Exploring the co-evolution between Technical Innovation and Technology Standardization in Mobile Communication Industry

YE Weiwei[a], TIAN Hua[b,*]

a Zhejiang University of Finance and Economics， School of Finance and Public Administration， Hangzhou, China

b Beijing University of Posts and telecommunications, School of Economy and Management, Beijing, China

*corresponding author: tel:.+8613718533082, email:tianhua77@bupt.edu.cn

Abstract

Technology standard and technical innovation are the core factors affecting advances of mobile communication competition individually and collectively. By respectively reviewing the past 40 years of evolutions of technology standard and technical innovation, this paper explores the co-evolutions mechanism between technology standard and technical innovation. Based on the analysis, this paper firstly discovers that technology standardization tends to concentrate, while the modes of technical innovation switched from standalone closed innovation to systemic synergetic innovation. Secondly, explores both the co-evolution mechanism and effects between technology standardization and technical innovation. Thirdly, further argues that it is the synergetic innovation that plays a very important role to balance the value creation of technical innovation and value sharing of technology standardization. The conclusions of this paper have important practical implications for nurturing synergetic mechanism of technical innovation ecosystem of mobile communication industry.

Keywords: Co-evolution mechanism; Collaborative innovation mechanism; Technical Innovation; Technology standardization; Mobile communication

1. Introduction

China has witnessed the fast growth of its mobile communication industry over the last two decades since the first mobile operator China Unicon was founded in 1994 (Xia, 2012). Two meaningful institutional changes in telecommunication sector with Chinese characteristics, including the twice restructuring of the telecom operators around 2000 and 2008, were all mainly for mobile communication and made some far-reaching influences on the development of the mobile communication (Xia, 2011) By the end of June of 2014, mobile phone subscribers reached to 1.26 billion, meanwhile penetration rate reached to 92.6 phones for every 100 people (MIIT, 2014). With the continuing expanding of mobile communication networks, majority of the mobile communication standards from 1G systems to 4G systems, had been operated or experimented within China whatever their results were success or failure.

As a result, a lot of actors and organizations have made great progresses, contributing to the construction of ecological system of mobile communication. For instances, not only three network operators have been nurtured their powerful operation capabilities; network equipment manufacturers such as Huawei and ZTD, have been enormously successful while other MNC's were facing the devastating failures; and content/application providers such as Baidu and Tencent etc., achieved greatest successes too; but also service providers such as China Unionpay and Alibaba, handset manufacturers like Huawei, Millet, Lenovo and ZTE, all have been gradually raised.

While the ecological system of mobile communication has been becoming more and more diversified, the unsatisfactory performance of the homegrown TD-SCDMA standards can't be widely accepted in such a good market environment, not only China Mobile who invested a lots but failed to withdraw their investment. Why could China fail to enjoy the fruits from the victory of the homegrown TD-SCDMA? Is the innovation more important than standardization? What is the co-evolution mechanism between technology standardization and technical innovation?

In order to explore these questions, this paper firstly generalize the past 40 years of evolutions of the successive generations of standards in mobile communication industry; Secondly, the paper reviews the corresponding evolutionary process of the technical innovations mechanism and their ensuing results which accompanied by the standardization processes of mobile systems; Thirdly, explores the co-evolutions mechanism between technology standard and technical innovation.

The contributions of this paper are as follows: Firstly, it provides a historical review on successive processes of standardization in the mobile communication from the first beginning, and discovers in a global perspective that the model of standardization shifted from performance-based de facto standards to design-based de jure technology standards between the 2G and 3G mobile communication system accompanied by the emergence of 3GPP and 3GPP2.

Secondly, based on comparison of the functions of technical innovation and technology standardization, this paper elicits that the major force of technical innovation was oriented to make varied for value creation and the main dynamics of technology standardization was focused on integration for value sharing.

Thirdly, according to analysis of mutual effects and co-evolution mechanism between technology standardization and technical innovation, this paper finds that the synergetic innovation mechanism played a decisive role of promoting the performance of technology standardization and technical innovation in mobile communications industry rather than standardization.

2. Literature review

2.1 Innovation impact on standardization

In most cases, technology innovation functioned as market dynamics to determine a de facto standard. According to U-A dynamic model, alternative technologies intensely compete until the dominant version gains sufficient market share to become the single standard (Utterback, 1994; Tassey, 2000). Market control by one firm can truncate this competitive process. Such control is particularly effective in cases of increasing returns and can quickly force acceptance of the monopolist's proprietary technology element as the standard (Tassey, 2000). So for a de jure standard, the literature normally recognizes that standardization is a down-stream phase of innovation rather than a basis of technology innovation. So, technology standards only serve as the references for technology innovation (Jiang et al., 2012).

2.2 Standardization impact on innovation

Standardization affects the R&D, production, and market penetration stages of economic activity and therefore has a significant collective effect on innovation, productivity, and market structure (Tassey, 2000). However, these effects can be both positive and negative.

Standards play an important positive role to promote and drive innovation. The use of standards triggers innovation because technology providers can reduce their costs to serve customers by applying or providing innovative technologies. Standards can codify information of a particular technology, disseminate new knowledge, facilitate interoperability between new products and services, and provide a platform for further innovation (Jiang et al., 2012; Friedrich J, 2011). In addition, standardization played an important role to synchronize disjointed technical innovations in a systemic innovation, this then led to the design and proto-type manufacture of viable products that attracted the attention of the business people to seriously consider their introduction into the market (Kano, 2000).

However, standardization can increase efficiency within a technology life cycle, but it also can prolong existing life cycles to an excessive degree by inhibiting investment in the technological innovation that creates the next cycle (Tassey, 2000). So, a two-tiered approach in mobile communications, which defined successive generations of standards and only specified the interface specifications between sub-systems, was in order to alleviate negative effects of standardization on technical innovations (Kano, 2000).

3. Research design

3.1 Research architecture

Since the days of Schumpeter (1950), technology and technical innovations have played an important role in the studying of economics, industrial organizations and development (Dosi, Teece & Chytry, 1998; Chandler et al., 1998; Kano, 2000). However, the literature is still seriously lacking for further researches focusing on innovations in mobile communication. Otherwise, standards were regarded as a tool for regulation and technical interconnection in telecommunication industry (Kano, 2000, Jiang et al., 2012), but the papers are seriesly short of exploring the relationship between innovation and standardization in mobile communication (Jiang et al., 2012).

Hence, this paper will review the past 40 years of evolutions of the successive generations of standards in mobile communication industry in section 4. Secondly, this paper will further review the corresponding evolutionary process of the technical innovations in section 5. Thirdly A systemic thinking would be made by combining the viewpoints of both innovation and standardization, to exploring the co-evolutions mechanism between technology standard and technical innovation in section 6.

A case study method (Eisenhardt, 1989; Yin, 1989; Gao & Liu, 2012) was used to study this complex process, focusing on identifying the key factors and underlying mechanisms affecting this process. Specifically, the study tried to answer the following questions: what are the key functions that technical innovation and technology standardization played during the evolution of mobile communication. What factor impacts the co-evolution process?

3.2 Research method

Data were collected for case analysis mainly by means of searching for the second data in literature and interviewing people who are familiar with the development of the mobile communication. There are two aspects of considerations to do so: Firstly, one of the authors started his career in 1986 as a telecommunication senior engineer engaged in technical project of various telecommunication systems. For example, Ericsson's AXE-10 Programmed Exchange System in China Telecom for 13 years, GSM mobile network in China Unicom for 3 years, IP broadband backbones network in China Netcom for 4 years. Hence, the advantage of author's career benefited for interviewing the concerning experts of communication technologies and officials in government agencies. Secondly, two authors of this paper have studied together on collaborative innovation during the doctoral period since 2006, and fostered good capacities to make senses and capture the key points at the interviews.

These interviews occurred between 2010 and 2014. People interviewed are from many organizations and government agencies, including multinational firms such as Siemens,

Ericsson, Alcatel-lucent, Qualcomm, LG, and Samsung; key domestic equipment firms such as Datang, ZTE, Huawei, and Potevio; mobile carriers such as China Mobile, China Telecom , and China Unicom; content/application providers such as Baidu and Tencent; service providers such as China Unionpay and Alibaba, Handset makers such as Huawei, ZTE, and Lenovo, Millet; IC suppliers such as T3G, Spreadtrum Communications, CCSA, CYIT; TD-SCDMA Industry Alliance, TD-SCDMA Technology Forum; government agencies such as MIIT, the Ministry of Science and Technology (MOST), and the National Development and Reform Commission(NDRC).

Following the grounded theory development principles, data analysis was conducted simultaneously with data collection (Glaser &Strauss, 1967; Strauss & Corbin, 2008).According Gao & Liu(2012), commentaries were written on each interview and whenever a new theoretical concept emerged. To assure validity, the theoretical sampling principle and data saturation principle were followed. Patterns were also searched for by comparing across events to look for different interpretations of those events by the key players as many as possiple.

4. Co-evolution mechanism between Standardization and Innovation

4.1 Evolution of standardization

Since the first mobile phone set of the 1G Systems put into service in 1973(Chen, 2013), systemic innovations in mobile communication are the successive generations, each of which required a new standard (Antonelli, 1998). From the viewpoint of standardization, a systemic innovation requires an overall framework and a set of interface specifications among component subsystems. But emergence of mobile phone equipments was regarded as a component or sub-system of total fixed telephone system rather than as stand-alone system in the mid-1970s.

The first generation (1G) mobile systems, which supplied public cellular mobile communication services as a system rather than sub-system, was standardized around 1980s. Since there is no predecessor to follow, the type of innovation of 1G system obviously was a systemic innovation by setting up of a new standard architecture..

The 1G systems was mainly launched by monopoly operators of fixed telecommunication networks, or closed cooperators between operators and manufactures. For example, NTT mobile System which developed originally by the Japanese biggest telecommunication corporation NTT, and firstly operated in 1979; Nordic Mobile Telephony(NMT) was launched in 1981 and Total Access Communication System(TACS) was launched in 1985 in Europe; Advanced Mobile Phone System (AMPS) developed independently by AT&T and put into use around USA in 1983. Besides that, the 1G standard was all regional standards, because the

mobile phones at those times were too big to carry across the Atlantic or the Pacific Oceans.

The second-generation (2G) digital systems， were standardized in early 1990s, including two main streams (Kano,1999): Firstly, the personal communication systems (PCSs), such as Digital Enhanced Cordless Telecommunications (DECT) of Europe standardized in 1993, Personal Handy phone System (PHS) of Japan also in 1993, and as many as seven standards in USA in 1990s. Secondly, the cellular mobile systems, such as Global System for Mobile Communication (GSM) of Europe in 1992, Personal Digital Cellular (PDC) of Japan in 1993, and ANSI-136 (based on TDMA technology) and ANSI-95 (based on CDMA technology, dubbed as CDMA one) of USA, standardized in 1993 and 1995 respectively. In this paper the authors pay more attentions to the cellular mobile systems rather than the personal communication systems (PCSs) in order to focus on the research target.

The 2G standard was also regional standards based on global viewpoint, because they were not approved officially by ITU. However, from the regional viewpoint of Europe, the GSM standard was regional de jury standard within Europe, which officially approved by ETSI. Due to the double harvests in monopolized market in Europe and competitive market outside Europe on one side, and increasing the efficiency of economic activities by improving products' compatibility & interoperability on the other side, the GSM standard gained more competitive advantages in the market than the other competitors, and began to show a prototype of world class standards.

The third-generation (3G) multimedia systems，included two main streams: International Mobile Telecommunication-2000 (IMT-2000) and wiMAX. In this paper the authors ignore the wiMAX in order to focus on the research target. Three main technical standards were covered by IMT-2000 and were officially standardized in year 2000. The GSM evolved 3G system standard (dubbed as WCDMA), was developed by an industry forum called the 3GPP (3rd Generation Partnership Project); and ANSI-95 evolved 3G standards (dubbed as CDMA2000) by the 3GPP2. While Japan decided not to evolve its 2G system which called PDC, Chinese began to become a new member of the 3G family with the homegrown TD-SCDMA standard instead.

The 3G standard was global standard, which was officially approved by ITU and licensed by governments around the world as regulation policies. The procedures and modes of standardization changed greatly from 3G, which left the cut-throat competition behind the standard and paid more attentions to the technical design-based proposals.

The fourth generation (3G) LTE syetem， dominated by the 3GPP (3rd Generation Partnership Project). LTE Release 8 was frozen in December 2008 and this has been the basis for the first wave of LTE equipment. The 3GPP officially began research woks from R8 in 2004, and released five versions of standards about LTE until now, such as R8、R9、R10、R11、R12. The standard version of R10 which be completed in March 2011 and be called LTE-Advanced system (Sun et al., 2013). The two versions of LTE family, such as FDD-LTE(WCDMA evolved 4G system standard) and TD-LTE (TD-SCDMA evolved 4G

system), are very similar.

In fact, they differ only in the physical layer and, as a result, the version implemented is transparent to the higher layers. This means that UEs will be able to support both TD-LTE and FDD-LTE with one chipset with only minor modifications required. All major chipset vendors, such as ST-Ericsson, Altair, Semiconductor, and Qualcomm have already released chipsets that support both LTE flavors. UEs based on those chipsets are available from Sony Ericsson, Huawei, Samsung, Nokia, and others (Ascom, 2012).The architecture of distributing the intelligence amongst the base-stations in LTE, provides a chance to enjoy same base station by different operators.

By generalizing the successive generations of standardization in mobile communication, three trends could be highlighted:

Firstly, the number of standards from 1G to 4G was gradually deceased while reached the peak number more than 10 standards for 2G systems, for example, three versions in IMT-2000 family and two versions to only one LTE family. The trend is clear that the form of standards is integrated based on the viewpoint of quantity of standards.

Secondly, the differences between the standards became smaller. For 3G standards of IMT-2000 family, there were a little differences among the three standard versions due to backward compatibility with different 2G systems; and for 4G standards of LTE family, there were only small differences in the physical layer of user terminals. It is obvious that the content of standards is getting integrated based on the viewpoint of differences between the standards.

Thirdly, the model of standardization has been shifted between 2G and 3G system. According to preceding classification of the standards as four types, the standards for 1/2G systems are regional performance-based de facto standards, which mainly determined by market dynamic, the standards for 3/4G systems are global design-based de jure standards, which mainly determined by consensus of various combinations of vertical and horizontal consortia and accepted by governments finally. Understanding the transition of standardization models can clarify the pattern of market competition after the deployment of 4G standard to reshape new market advantages.

4.2 Evolution of innovation mechanism

Since the first mobile phone set of the 1G Systems put into service in 1973, the global market place and the information and telecommunication technologies have gone through tremendous changes. The traditional approach of self-reliance or self-sufficiency for global competition became a virtually impossible goal. Even the global leaders in their respective industries found it necessary to find collaborative partners to design an innovative value chain, combining their own core competencies with that of other world-class firms (Tapsott, 2006). Hence, the models of innovation mechanism in mobile communication industry also have

varied rapidly from closed innovation to open innovation at the firm's level, and from standalone innovation to synergetic innovation based on innovation system viewpoint. Hence, this paper bases on the perspective of industry innovation system level to divided innovations into standalone closed innovation and systemic synergetic innovation, in order to explore the evolution of innovation mechanism in mobile communication industry.

By generalizing the evolution process of innovation mechanism in mobile communication, three trends could be highlighted:

Firstly, the systemic synergetic innovation was pulled by the market dynamic forces. Need for compatible mobile communication system in that mobile phones could be used around the world. In 1/2G systems because users could go more easily across national borders in Europe, regional standardization within Europe was considered more necessary than other countries. As a result, closed collaborative innovation mode was first operated in Europe. After mobile phones had become so small as to be carried in a pocket, and many people traveled around the world suffered from incompatible 2G standards adopted by different countries. Therefore, motivation of users would like to use the same mobile phone and the same mobile phone number around the world, became the dynamics of synergetic innovations under on a global basis (Kano, 2000).

Secondly, the innovation mechanism was dominated by the international standard organizations such as 3GPP and 3GPP2 since the introduction of 3G system. The 3GPP and 3GPP2 play very important role as focal organizations in the ecosystem of innovation to achieve synergies between actors and organizations in mobile communication industry around the world, such as government, network operators, network equipment manufacturers, handset manufacturers, univversities etc. to carry out systemic synergetic innovation for value creation.

Thirdly, the balance between the integration of the mobile communication system and diversification of users terminals is realized by the a two-tiered approach in mobile communications, which defined successive generations of standards and specified the interface specifications between sub-systems in order to alleviate negative effects of standardization on technical innovations (Kano, 2000).

4.3 Balancing value creation and value sharing by synergetic mechanism

There are two complementary forces promoting the co-evolution of the mobile communication, i.e. the technical innovation force and the technology standardization. The force of the technical innovation which dominated by market factors promotes value creation for the diversity of the mobile systems and auxiliary equipments, while the force of the technology standardization which dominated by regulation factors guarantee integration disjointed innovation for value sharing.

In the previous literature, the government should play the role to coordinate with both the

technical innovation force and the technology standardization in search for balance. Such as, relevant government departments should be keen to discover and absorb the value of innovations, and release it for technology standard at the right time, to ensure the space for industrial technology innovation and the reasonable restriction on industry development, but problem is how can ensure the government to do all the decisions correctly?

However, the synergetic innovation mechanism, which dominate by 3GPP and 3GPP2 as focal actors in the mobile communication ecosystem, play important role. The function of the synergetic innovation mechanism, like a resonance between the wave of technical innovation force and the wave of technology standardization, balance the synchronization of them to ensure the diversity and integration of the mobile communication system.

5. Discussion and conclusion

5.1 Discussion

Both technical innovation for value creation and technology standardization for value sharing are very important in the advances of mobile communication. However, the synergetic mechanism is more significant to balancing the value creation and value in a vivid industrial innovation system. The lack of synergetic mechanism in an innovation ecosystem to ensure synergetic innovation, no standard that even has gained the first mover advantage can survive from the intense market competitions. TD-SCDMA was based mainly on technologies from Datang who proposed individually in 1998, and accepted as one of the three international standards by ITU in 2000 and 3GPP in 2001. The advantages of first mover from the 3G standard is very tremendous, but Until China Mobile officially adopted TD-SCDMA in January 2009, the synergetic innovation ecosystem for homegrown TD-SCDMA had not been established duo to a lot of reasons, such as the network operators hesitated to operate, network equipment manufacturer Huawei was reluctant to join in at the beginning, most handset manufacturers worried their investments, and even the attitudes of government is uncertain for a very long time (Gao &Liu, 2012). As a result, the operators of TD-SCDMA such as China Mobile are searching for a next-generation technology that will overcome the limitations of TD-SCDMA, such as limited/expensive handsets available only in the domestic market; multiple mode handsets needed for global roaming (Ascom, 2012). So, work hard in establishing synergetic innovation ecosystem for 4G TD-LTE, should be the key to the catch-up strategy for china mobile communication industry.

5.2 Conclusion

By reviewing both the successive generations of standards and the corresponding evolutionary process of the technical innovations in mobile communication industry from the

first beginning , the paper reviews the corresponding evolutionary process of the technical innovations respectively and comprehensively, the paper explores the co-evolutions mechanism between technology standard and technical innovation.

The contributions of this paper are as follows: this paper elicits that the major force of technical innovation was oriented to make varied for value creation and the main dynamics of technology standardization was focused on integration for value sharing, and the synergetic innovation mechanism played a decisive role of promoting the performance of technology standardization and technical innovation in mobile communications industry rather than standardization only.

The conclusions of this paper have important practical implications. For example, the government should realize that the success of the 4G standard and market requires a competent innovation ecosystem encompassing participants in various roles to realize the synergy. In addition, the related businesses should reshape their collaborative innovation strategies based on their network positions and should develop new synergistic innovation-based competitive advantages instead of adhering to the paths that were successful in the past.

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References

1. Abernathy, W. J & Utterback, J.M.（1978）. Patterns of Industrial Innovation. Technology Review, Vol. 80, No. 7: pp40-47.
2. Afuah, A. N. & Utterback, J.M. (1997). Responding to Structural Changes: A Technological Evolution Perspective. Industrial and Corporate Change, Vol. 6, No. 1: pp183-202.
3. Chesbrough, H. (2003). Open innovation, the new imperative for creating and profiting from technology. Harvard business school press.
4. Christensen, C. M. & Overdorf M. (2000). “Meeting the Challenge of Disruptive Change,” Harvard Business Review, pp. 66-76.
5. Christiansen, J.A.(2000). Building the Innovative organization. London: MacMillan Press.

6. Friedrich J (2011) Making innovation happen: the role of standards and openness in an innovation-friendly ecosystem. In Proceedings of 2011 7th international conference on standardization and innovation in information technology, Berlin, pp 1–8
7. Gao, X.D. & Liu, J.X.(2012). Reprint of: Catching up through the development of technology standard: The case of TD-SCDMA in China. Telecommunications Policy, 36: pp817–831.
8. Haken H.(1983). Synergetics, An Introduction. Spinger.
9. Henderson, R. M. and Clark, K.B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Science Quarterly, 35 (1990): pp9-30.
10. Hou K (1996) International standardization compiling. Shanghai University of Finance and Economics Press, shanghai.
11. Hua, H., Wan, X., Lv. K., Xu, M.(2012). Mapping China's 3G market with the strategic network paradigm. Telecommunications Policy, 36(2012): pp977–988.
12. Jiang H., Zhao, S.K., Zhang,Y., Chen, Y.(2012). The cooperative effect between technology standardization and industrial technology innovation based on Newtonian mechanics. Infromation Technology Management, 13:pp251–262.
13. Kano, S.,(2000). Technical innovations, standardization and regional comparison—a case study in communication communications. Telecommunications Policy, 24: pp305–321.
14. Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. American Economic Review, 86(3): pp562-583.
15. Lichtenthaler U (2012) Licensing technology to shape standards:examining the influence of the industry context. Technol Forecast Soc Chang 79(5):851–861
16. Roberts, E. B. (1991). Entrepreneurs in High Technology. New York: Oxford University Press.
17. Sang M. Lee, David L. Olson, Silvana Trimi, (2012). Co-innovation: convergenomics, collaboration, and co-creation for organizational values. Management Decision, Vol. 50, Iss:5, pp817 - 831
18. Schumpeter, J.(1950). Capitalism, Socialism and Democracy. Happer and Row, New York.
19. Sull, D. N.(1999). "Why Good Companies Go Bad," Harvard Business Review, pp. 42-52.
20. SUN Zhengqiang, ZHU Caiqin, Maochongjie, CHEN Yunqing. (2013). Constructing carrier—grade LTE network. Beijing: Publishing House of Electronics Industry.
21. Tassey, G.(1997). The Economics of R&D Policy. Quorum Books, Westport, CT.
22. Tassey.G.(2000). Standardization in technology-based markets, Research Policy. 29: pp587–602.
23. Tushman, M. L. and Anderson, P. (1986). "Technological Discontinuities and

Organizational Environment," Administrative Science Quarterly, vol. 31: pp 439-456.

24. Ulrich, K.(1995). The role of product architecture in the manufacturing firm. Research Policy 24: pp419–440.
25. Utterback, J. M. (1994). Mastering the dynamics of innovation. Harvard Business School Press, Boston, Massachusetts.
26. Utterback, J. M. and Suarez, F.F.(1993). Innovation, competition, and industry structure. Research Policy, 22: pp1-21.
27. Utterback, J.M. & Abernathy, W.J.(1975). A dynamic model of process and product innovation. Omega, 3(6): pp639-656
28. Weil, H. B.(1996). Commoditization of Technology-Based Products and Services: A Generic Model of Market Dynamics. Sloan School of Management Working Paper #144-96, Massachusetts Institute of Technology, Cambridge.