/A	N/A	N/A	N/A
lnFamily	0.031*	0.401*	0.311*	0.210*	0.213*	–0.050*	0.025*	–0.066*	0.127*	0.036*	0.242*	0.229*	1.000	N/A	N/A	N/A	N/A	N/A
dGranted	0.212*	0.136*	–0.057*	–0.043*	–0.017*	–0.009	–0.030*	–0.211*	–0.072*	0.207*	0.354*	0.344*	0.054*	1.000	N/A	N/A	N/A	N/A
Filing_year	–0.065*	–0.329*	–0.0018	0.012	–0.046*	0.064*	0.013*	0.224*	0.193*	0.369*	–0.025*	0.152*	–0.092*	–0.258*	1.000	N/A	N/A	N/A
geo_na	0.138*	0.163*	0.721*	0.583*	0.382*	–0.093*	–0.015*	–0.252*	0.040*	0.022*	0.142*	0.032*	0.197*	–0.031*	–0.064*	1.000	N/A	N/A
geo_eu	–0.047*	–0.095*	–0.400*	–0.290*	–0.190*	–0.060*	–0.065*	0.159*	–0.168*	–0.154*	–0.133*	–0.144*	–0.229*	0.110*	–0.274*	–0.498*	1.000	N/A
geo_asia	–0.104*	–0.086*	–0.398*	–0.352*	–0.230*	0.155*	0.076*	0.122*	0.112*	0.118*	–0.028*	0.099*	0.002	–0.068*	0.320*	–0.604*	–0.390*	1.000
wipo_digital	–0.113*	–0.324*	–0.075*	–0.025*	–0.092*	0.003	0.020*	0.171*	–0.004	–0.102*	–0.273*	–0.152*	–0.157*	–0.175*	0.207*	–0.104*	0.097*	0.022*
wipo_telecom	0.093*	0.120*	0.040*	0.029*	0.029*	0.032*	–0.044*	–0.064*	0.069*	0.114*	0.159*	0.075*	0.079*	0.087*	–0.037*	0.039*	–0.102*	0.053*
wipo_reference	0.031*	0.251*	0.034*	–0.005	0.076*	–0.044*	–0.003	–0.133*	–0.078*	–0.016*	0.142*	0.108*	0.110*	0.114*	–0.207*	0.073*	0.007	–0.083*

*$p < 0.05$.