Co-Evolution of Markets for Technology and Markets for Products in Mobile Telecommunication Standards: Examination of Essential Patents for GSM, WCDMA, and LTE Standards

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Abstract--**Patents conforming to technology standards ("essential patents") in a rapidly-changing and technology-intensive industry such as mobile telecommunication industry have strategic values to the holder of the patent. Firms who play in such an industry, either manufacturers, parts suppliers, or non-practicing entities, thus fiercely compete against each other to develop standards-conformant technologies. In mobile telecommunication industry, complex dynamics among firms (that stems from the different positions of each firm in the market for products and for technology) has formed interesting emerging patterns. In the paper, we examine the evolutionary pattern of the relationship between the position of a firm in product markets and its position in technology markets as the dominant design shifts from one to the next. In particular, we analyze essential patents conformant to different generations of mobile telecom standards (i.e. GSM, WCDMA, and LTE) from 2 different perspectives: 1) the product market position of the patent holder; and 2) the impacts of experience in product market and technology development on the position in the technology market for the subsequent standards. We discuss the emerging patterns of players in relation to their positions in both product markets and technologies.**

I. INTRODUCTION

In mobile telecommunication industry, patents conforming to a technology standard ("essential patents") can generate strategic as well as financial value to the holder of the patents. As exemplified by Qualcomm who developed a core technology for CDMA telecommunication protocol, a firm who owns essential patents can leverage them to take a long-term strategic position in a competitive dynamics. Therefore, firms active in this industry are eager to develop standard-conformant technologies or to promote the developed technologies into a set of standards[4]. Mobile telecommunication industry shows a clear transition from one generation to the next (e.g. from GSM to WCDMA and LTE). As a new generation of technology standards replaces the old one, some firms emerge, some firms hold its current position, and others fade away in both markets for products and markets for technologies.

This study aims to examine underlying co-evolutionary pattern between markets for products and markets for technology as transitioning from one standard to the next posits either an opportunity to some or a risk to others. At the beginning stage of our endeavor, this study reports the results of our exploration of changing patterns of markets for technology by examining the essential patents across three different mobile telecommunication standards: GSM, WCDMA, and LTE.

This study contributes to the literature in at least three points. First, different from the previous studies most of which examine patterns and standardization procedures for one generation of standards[1, 2, 4, 10], it examines changing patterns across multiple consecutive generations of mobile telecommunication standards. Second, it provides an empirical account on firm dynamics in technological standardization on several important dimensions including positions in the value chains of mobile handset manufacturing and geo-cultural origins of firms. Lastly, although incomplete at the current stage of research, we attempt to relate the changing patterns in markets for technology to the changing patterns in markets for products.

The paper is organized as follows. Section II introduces the standardization and essential patents of mobile telecommunications and research questions. Section III introduces the empirical data we use and how to process those empirical data before an analysis. Section VI presents the results of the analysis and Section V concludes the paper and discusses its implications.

II. LITERATURE REVIEW

In ICT industry standardizations of technologies have been led by various Standards Developing Organizations (or SDOs) and therefore, essential patents, which are patents that are related to the standard technologies, are appeared more important than non-essential patents. There are many studies with both essential patents and standardization performed in both theoretical and empirical. According to Narayanan and Chen [10] there are over 89 papers relevant to technology standards in influential journals in management, marketing and management-related disciplines. They suggest complex models that take into account the two boundary conditions in the previous literature; technological complexity and institutional environment. They also explain that theoretically grounded works is important as for the collective action and strategic choice views, but the integrative works will give us better opportunity to get a comprehensive view of technology standards.

The ownership of essential patents is considered as a very valuable bargaining tool in cross-license negotiations. What is the main factor to create essential patents? Bekkers, Bongard and Nuvolari studied the determinants of essential patent claims in compatibility standards[3]. In particular, they assessed the role of two main factors: the technical value contained in the patent and the involvement of the applicant of the patent in the standardization process. From an extensive analysis on self-declared essential patents for W-CDMA, the third-generation standard technology in the

mobile telecommunications they found that both factors have meaningful impact on judging "essentiality" of a patent, but the latter is a stronger determinant than the former.

As to the relationship between standardization and patenting, Blind and Thumm [5] focus on the ambivalence of intellectual property rights and how this ambivalence affect the relationship between strategies to protect IPRs and standardization activities. Pursuing the research question they consider theoretically two opposite hypothesis: 1) strong protection of technological know-how lead high likelihood of joining formal standardization processes for leverage effect of their technical know-how; and 2) companies who have high technical competitiveness are already in a strong position so that they do not need to join or support of standardization organizations. They found a supporting evidence for the latter hypothesis: the higher technical competitiveness companies have, the less companies need to join standardization processes. This result means that policy makers will not exploit fully the positive economic effects of standards. Therefore solutions are needed in order to give additional incentives for leading technologically strong companies to participate in standardization processes without concerns about unintentional spillovers of their technological know-how. Finally several recommendations about strategic standardization polices, especially licensing rules are proposed.

In addition, there are papers in regard with the companies' strategy for patenting and standardization. One of the papers is "Filing behavior regarding essential patents in industry standards" by Berger, Blind and Thumm [4]. This paper addresses companies' filing behavior concerning patents relevant to standard technologies, which can be called essential patents. They consider applicants' incentives in case of that patents conforming with technology standards under development. Based on thes incentive structure, they present hypotheses; the claims of essential patents are amended more often than ones of comparable patents and essential patents have longer pendency than comparable patents because incentives make it delay the grant decision. Finally they validate their hypothesis using procedural patent data of European patent application process.

Besides essential patents and standardization of companies, there are studies about SDOs' policies . Blind and Gauch analyze the relationship between standardization activities in formal SDOs and consortia SDOs and perform empirical examination for their analysis[6]. Their major question is whether the relationship between formal SDOs and consortia SDOs in the ICT industry is a complementary or a substitutive. In order to compare ICT standardization activities in formal SDOs and consortia SDOs they quantify the standardization activities in the ICT industry by using the database PERINORM for formal standards and two CEN/ISSS surveys of standardization consortia in 2000 and 2004. From the result of the analysis it is confirmed that the technical content of activities in the both formal and informal standardization bodies is complementary rather than substitutive because most technical issues are addressed by both formal standardization bodies and standardization consortia. In addition, it is observed a consolidation of consortia activities through a significant reduction of consortia. However, this reduction has not affected the distribution of consortia activities depending on technical fields and complementary relationship between the activities of formal and informal standardization bodies. Based on this result, they suggest some discussion items for further studies; future theoretical analysis of decisions on standardization types and ICT policy regarding the interaction between standardization and technical regulation.

Bekkers and West examine the nature and role of patents in the ICT standardization efforts of that of the Universal Mobile Telecommunications System (UMTS), a third-generation standard technology in the mobile telecommunications[1]. This standardization effort was made and governed by the IPR policy developed based on the various difficulties when handing patents during GSM standardization. They have two research questions. Firstly, how do companies use IPR strategies for UMTS compared to GSM? Secondly, how well do SDOs IPR policies deal with quantitatively and qualitatively increasing patent portfolios? Based on these research questions, they analyze patent timing and firm strategies (targeting and technology diversity) of UMTS patents compared to the GSM case and also, evaluate patent policy changes and alternatives of SDOs.

III. STANDARDIZATION OF TECHNOLOGIES AND ESSENTIAL PATENTS IN THE MOBILE TELECOMMUNICATION INDUSTRY

Technologies of mobile telecommunications are categorized by 'generation' depending on the main technologies and features. Analog technologies based on FDMA (Frequency Division Multiple Access) were considered as the first generation technologies. However, the standardization was not effectively applied in those days because mobile communication industry and the community of mobile communication experts were just at the beginning stage. After the first generation GSM and CDMA technologies emerged in Europe and in North America, respectively. These technologies were very successful and evolved into technological modifications with better performance which were dubbed as the second and the third generations of mobile telecommunication standards. Currently standardization of the fourth generation technology is at the final stage and E-UTRA (or called LTE, Long Term Evolution) and the evolution of E-UTRA technologies is widely used around the World which are called the 3.9^{th} and 4^{th} generation standard technologies. The standardization of mobile telecommunications had started actively since the third generation technologies because of the establishment of 3GPP (3rd Generation Partnership Project) in 1998.

Launching in 1998, 3GPP is a collaboration project group between groups of telecommunications associations to make a globally applicable 3^{rd} generation mobile phone system specification based on evolving GSM specifications within

the scope of the IMT-2000 project of the ITU (International Telecommunication Union). Members of 3GPP include major SDOs (Standard Development Organizations) such as ETSI, ARIB, TTC, CCSA, ATIS and TTA. 3GPP structures each generation technology into specific features by the time when making of the related specification is completed and calls it release 'x'. According to 3GPP the technology of 2nd generation indicates the technologies cover specification from pre-release (called phase 1 and 2) to release 98. The 3rd technology called WCDMA is the technology that covers specifications from release 99 to release 7 and the 3.5th and after technologies indicates the technologies that cover specifications from release 8.

Essential patents are patents that have at least one claim covered by standards of SDO. When a product or service is designed and implemented according to the standard technology essential patents should be used. The added value of essential patents are higher than non-essential patents because infringement of patent can't be avoided when conforming to the standards and standards, themselves are evidence for infringement of patents. In addition under the WTO agreement the technologies not conforming to the international standards should not be allowed to apply around the world and so that essential patents became even more important.

SDOs generally make their essential patents available for licensing under the term called FRAND, an acronym that refers to the Fair, Reasonable and Non-discriminatory conditions that parties need to ensure for the licenses of their essential patents. FRAND's principles are as follows[1]: (1) Holders of IPR, member or not, will be rewarded in a suitable and fair manner; (2) Members will make a reasonable effort to inform the SDO of relevant IPRs of which they are aware. If they propose a technical design to the SDO they will also, in good faith, draw attention to IPRs that could become essential once that proposal is adopted; (3) If an essential IPR is identified, the SDO will request its holder, member or not, to make licenses available under FRAND terms; (4) Members can choose not to license an IPR; if they persevere, the SDO will try to change the standard so it no longer draws upon that patent. If it does not succeed, it will withdraw the standard or stop working on it. Usually the information of those essential patents is maintained by a database of SDOs and can be accessed. In mobile telecommunications typical essential patents are patents are patents that are indispensable for designing and manufacturing products conforming to the standards of 3GPP and those are managed by ETSI database, 'ETSI IPR Online Database'.

The database of SDOs is composed of essential patents that are declared by patents holders and after the first declaration the follow-up actions such as separation and additional application of family patents are not updated immediately. That should be considered when using essential patents information from the SDO's DB.

[1] These principles remain in the ETSI Rules of Procedures as published in Nov. 2006.

Bekkers and West [1] found that two determinant factors for essential patents are technological merit and the involvement of the applicant of the patent in the standardization process. It means the standardization and essential patents of companies can be used as an indicator to find R&D and market strategies of companies as well as R&D competitiveness. Based on this concept, we analyze essential patents to understand the evolutionary pattern of the relationship between the position of a firm product markets and its position in technology markets as the dominant design shifts from one to the next. Most extant studies focus on one generation of technology [1, 3, 7, 11] and therefore are some limited in providing insights about inter-generational aspects of participants in the standard technologies. This study analyzes essential patents for three different generations of mobile telecom standards (that is, GSM, WCDMA, and LTE) from two different perspectives: 1) the product market position of the patent holder; and 2) the impacts of experience in product market and technology development on the position in the technology market for the subsequent standards. We discuss the emerging patterns of players in relation to their positions in both product markets and technologies.

IV. DATA

This paper examines essential patents relevant to GSM, WCDMA[2] and LTE standards because they account for the largest market shares in the respective generations of mobile standards (i.e. the second, the third, and the fourth generations) and their standardization was coherently coordinated by an authoritative standardizing body: the 3GPP. We collect an initial list of essential patents for these three standards from the IPR Online Database of the European Telecommunications Standards Institute (henceforth, ETSI)[3]. On the database we search for essential patents for GSM using keywords 'GSM' or 'GERAN', for WCDMA using 'WCDMA' or 'UMTS', and for LTE using 'E-UTRA' or 'LTE'. This search results in 6,898 patents for GSM, 13,693 for WCDMA and 13,851 for LTE. As for the LTE technology, there is a truncation issue in coverage because the standardization of LTE and the advanced LTE is still under progress. Out of these patents we only selected the patents that are filed to the United States Patent and Trademark Office (henceforth, USPTO) which explain the dominant share and provide most accurate and reliable information.

Next, we post-processed the collected list of essential patents taking the following steps: First, we cleaned the list and removed the duplicates. Second, we cleaned and harmonized the names of firms. Lastly, by resorting to the secondary sources, we categorized each firm based on the geographic location of headquarter and its position in the product markets (that is, manufacturing, telecom service

[2] WCDMA and related technologies have also been called Wideband CDMA or UMTS. WCDMA name is used in this paper for consistency's sake.

[3] http://ipr.etsi.org

provider, or non-practicing entity).

V. ANALYSIS

Before our main analysis, we examine the trends of essential patents filing in our dataset. Figure 1 shows overall trends of the US patents as declared by the owner to be essential to each generation of standards. Essential patents in our dataset span over about three decades. The first patent for GSM was filed in 1977, for WCDMA in 1981 and for LTE in 1984. The median filing year of essential patents for GSM is 2007, for WCDMA 2006, and for LTE 2009. The modal year for GSM is 2010 and for WCDMA and LTE 2009. Although the standardization process for GSM and WCDMA was finished in early or mid 2000s, the handsets conforming to those standards are still on sale especially in developing countries and technologies relevant to them are still under development and filed for patents. The number of different firms who declare to own essential patents is similar across technologies: 47, 50, and 49 firms for GSM, WCDMA, and LTE, respectively.

A. Firm-level breakdown

Table 1 shows a breakdown of essential patents by different generations and by holders. Most obviously, Qualcomm, a developer of core technology for CDMA and following communication technologies, leads the list for all three generations. However, its dominance seems to decrease as indicated by its share of 23% in GSM essential patents being reduced in LTE essential patents to 17%. Surprisingly, InterDigital, a non-practicing entity, takes the second place on our list. Not so surprisingly, core players in mobile handset manufacturing business (as shown in Table 2) such as NOKIA, Samsung, LG, Ericsson, and MOTOROLA also explain a substantial share in essential patents. There are several notable developments though. Nokia, a debilitating giant in mobile handset manufacturing, shows a significant drop in its claimed share from GSM(16.9%) to LTE(4.5%). Contrastingly, an emerging star such as Samsung shows an opposite trend in essential patents raising its share from mere 0.1% for GSM to 10.5% for LTE. This quick observation hints on co-evolution between the markets for products and markets for technology. However, given that other emerging players such as Huawei or Apple show stable or decreasing trends in essential patents as generation shifts, we can postulate that firm-level heterogeneity also plays a role in co-evolutionary development between technologies and products.

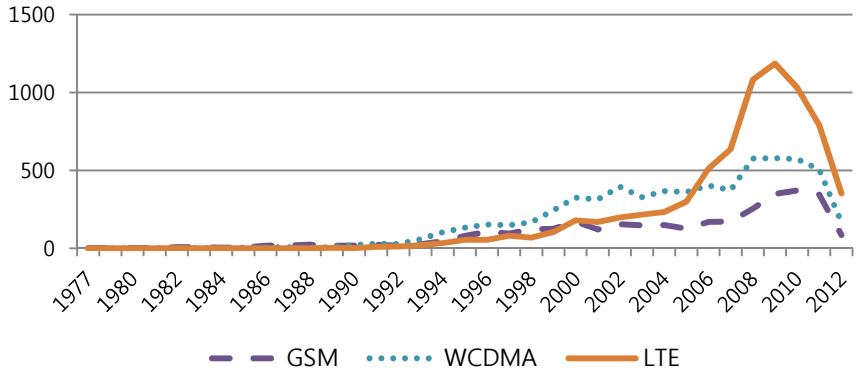

Figure 1 Trends of essential patents filing: GSM, WCDMA, and LTE standards

TABLE 1 TOP 20 HOLDERS OF ESSENTIAL PATENTS IN GSM, WCDMA, AND LTE

Patent owner	NPE, MFG, SVC	Location	All essential patents	Share of US essential patents			Growth WCDMA ->LTE
				GSM	WCDMA	LTE	
Qualcomm	MFG	NA	3290	0.226	0.190	0.174	3.8
InterDigital	NPE	NA	2252	0.082	0.157	0.130	-6.5
LG Electronics	MFG	Asia	2002	0.186	0.090	0.106	34.1
NOKIA	MFG	EU	1710	0.169	0.123	0.045	-59.1
Ericsson	MFG	EU	1163	0.058	0.068	0.071	17.3
Samsung Electronics	MFG	Asia	978	0.001	0.031	0.105	279.3
MOTOROLA	MFG	NA	901	0.052	0.053	0.052	11.4
Huawei Technologies	MFG	Asia	536	0.015	0.050	0.022	-51.2
Apple	MFG	NA	460	0.039	0.025	0.023	3.1
Panasonic	MFG	Asia	388	0.002	0.022	0.032	67.6
NEC Corporation	MFG	Asia	361	0.001	0.023	0.028	34.9
Sharp	MFG	Asia	343	0.022	0.012	0.026	138.0
Nokia Siemens Networks	MFG	EU	217	0.015	0.009	0.014	68.9
NTT DOCOMO	SVC	Asia	211	0.002	0.001	0.027	3200.0
Siemens	MFG	EU	201	0.013	0.018	0.005	-69.7
Texas Instruments	MFG	NA	174	0.000	0.002	0.022	1042.9
HTC Corporation	MFG	Asia	164	0.016	0.009	0.007	-3.6
Philips	MFG	EU	147	0.008	0.019	0.000	-100.0
Nortel Networks	MFG	NA	142	0.006	0.004	0.014	334.8

TABLE 2 MARKET SHARE IN MOBILE DEVICE SALES FROM 2000 TO 2008

Company	2000	2001	2002	2003	2004	2005	2006	2007	2008
NOKIA	30.6	35.0	34.2	35.9	30.7	32.5	34.8	37.8	38.6
MOTOROLA	14.6	14.8	17.0	14.6	15.4	17.7	21.1	14.3	8.7
Samsung Electronics	5.0	7.1	9.5	9.9	12.6	12.7	11.8	13.4	16.3
LG Electronics	-	-	3.0	3.8	6.3	6.7	6.3	6.8	8.4
Sony Ericsson	10.0	6.7	5.2	5.2	6.2	6.3	7.4	8.8	7.6
Siemens	6.5	7.4	8.0	7.0	7.2	3.5	-	-	-
Others	33.2	29.0	23.1	23.3	21.6	20.6	18.6	18.9	20.4

Sources: Gartner's Dataquest

B. Evolutionary pattern, generation shifts and standardization

A study about relationship between standardization and patenting of companies by Blind and Thumm[5] states that companies who have high technical competitiveness are already in a strong position and do not have incentives to join or support standards. This observation implies that companies who have less technical competitiveness such as start-up companies tend to have stronger interest in staking in standardization processes and make their effort to secure essential patents. Drawing on their claim, we hypothesize that the competitive landscape in mobile telecommunication standardization would become more fragmented as technologies advance from GSM through WCDMA to LTE. Underlying assumption to this hypothesis is that interests in standardization accelerate at a higher rate in less technologically competitive emerging firms than in incumbents as relevant technology diffuses and market potential of technologies become more promising as indicated by advancement and deepening of technological standards. We use Herfindahl index to examine the competitive landscape across advancement of standards.

Herfindahl index (also known as Herfindahl-Hirschman Index, or HHI) is used as an indicator to measure the concentration ratio of firms and the amount of competition among them in competition law and technology management areas. The formula is as follows.

$$\mathrm{H} = \sum_{i=1}^{N} S_i^2$$

Where S_i is the market share of firm *i* in the market, and *N* is the number of firms.

The Herfindahl index(H) ranges from *1/N* to one, where *N* is the number of firms in the market. In this study S_i is the ratio of essential patents of firm and thus, the index for each technology is as follows;

- Herfindalh index for GSM = 0.131
- Herfindalh index for WCDMA = 0.098
- Herfindalh index for LTE = 0.085

Decreases in the Herfindahl index generally indicate increases in competition. Our analysis shows that the number of participants of technology standardization processes increase and a competitive landscape tends to be more fragmented as technology evolves.

Secondly, we examine dynamic patterns in the geographic origin of patent holders. We calculated geographic share (North America, Europe, and Asia based on the location of corporate headquarters) of essential patent holders for three generations of standards (Table 3). The results are summarized as follows: 1) the ratio for the number of essential patents by firms in North America is kept staying over generations due to major incumbent companies such as Qualcomm and MOTOROLA; 2) the ratio of firms in Europe is decreasing; 3) the share of Asia is increasing. The dynamic shifts in geographical distribution of essential patents show consistent pattern with the pattern in product markets: Europe's shrinking and Asia's expanding.

TABLE 3 GEOGRAPHICAL DISTRIBUTION OF ESSENTIAL PATENTS: GSM, WCDMA, AND LTE

	GSM	WCDMA	LTE
NA	44.3	47.0	46.1
EU	28.7	25.1	14.2
Asia	27.0	27.8	39.7

When we take a closer look at the geographical distribution by drilling down the nature of player in product markets, we find different patterns between different types of firms. We calculate the share of essential patents claimed by manufacturing firms by geography and by generation of standards (Table 4). The rest includes non-practicing entities or technology consultants, telecommunication service providers, and others. The patents affiliated with North American firms are divided into both manufacturing (68.8% for LTE) and non-manufacturing firms while patents from other two regions are almost dominated by manufacturing firms (for LTE, 98.9% in Europe and 87.2% in Asia). This indicates that technological capabilities relevant to mobile telecom standards are more widely distributed over value chain (spanning from components technologies to design

service for core technologies as done by fabless or non-practicing entities of patented technologies) in North American than in other two regions.

TABLE 4 MANUFACTURING SHARE OF ESSENTIAL PATENTS BY GEOGRAPHY AND BY GENERATION

	GSM	WCDMA	LTE
NA	77.9	62.6	68.8
EU	98.4	99.1	98.9
Asia	97.1	94.9	87.2

Thirdly, activities of Non-practicing entities are intensifying as technology is evolved and standardization begins. NPEs profit from sales of intellectual property rights. As a technology turns out to be subject to more demands either by increasing markets or reduced uncertainty in technological utilization, NPEs will invest more in securing patents in the relevant technologies. In order to examine this aspect we examine how the share of NPEs' essential patents changes over generations of mobile telecom standards and in different phase in standardization. Table 5 shows the share of NPEs' share of essential patents before and after standardization process for each generation of standards. Overall, NPEs share increases as mobile standards advances as indicated by increasing share "Before standardization." When we look at the NPEs' share after standardization, it also increases from GSM to WCDMA (LTE standardization process is still ongoing at the time of this study).

NPE shares of essential patents between pre- and post-standardization period show divergent pattern between two generations (GSM v. WCDMA) compared. While NPE share for GSM decreases after standardization, it rises for WCDMA. NPEs seem to act in a more preemptive way as technologies become mature and markets expand as shown in the increase of NPE share along with technological generation. Although it cannot be confirmed in our analysis, NPEs are more likely than manufacturers to play exploitation strategy rather than preemptive strategy as indicated by a larger share of NPEs in post-standardization essential patents than in pre-standardization essential patents.

TABLE 5 NPE SHARE OF ESSENTIAL PATENTS: GSM, WCDMA, AND LTE

	Whole period	Before Standardization	After standardization
GSM	0.099	0.126	0.094
WCDMA	0.181	0.147	0.244
LTE	0.166	0.166	N/A

VI. CONCLUSION

The leverage effect of standard technologies on market has been considered stronger in mobile communications industry. Therefore, a competition for essential patents among companies is intensifying and may act as "invisible war". In this study, we focus on the co-evolution of markets for technology and markets for products in mobile telecommunications standards and examine about 30,000 essential patents. Unlike the most previous empirical studies that examine only one generation of mobile standards, this study examine essential patents claimed for three consecutive generations, from GSM to LTE.

This study provides an initial and descriptive analysis of data we compiled. Our findings are summarized as follows:

- As technology advances and market expands as captured by shifts in mobile communication technology standards from GSM through WCDMA to LTE, technology competition becomes harsher, as indicated by increase in Herfindahl index of essential patents.
- Our analysis indicates a clear geographic trend in essential patents matched with a trend in product markets: emergence of Asian firms and falls of European strongholds.
- However, at the firm level strength in product markets is not consistently correlated with strength in essential patents. In other words, firm-level heterogeneity must play a substantial role in linking technology to products.
- There is an enormous heterogeneity in geography of firms in terms of the value chain strategy of mobile communication technology. While firms based in either Europe or Asia seem to link the value of essential patents to their manufacturing and product market strategy, firms based in North America comprises two different types in a broad sense. Like European or Asian counterparts, the first group plays a manufacturing-based value exploitative strategy. Firms in the second group, accounting for 31% of firms in North America, play a technology-based value exploitative strategy, independent from manufacturing or market strength of their own and heavily dependent on the influence of essential patents.
- Finally, we found an indication for extended role of NPEs toward two seemingly divergent direction, although in an inconclusive way. NPEs seems to expand into more explorative territory of standardization (in other words, patenting before technological standards are established). On the other hand, NPEs seems to take a stronger presence in exploitative territory of standardization (i.e. patenting after most technical issues for standardization are resolved). This is a puzzling finding which, unfortunately, we cannot dig deeper into at the current stage of analysis.

In this paper, we present some interesting findings about dynamics of technology and markets along with advancement of technologies and markets. Our analysis, although mostly descriptive and data-driven, indicates co-evolution of capabilities in technology space with capabilities in product space not without a nuance. Taking firm-level heterogeneity in both spaces into consideration will lead us to a clearer understanding of this relationship, which directs a promising

avenue for future research.

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