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The decision and process of standard-setting in a catch up strategy for latecomer countries: the cases of China and Korea

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The decision and process of standard-setting in a catch up strategy for latecomer countries: the cases of China and Korea

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Abstract:

This paper examines standard-setting process in China in relation with standard-setting processes in Korea to illustrate the key factors and mechanisms affecting catch up in latecomer economies, particularly from the perspective of government decision and support. It has three contributions to the existing literature. First, it offers a new perspective in understanding standard-setting in the context of latecomer economies. Most of the existing research focus on either the Chinese standard or pay attention to the Korean standards. Only a few studies have compared the standard-setting process from the two countries. Although there are a number of studies on Chinese innovation and catch up, discussions and analyses from standard-setting perspectives are still rare. Until now, within latecomer economies, the only successful standard-settings come from Korea and China (ITU, 2007) and lessons drawn from the two countries will be significant. This research fills gap and explores catch up strategy from the view of standard-setting based on the successes in two countries. Second, this paper further articulates the key factors and mechanisms affecting catching up through technology standard development, particularly from a government decision perspective. How a technology standard is set in a latecomer economy and how the Chinese government has dealt with the diverse interests of various market actors while pursuing its own policy agenda are being explored. It is of particular interest to investigate to what extent government intervention can modify the outcome of a path-dependent process of standard competition. Third, the findings have important practical implications. This paper aims to bridge catch up theory and standardisation theory to understand how the method of standard-setting can serve national goals in a latecomer economy. It also examines neo-classical and path dependence theories in the context of latecomers.

Key words: catch up, latecomers, telecom, standardisation, innovation, path dependence

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1. Introduction

The existing literature on catch up focuses mostly on the transfer and imitation of matured technologies from MNCs or the internal development of emerging new technology. The latecomer's technological catch up is regarded as benefiting from institutional intervention and government control (Amsden, 2001; Choung, Hwang, Choi, and Rim, 2000 and Vogel, 1991). But different countries present different patterns based on their own industry structures and dynamics. The development of Korean industries relied on giant "Chaebols" (large industrial groups) and the Taiwanese development came from small and medium enterprises (SMEs) (Choung, 1998). Standardisation received increasing attention from researchers as standards played a significant role in achieving economic goals (Blind, 2011), and the standard owners might capture the direction of future technological progress through standard-setting. Over the past two decades, a growing body of technical standards in the telecom industry has emerged; focusing on the emergence of technical standards driven by technical and economic interests, while paying less attention to the political dimension (Antonelli, 1998; David & Steinmueller, 1994). According to Antonelli (1997), ''Path dependence defines the set of dynamic processes where small events have long-lasting consequences that economic action at each moment can modify yet only to a limited extent." Recently research has started to pay attention to non-market processes or mixed processes between many actors, including government, institutions and culture. It has been recognised that the political and social interests and pressures behind technical standardisation play a crucial role in defining the path of technical and industrial development (Dosi, 1982; MacKenzie & Wajcman, 1985). However there are no sufficient studies about standard-setting in the context of latecomer countries (Ernst, 2009; Jho, 2007; Suttmeier & Yao, 2004; Suttmeier, Yao, & Tan, 2006).

In recent years, the Chinese government has become more involved in initiating and facilitating technology standardisation, and there are more academic debates and discussions about the Chinese standardisations (Kennedy, 2006; Ure, 2006). During the 1990's, China's high-tech sector was experiencing a milestone event: the birth and operation of the Chinese independently designed 3G standard "TD-SCDMA" (Time Division-Synchronous Code Division Multiple Access). TD-SCDMA was the 3G standard proposed by the Chinese government to ITU in 1998, and it was approved as one of the international standards in 2000. After eight years of development, TD-SCDMA was launched commercially in China in 2008. This also caused the division of the Chinese market into three types with other two standards WCDMA (Wideband Code Division Synchronous Address) and CDMA2000 (Code Division Multiple Access).

Along with the standard-setting from latecomers, related research accordingly emerged. Gao *et al.* (2014) categorised the multiple-faced role of government in technology standardisation in catching up contexts. Pierre Vialle *et al.* (2012) investigated to which extent economic actions and public policy initiatives could modify the path-dependent process of competition between standards. Gao *et al.* (2012) found that the standard-setting of TD-SCDMA was a complex co-evolution process between corporate strategy and government policy aimed mainly at solving the challenges of latecomer disadvantages. Whasun Jho *et al.* (2007) examined empirical cases of standardisation in the Korean mobile market as vehicles for approaching the broader political and institutional context of standardisation in telecommunications. Regarding studies on Chinese innovation, researchers usually studied specific industries and explored economics insights from an evolutionary perspective. For example, Wu *et al*. (2009), attempted testing the preliminary conceptual model of secondary innovation and explored new thoughts and implications for further development. Liu *et al.* (2009) examined how companies' technological capabilities development were affected by corporate governance. Liang *et al*. (2009) constructed a conceptual model for the sector innovation system and utilised this model to analyse the main mechanisms of interaction in the context of Chinese autonomous innovation. Li *et al*. (2009) delineated the evolution path and a theoretical model was proposed which included six factors (firm strategy, demand, resource, policy, and technology paradigm and industry structure). Ludovico *et al*. (2009) examined the latent factor structure of the individual, managerial and cognitive dimensions of knowledge generation and investigated how these factors relate to each other and to product innovation in the context of companies in China. Few researches explored catch up and innovation strategy in a latecomer economy from the telecommunications standard-setting perspective.

2. Research Methods

The case study method is used to excavate this complex process; focusing on the identification of the key factors and underlying mechanisms affecting standard-setting in a context of latecomer economy (Eisenhardt, 1989; Glaser & Strauss, 1967; Strauss & Corbin 2008; Yin, 1989). The research is primarily based on an exploratory qualitative method which fit the research setting as a pilot case study. Information was collected primarily from archival data and interview data. Archival data include government documents, regulations, laws, statistics, media reports, company statements and research publications. Interviews were collected by targeting four categories of interviewees: government officials, industry professionals, industrial organisations and academics. Government documents were acquired from either libraries or requested from government departments. The searching and retrieving of media reports, company statements and research publications were done through the internet. For web based sources, priorities were given to government portals, news portals, government knowledge databases, prestigious trade websites and telecom carriers' websites. International archival data was mostly focused on the SCI and SSCI databases.

For each interview, the researchers prepared concise key research questions and the interviews were carried out by sub-questions, tier upon tier. For each interview, the selection of theories also guided every question put to the interviewee. All interview conversations were recorded by digital recorder. Notes were taken ad hoc. Useful data from interviews were edited and coded. On top of the large quantity of information obtained through the interviews, information was sorted by skipping the non-relevant discussions and outlining the answers to the key questions. To capture useful data from the voluminous raw materials, it was attempted to mine the relevant information from the raw archival material centred on the main theme of the research, by marking the related sentences, paragraphs, or passages, or inserting abridging comments in page margins (Yin, 1989). For each interview reference was made to the research question list, and each question was answered based on the interview contents. The information of the interviews was integrated into different parts of the analysis. An initial concept of mapping was established along with the analysis of archival documents and increasing of the interviewing data. Through these interviews and seminars first hand industry phenomena were observed and insights obtained.

It is essential to select appropriate interviewees and secure reliable information sources. The selection of interviewees relied on the researchers' expertise in the field of telecommunications. The contribution made by these interviews with people involved in different areas of the telecommunications industry has played a significant part in the overall study. The authors interviewed three officials in three different cities in Beijing and Shanghai, 18 industry professionals, five Chinese academics, three members of staff of industrial organisations and several ad hoc interviewees (for example during breaks at conferences) in Beijing, Shanghai and Hangzhou. The interviews (not including ad hoc interviews) varied from one hour to three hours in different locations including company offices, coffee bars or interviewee's home. The interviews were conducted in a semi-organised way. The selection criteria for interviewees were as follows: 1) Relevant industry experience; 2) Continual contribution to ongoing projects in their field; 3) Ability to provide industry insights.

The structure of this paper is divided into 7 parts. The first two parts are introduction and research methods. Part three is the literature review, elaborating on catch up theory focusing on window of opportunity, technology development from a neo-classical paradigm, standardisation theories and neo-techno nationalism. In part four, the paper will review the background decision and process of TD-SCDMA. The development process and industrialisation process will also be introduced. Then in part five, two Korean standardisation cases, WiBro and CDMA2000, will be presented. Part six is the discussions and analyses based on the previous facts study. Finally pat seven summarises the findings and presents the potential policy learning lessons.

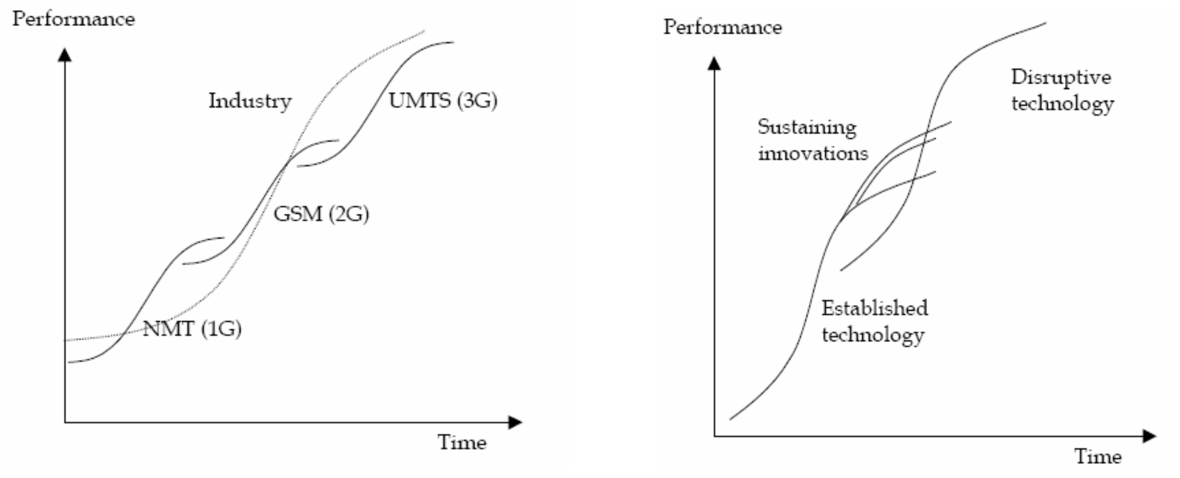
3. Literature review

3.1 Catch up theory and technological life cycle

On catch up theory for latecomers, Lee and Park (2010) identified three windows of opportunity. One is the emergence of a new techno-economic paradigm (Perez and Soete, 1988) which place the incumbent and latecomer at the same starting line of the competition (Lee, Lim and Song, 2005). The second window of opportunity is the business cycle where it opens during the business cycle downturn; incumbents may have hard times while latecomers may have lower entry costs than the incumbents (Lee and Mathews, 2011; Mathews, 2005). The third window of opportunity is government regulations (Lee, Mani, and Mu, 2011). New windows are likely to open, as the techno-economic paradigm and business cycles are constantly changing.

Followed by the first "techno-economic paradigm", numerous experiments are carried out during the beginning of a product life cycle, particularly in terms of different designs and technologies resulting in numerous innovations (Utterback 1994). In the early development stage accelerated market dynamics and persistent uncertainties are also observed. In the mature phase innovation rate fades as the products become standardised and the market is manipulated by oligopolies. In the decline stage the market contracts and technology exits. The concept of technological life cycles can be applied to the evolution of mobile communication technologies. The transformation from first generation (1G) Nordic Mobile Telephony (NMT) technology to second generation Global System of Mobile (GSM) constituted a shift in technological life cycles. The coexistence and shifts of different technological life cycles are not an S-curve, which is prone to disruption. The 1G mobile technology (*i.e.*, Nordic NMT) began in 1981 and made up the first cycle. The digital technology GSM entered the market as a disruptive technology before NMT had entirely withdrawn from the market; GSM developed into the dominant technology replacing both NMT and even fixed telephones. Dalum (2002) stated that with the further development of mobile technology, 3G, as the next generation technology, could be predicted according to the technology life cycle. Next generation technology would have to go with the evolution of other technologies. The charts of S-curve technology and technology life cycles are illustrated in Figure 1.

Figure 1:
S-Curve Technology and Mobile Technology Life Cycles



(Source: Dalum 2002)

3.2 Technological development: path-dependent or "social fabric"?

The neo-classical paradigm argues that technological development follows a predetermined trajectory because there is no cost during assimilating processes (Williams & Edge, 1996). Neo-classical economists also claim that although cultural and ideological aspects exist, their influence is not enough to change the predetermined trajectory. However, Nelson and Winter (1982) criticised that the neo-classical model neglects actors' decision-making freedom of manoeuvre in respect of organisational routines, political and legal frameworks and other institutional obstacles. Archibugi & Michie (1997) argued that technological changes appear within a "social fabric" circumstance, where technology cannot be dealt with isolated from the rest of the economic and social system. Dosi (1982) reinforces the link between technology and the social fabric by arguing that technology evolves in a path-dependent way, social and political changes are key ingredients for technological innovation along the "technological paradigms". Technology evolves along a relatively ordered track with technological change assuming nuanced forms depending on the political and cultural influences (Dosi et al., 1988; Tyson & Zysman, 1989).

3.3 Standardisation

Standardisation is one of the crucial factors in a technology trajectory. According to Farrell and Saloner (1986) "standardisation" is a coordination process resulting in the production of goods that are interchangeable or compatible. Standards in telecommunication systems play a central role in maintaining service quality (David & Steinmueller 1996). The highest priority of standard-setting is interoperability. However, they also stated that technical compatibility standards do not flow "naturally" from the best engineering practice, but rather reflect the full range of strategic behaviours. Tushman and Rosenkopf (1992) argued that a standard is typically the result of a complex interplay between technological factors and user demands as well as among political, social and economic factors. Different technological designs backed by different sponsors compete for the position of dominant design in a process wherein economic, technological, and socio-political factors are intertwined. Generally, the more complex the product, the more actors align to a technological design and the more complicated becomes the sponsoring role. This means that a complex system should focus on interfaces and negotiations with different users and producers of complementary products, through which it evolves from simple technological artefacts to more complex ones. Network effects indicate that the utility derived by a consumer is affected by the total number of consumers subscribing to the same network. The adoption of a certain system will be partially dependent on the number of other consumers purchasing similar systems. A large installed base is associated with higher rates of adoption for a specific technology. Some first-mover advantages have an influence on the emergence of a dominant design (Katz and Shapiro, 1985). It follows that the higher the switching costs, the more difficult it may be for a company to attract customers from rivals, which results in a more loyal customer base. From a path-dependency perspective, a company's ability and incentive to adopt a newer technology largely depend on its level of related experience with prior technologies (Lyytinen and Robey, 1999).

3.4 The practice of standard-setting

Political forces influence standard-setting; they are complicated and difficult to predict. David and Steinmueller (1996) observed that government regulatory bodies may have an interest in standard-setting, because some government agencies hold the authority to regulate the industry's players. They perceived that the results of standardisation activities affect important national goals such as protecting domestic employment or maintaining defence capabilities. Second, government intervention also tends to accentuate identifiable "vested" interests. They pointed out that governments have incentives both to promote and to discourage the adoption of inter-operable compatibility standards in telecommunication services. The incentives to promote standards arise when compatibility standards will contribute to user welfare, while having either positive or negligible adverse effects on domestic producers. When governments must weigh the promotion of inter-operable compatibility standards against the demise of a domestic producer or the compromise of other perceived national interest, common international standards or inter-operable compatibility standards are likely to be neglected. One way to preserve a domestic market position is to mandate or promote the use of compatibility standards to achieve inter-connectivity rather than inter-operability. Inter-connectivity assures that two devices may be connected through a converter or bridge that renders them mutually compatible. A government policy favouring inter-connectivity is most likely to provide more opportunities for domestic production. David and Steinmueller (1996) warned that such protection should be weighed against the possibilities of retaliation and more importantly, major consumer welfare losses arising from promoting an "inferior" standard.

3.5 "Neo-techno-nationalism" "Neo-techno-nationalism" that is termed by Yamada (2000) has four main characteristics: expanded state commitment to promote technical innovation domestically; further reliance on the private initiative and the public-private partnerships; further openness toward foreign R&D entities; and expanded commitment to international rule-making and policy coordination (Yamada, 2000). There are two alternatives of national technology strategies in the neo-techno-nationalism. The first is "fast follower" mode. In this approach, the dominant architecture is normally not challenged and it serves as a type of collective good, infrastructure or framework. The second approach is to challenge the dominant architecture, attempting to replace it with a new one and bear the costs of providing the collective good (Naughton & Segal, 2003). But it is higher-risk, costly and likely to be chosen only by countries with substantial resources: abundant financial resources; large markets with the potential to attract in terms of economy, institution and culture; an innovative R&D system which is linked to an economy of proven productivity and substantial political power able to manage large risks. In addition, it might also be undertaken by countries dissatisfied with the royalties, they must pay (Naughton & Segal, 2003).

4. About the TD-SCDMA: background, decision and process The Chinese company "Datang" proposed in 1998 TD-SCDMA to ITU as a candidate of 3G standards with the support of the Chinese Government. ITU received 16 applications from the United States, China, Japan, South Korea and various European countries. WCDMA was initiated by European and Japanese manufacturers and other standardisation organisations. WCDMA naturally evolved from the 2G mobile communication system. The European Telecommunications Standards Organisation - European Telecommunications Standards Institute Special Mobile Unit (ETSI SMG) adopted the WCDMA proposal as a standard in January 1998. The competitor CDMA 2000 was the American proposed air interface standard, sponsored USA and South Korean companies. Behind CDMA 2000 are Qualcomm, SKT and other Korean companies. The power between WCDMA/CDMA 20000 and TD-SCDMA was very unbalanced. Although competition was tough, in 2000 ITU formally accepted TD-SCDMA as one of the 3G standards. This sparked the development towards industrialisation and commercialisation. In 2008 it was launched in China within a testing network and a commercial network. The key events of this evolution process are reported in Table 1.

1998	Under direct instruction by the Chinese government, Datang presented the TD-SCDMA technology on behalf of China
2000	TD-SCDMA was accepted as one of the 3G standardisations. This was a significant breakthrough in Chinese telecom history.
2001	March, TD-SCDMA was accepted by 3GPP (3G's partner project)
2002	October, TD-SCDMA was allocated spectrum 155MHz (1880-1920MHz, 2010-2025MHz and 2300-2400MHz). TD-SCDMA industry alliance was established. Datang, Huawei, Holley, Lenovo, ZTE, Zhong CECT and Petvio became the first group members and signed the "Agreement of Initiator" to collectively promote TD-SCDMA in China.
2003	The TD-SCDMA Industry Alliance counted 65 members. A complete and mature multi-vendor environment was formed.
2004	March, the first TD-SCDMA mobile terminal was developed by Datang Mobile.

2006	January, the Ministry of Information Industry (MII) announced that TD-SCDMA became the Chinese national technology standard for the telecommunication industry.
2007	November, the *Long Term Evolution, Time-Division Duplex* (LTE TDD) fusion technology program was signed by 27 companies on 3GPP RAN151 meeting, and its frame structure was identified based on the frame structure of TD-SCDMA. It opened the door for TD-SCDMA to evolve towards *TD-Long Term Evolution* (TD-LTE) and 4G standards.
2008	TD-SCDMA trial use and commercial networks were formally launched.

(Source: adapted by the authors)
Table 1:
TD-SCDMA's Major Developments from 1998-2008

4.1 Policy background: independent innovation policy

After the rapid economic development through the 1980's and 1990's, the Chinese government realised that the bottleneck of the Chinese economy was the weakness in innovation in the country's industries. Due to the lack of independent innovation technology, most Chinese industries were hovering in the low end of the industry chains, resulting in low levels of profit margin and heavy dependency on foreign patents. Under such circumstances the Chinese government proposed a new national strategy of independent innovation in the late 1990's. Chinese government in its 2006 "National Innovation Strategy" proposed to raise the R & D budget to rise from 1.2% of GDP to more than 2.5 % to grow by 2020. "The Government allocated more than US$ 77.82 billion to invest in science and technology in 2011 with nearly a 20% annual growth rate since 2005."(Fu, 2014; 15).The Government also called for improving the capability of independent innovation and build an innovation-oriented environment as the strategic objective of the country. The policy also indicated that independent innovation should be the core of a national development strategy and the key to improve overall national strength. The policy proposed a transformation into an innovation- and knowledge-based country in the year of 2020 primarily by enhancing the independent innovation capacity's contribution to the national economy. From a micro economic point of view, along with the internal technological breakthroughs, a strong self-organised ability and market leadership can help to get rid of dependency on foreign technology. In general, independent innovation would be a process to explore potential markets through in-house R&D activities and external knowledge acquisition (Chen 2004). One interviewee from the science and technology department said: "This national innovation strategy is very crucial for the Chinese economic development. It basically denied the result of previous policy 'market exchanging technology'. It is a watershed of the Chinese science and technology development from external-oriented to inner-oriented/"

The Chinese government also proposed that the per capita GDP should quadruple from 2000 to 2020, which indicated that the country should upgrade the transformation of economic development mode, by using high-tech, low energy consumption and low pollution technologies. The proposal pointed out that the key to promote the optimisation and upgrading of industrial structures was by mastering high-tech achievements with independent intellectual property rights (Lu 2005, Sun 2005). The policy suggested that "driven by major technological innovation through the government procurement" was one of the ways to create an environment for independent innovation. The policy also illustrated that "major state construction project is the main battlefield of technology application, technology integration and innovation. They are originated from the country's need and reflected the will of the state. In the competition for nationally established key projects, applying independent innovation will not only boost a large number of strategic industries, but also achieve significant technological innovations in key areas. China should select a number of major key projects, by mobilising national R&D resources to conquer and master the key technologies, and enhance the capabilities of independent innovations in China" (Peng, 2006; Chen, 2005; Liao, 2005). One interviewee from a university expert said that he can fully understand that the government prioritises self-innovated technology when competing for government project. "Particularly for developing countries, this is the only solution for self-developed innovation."

4.2 The decision of standardisation

- *Market potential*

The potential of the large Chinese market may be the best incumbent market for a new standardisation due to the fact that the Chinese market alone can sufficiently sustain the running of the technology. Ever since China introduced the first mobile telephone system in 1987 and opened the GSM system in 1994, the number of mobile subscribers has leaped every year. From 1987 to 1993 the annual growth-rate of subscribers was 200%. In August 2001, the subscribers of mobile communication in China reached 120 million and overtook USA, which had until then had the largest number of subscribers in the world (Beijing Chenbao, 2004). If TD-SCDMA was not accepted, the Chinese government would operate the network independently (SinaTech, 2005), since the Chinese market have the capability to support its own standardisation. China could use its market size as an asset when developing distinctive standards with the expectation that its standards would take on an international identity.

- *Industry Foundation*

Information technology is the highland of state-of-the-art technology in the world. Among that, mobile communications is the fastest growing field of technology. At the time China experienced difficulties in making a breakthrough in the area of CPU as well as other technologies. They were still relatively weak in R&D and also challenged by the fast changes in international standards. In contrast, the R&D capability in telecommunications was stronger than that of other areas and the cycle of establishing and eliminating a standard in telecommunications is longer than that of other industries. The achievements of several Chinese manufacturers contributed to an increased confidence in developing a Chinese standardisation. In 1992 Huawei successfully opened the rural market with its self-developed product C&C08. Five years on Huawei commenced R&D in the area of GSM. At the same time Huawei established joint laboratories with many international companies. In 1998 Huawei had developed into a company with a certain recognition and obtained a solid market share in the domestic market with its self-developed products. Another emerging company ZTE also successfully presented the ZX500 exchange in 1990. In 1998 ZTE established three research centres in USA and also won exchange turnkey projects in Bangladesh and Pakistan, which were then the largest overseas projects for the Chinese telecom companies (Xin, 2006). When the Chinese government decided to apply the standardisation, the Chinese telecom companies were experiencing faster development than ever; with acquired knowledge, experience, technology and skills accumulating every day. Thereby the Chinese government launched a level of higher ambition of more challenges for the Chinese telecom industry.

- *Transition from 2G to 3G*

According to the experience from 1G over 2G to 3G the technology life cycle of mobile communication is about ten years. 1G began to appear in the 1970's; 2G was developed in the late 1980's and 3G was developed from the late 1990's. During the transition period of two generations of technology emerging companies are very active, and it was a perfect opportunity for small innovative companies to interrupt the market to realise a breakthrough and gradually to replace dominant technology. It is the best timing for an emerging company to raise a new standard as the trend of technological development naturally will need a new standard. The Chinese government expected to use the chance during the transition of technology life cycle to propose an independently designed technology standard. This was an inevitable trend of industrial development, while the process of industrial evolution also provided a rare opportunity for survival and growth to emerging technologies.

- *The low end of the value chain*

At the opening of the country in 1978, China's participation in the global economy was characterised by low–tech participation, which was due to the restrictions of low-tech levels and the international production networks established by MNCs. In the international production hierarchy, the Chinese manufacturing industry was located at the bottom. Although China had plenty of human resources, the corresponding profit and value-added ratio remained very low. The National Bureau of Statistics information showed that the value-added to the product of the Chinese manufacturers was 26.2%, which was much lower than that of USA (49%), Japan (48%), and Germany (37%). Particularly in communication equipment, computers and related equipment manufacturing, the ratio was only 22%, which was 35% lower than that of USA (Yang, 2006). The Chinese manufacturers could hardly share the fast-developing markets in China. During the 1G and 2G era China spent an estimated RMB 260 billion and RMB 800-1,000 billion purchasing foreign equipment (Zhou, 2011). Even the MNC's Chinese R&D divisions are insulated with the high end technology. One interviewee from a MNC complained that: "We feel not satisfied because our research in the Chinese department is not challengeable enough. The headquarter only gives us marginal work, because they don't want to share any core technology with us." The Chinese government decided to solve the problem and improve the domestic manufacturers' position in the international production network through the development TD-SCDMA products.

- *Dependency on foreign patents*

The international production networks employed technical standards which were set by MNCs. Most Chinese manufacturers were engaged in mobile terminal production. The production of mobile terminals was characterised by low entry barriers, low marginal profit and harsh competition. Large as well as small companies quickly set up production of mobile terminals in order to grab a share of the booming mobile industry. The manufacturers imported key parts of the software and hardware from developed countries for assembly by the local Chinese labour force. The Chinese manufactures had to pay patent fees for each mobile terminal they produced, which came to 8-15% of the sales price for each terminal. The more they sold, the more they had to pay in patent fee. The Chinese government became concerned about the excessive dependence on foreign technology, which would be at the expense of developing the national innovation system. Besides, there were increasing concerns about the distribution of benefits within the international division of labour and the relative gains flowing towards the standard setters in international production networks (Richard P. Suttmeier & Yao Xiangkui, 2004). China was still in a subordinate position vis-à-vis global industry leaders and it had not emerged as a significant force in innovation of production networks. These lessons served as a strong motivation for the country to seek its own standard(s) in order to reduce its major dependence on foreign technology. In turn, it would facilitate the development of a higher level of national innovation system.

4.3 The development and industrialisation process

After the standardisation was accepted the industrialisation and commercialisation that followed also required major investments and efforts. The Chinese government supported the whole process financially, reserved frequencies and timed arrangements. MII (Ministry of Information Industry) heavily supported TD-SCDMA development, arranging special funds as part of mobile projects and electronic development funds. The government invested RMB 1 billion (US$120 million) since the late 1990's, involving approximately 3,000 scientists and engineers across the country. A team of 10,000 technicians and researchers were established to develop the 3G technology and promote the 3G mobile services. In 2002 with government support, Datang established the TD-SCDMA industry alliance. The number of members grew to 65 in 2003 and an industry chain covering different parties was preliminarily formed. The radio spectrum was and is a scarce natural resource. According to MII documents, TD-SCDMA standard obtained the core frequency band of 55M and the expansion frequency band of 100MHZ, ranging from 1880MHZ to 1920MHZ, 2010MHZ to 2025MHZ, and 2300MHZ to 2400MHZ. The government cleared the frequency of other uses for the TD-SCDMA purpose (Ren, 2005). The Chinese government also postponed the launch of 3G awaiting maturity of the technology. It was tested finally during the 2008 Olympic Games and formally started in January 2009. This was approximately five years later than European countries and ten years later than South Korea.

4.4 Basic achievement

After more than ten years of efforts and careful arrangements the Chinese telecom market in the 3G era changed greatly. During the 1G era the development of the Chinese mobile industry was passive and stagnant. The market share of base stations and mobile terminals was almost zero, even the mobile phone bag had to be imported. All 6.5 million mobile phones on the market relied on import to a value of around RMB 130 billion. The station controllers and mobile switches also relied import at a cost of around RMB 130 billion. In comparison, the Three Gorges Project, the most expensive project in Chinese history, cost less than 190 billion, while 1G equipment had cost a total of RMB 260 billion.

During the 2G era MNCs still controlled technology standards by holding the intellectual property rights. However, the situation has gradually changed after TD-SCDMA was initiated (Zhou, 2011). Through mastering TD-SCDMA standards, system equipment, instrumentation, chips, terminals and other core technologies, a local telecom industry chain had been progressively shaped.

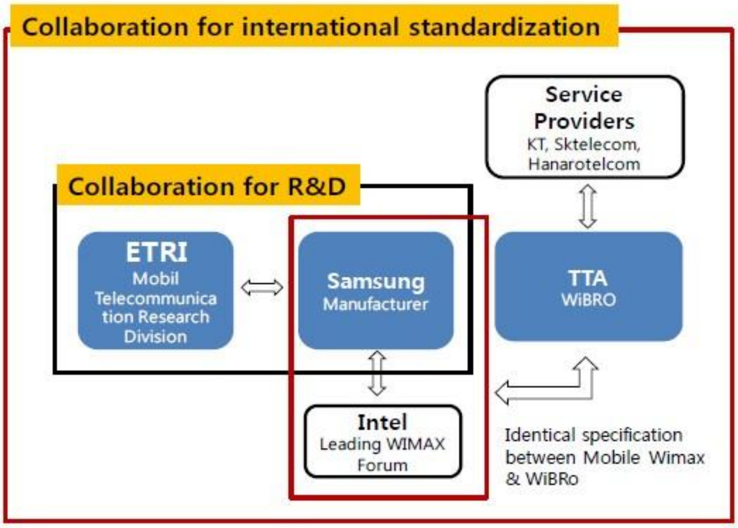
By the end of 2012 China's TD-SCDMA users reached more than 82 million subscribers. The industrialisation of the standard drove nearly a trillion RMB in investments, directly or indirectly pulled GDP growth to nearly RMB 500 billion, creating more than 430,000 jobs. By 2013 the Chinese manufacturers' share of the TD-SCDMA system market was more than 90%, while of the WCDMA and CDMA2000 market, the share was only 55% and 65%. The Chinese-developed TD-SCDMA chip also exceeded 70% of the market (Science and Technology Daily, 2013). TD-LTE was the evolution of the 4G standard based on TD-SCDMA. TD-SCDMA drove the overall breakthrough of the Chinese telecom industry chain and laid a solid foundation for the competitiveness of the TD-LTE industry. During the 3G era the lag between the industry chain of TD-SCDMA and that of the other two standards (WCDMA and CDMA2000) was around 5 years. However in the present 4G era, compared with the international mainstream standard FDD (Frequency Division Duplexing), the lag is about half a year. The 3G standard TD-SCDMA was only ever applied commercially on the Chinese market and no international mainstream operator chose this standard. After the development and accumulation during these years some leading international operators, system manufacturers, chip companies, and instrument companies have launched TD-LTE industry development processes for the 4G standard. In November 2012, 59 operators announced TD-LTE business plans and among them 12 TD-LTE commercial networks (Science and Technology Daily, 2013). "The Chinese government is the decision maker, chief designer and real operator of this TD-SCDMA standardisation," one of the interviewee from an industrial professional, "from the decision, to the industrialisation and commercialisation of this technology, the Chinese government played an unreplaceable role. None of any other Chinese company can undertake this job."

5. Two Korean Cases: WiBro and CDMA2000

WiBro

Korea has successfully raised its own technology, the WiBro standard (Wireless Broadband access service), to an international level although under different challenges and restrictions. After the Korean government decided to focus on the WiBro standard, it promoted R&D and planned for the internationalisation of WiBro. As a member of the World Trade Organisation (WTO) the Korean government could not interfere in choosing and supporting certain technologies. Instead it encouraged private companies to invest in R&D. As a result Samsung was able to share the technology and knowledge with other companies that the Electronics and Telecommunications Research Institute (ETRI) had been working on until that time. A system was created to promote collaboration between ETRI and private companies for further R&D. Here the R&D was not a collaboration among players under the government's control, but a pure collaboration between public institutions and private companies (Park and Han, 2011).

The Korean government provided funds for standardisation activities for organisations formed around the Korean Telecommunications Technology Association (TTA) by taking into consideration WTO restrictions on government interference ensuring that Korean technology could become a successful international standard. The Korean government also postponed marketing activities to promote products after they had achieved successful international standardisation levels. Likewise, the Korean government worked actively with IEEE802.16 working groups. For example, they allowed candidate firms to engage in business related to WiBro on the condition that their WiBro technology specifications should have interoperability with IEEE802.16. The Korean government further emphasised that qualification of the standard was the most important factor for acquiring the rights to use WiBro commercially (Park and Han, 2011). This quickly helped WiBro to become a domestic as well as an international standard. The Korean government played a crucial role in the entire process of applying and coordinating the standardisation process. Standardisation was not the harvest of one particular company, as in this case Samsung, but the triumph of the entire industry. More details on the efforts made by the Korean government in collaborating and allocating resources for the international standardisation of WiBro are presented in Figure 2.



(Source: Park and Han, 2011)

Figure 2:
Collaboration for International Standardisation

CDMA2000

Around 1990 the Korean government decided to develop wireless technology as the next generation technology. In 1991 an agreement was signed between Qualcomm Inc. and ETRI to develop and commercialise the CDMA system in Korea along with other manufacturers, operators and research institutes (West, 2001). Taking into consideration the interoperability, compatibility and effective utilisation of equipment, most of the companies and carriers preferred WCDMA due to GSM's dominant position in the world. The Korean Ministry rejected GSM and declared CDMA to be the national standard in 1993.The world's first commercial CDMA network was launched in early 1996. CDMA was rapidly taken on in Korea, making it the leading CDMA market after USA.

Although Korea did not propose their own 3G standard, the Korean government used the CDMA standard as a powerful tool to pursue the development of the telecom industry. The Korean government realised that the choice of WCDMA held no guarantee of international competitiveness for the Korean telecom industry. First of all, Korean manufacturers broke the dominance of MNCs such as Motorola on the domestic market in 2G technology. Based on the accumulation, the Korean manufacturers were able to make surplus profit on the domestic market. The domestic market posed as an excellent test to acquire valuable experience in mobile technologies. Second, the national CDMA standard could be an effective device in restricting international penetration of the mobile handsets market. The development of the CDMA system saved the cost of importing mobile telecom systems from international equipment manufacturers. Finally, the government also expected Korean telecom manufacturers to use the opportunity to become leaders in CDMA technology internationally. According to KISDI (2003), from 1998 and onwards Korean manufacturers provided 70% of the CDMA terminals and 80% of the infrastructure for the domestic market. In 2002, more than 70% of the handsets sold on the Korean market were made by Samsung and LG, while Motorola held a mere 7% of the market share (KISDI, 2003). The export of mobile equipment also increased from US$2.3 million (about RMB 15 million) in 1996 to US$2.2 billion (about RMB 14 billion) in 1999 and to US$4.1 billion (about RMB 25 billion) by 2001(MIC, 2003).

6. Discussion and analysis

6.1 External factors: policy and technological life cycle

According to the independent innovation strategy, the Chinese government aimed at mastering new technology with independent intellectual property rights through major projects. The strategy attempted to select a number of major projects, mobilising domestic technology strength to master key technologies and core technologies and enhance the capabilities of independent innovation. The Chinese government implemented the mission of independent innovation through the project of TD-SCDMA. The major developer of this technology (Datang) and the major purchaser (China Mobile) were both Chinese state-owned enterprises. A self-innovated standard for 3G network would give Chinese companies a competitive edge and allow them to take a share of a market dominated by MNCs. Through the process of promoting the standard of TD-SCDMA, the Chinese companies in the mobile industry value chain (for example handsets companies) had the possibility to upgrade to a new technology level. The Chinese government was determined to promote learning and innovation through the key project of TD-SCDMA and to achieve industrial upgrading and structural optimisation. From this point of view, this technological standard is no longer a matter within a technology scope. In such circumstance “common international standards or inter-operable compatibility standards are likely to be neglected” (David and Steinmueller, 1996). The interests of different parties seemed more important such as domestic producers, welfare of users and national interest. In the TD-SCDMA case, the ultimate goal of standard-setting was to speed up domestic industry innovation and the standard-setting belonged to be part of the industry innovation policy. Referring to the point made by Lee and Park (2010), the innovation policy would belong to the third opportunity of government regulation.

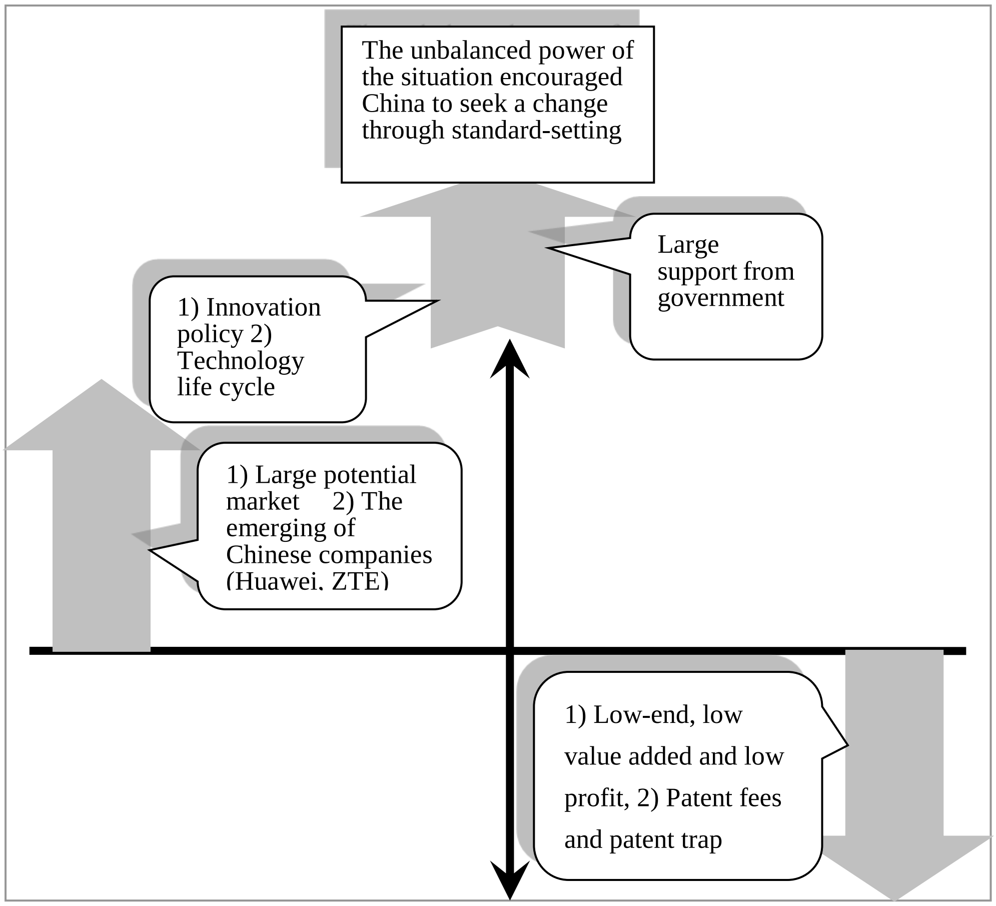
Opportunity from the technology life cycle belongs to the first window of opportunity: a new techno-economic paradigm. At the time the 2G technology had matured and was going into decline; an opportunity opened up to a latecomer's catch up. The industrial environment at the time was also positive for innovative disruptors. The Chinese government perceived the opportunity and provided strong support at the critical moment by helping domestic manufacturers complete the standard applications. Although the Chinese telecom industry was small at the time, the Chinese government was aware that the evolution of 2G to 3G was an overwhelming trend: if China had chosen not to exploit this opportunity, they would have had to wait for another couple of years. For the whole industry, it was a rare and a "must go" opportunity. The "Neo-techno-nationalism" suggests an approach to realise the strategy is to challenge the dominant architecture to replace it with a new one. The cost and risk of such an attempt was certainly very high. A country would need to have extraordinary resource in order to take on the challenge. As Naughton & Segal (2003) noted, abundant financial resources, a large market, an innovative R&D system and substantial political power are all necessary. Certainly, the Chinese government, the size of the domestic market and the fast developing telecommunication industry all met these criteria.

6.2 Internal factors: the emerging of Chinese companies despite low margins, patent trap and large market potential

The existing standard system provided a favourable framework for developed countries, because international production networks employed technical standards set by the MNCs from (the same) developed countries. Therefore, these MNCs captured value through their control over standards and intellectual property while Chinese manufacturers had minor margin profit because of the "patent trap", which required paying substantial royalties to patent holders. It implies that China was facing difficulties during the process to upgrade their position in the industrial value chain through the implementation of national innovation strategy. "*Deft execution*" requires a latecomer to steer smartly between a narrow techno-nationalism which causes friction and resentment in international business environments. Even though a latecomer as China expected that the self-developed standard would internalise and absorb the R&D process and eventually enhance its own technology competency.

Meanwhile, catch up firms could develop new technologies of their own and become more capable at joining the global competition. China had already fostered a few telecom manufacturers (Huawei and ZTE etc.) who were gaining a worldwide recognition and an increasing global market share. . These enterprises had the capability to catch up through the procurement of standardisation and eventually to drive the telecom and relevant industries to a higher technical level. A smart government would act as coordinator and guide to compensate for latecomer weaknesses through supporting R&D in domestic firms and universities. Some of the firms participating in government-sponsored standards projects would internalise the process of developing advanced technology. This direct participation of Chinese companies in international standard-setting indicated that the experience of China's official intervention was part of a larger learning process for firms and for policymakers alike. Companies would gradually develop new technologies of their own and become more capable at joining the global competition and technological innovation. As some Chinese companies became technologically sophisticated enough to pursue their own interests in global standardisation procedures, the role of government would likewise be reduced as was the experience from Japan, Korea and Taiwan. The policy of "independent innovation" was an attempt to establish a latecomer's own technology standard and eventually build its own innovation system to win a competitive position in international production value chain with a higher R&D competency. These external and internal factors pushed China to interpret and implement an approach to standards which focused on market power in the face of technological weakness, under the condition that China had confidence in its own ability to set innovation standards, which would positively affect its international competitiveness (Rosen, 2003).

The rising interest of standard-setting by the Chinese government was a strategic response to globalisation and the global economy. The telecommunication industry is often likely to be determined by government committees due to government ownership of the communications infrastructure in many countries. The standard-setting decision was caused by both external and internal factors. The government raised the importance of "independent innovation" to high priority and standard-setting became an important tool to materialise the strategy. The evolution from 2G to 3G provided the possibility for the Chinese enterprises in view of technology life cycle and the large domestic market in China offered the barging power for the standards negotiation and finally the Chinese domestic industry's accumulation provided a solid condition for this ambition., The Chinese companies would only stay in the low-end of the industry chain, earning low profit margins. At the same time the Chinese companies had to pay large amounts of patent fees to the foreign companies. These factors restricted the development and learning of the Chinese companies. The comprehensive effect of the above factors forced the Chinese government to find a solution to the industrial bottleneck caused by standard-setting. The decision process driven by the different factors is illustrated in Figure 3.



(Source: adapted by the authors based on this research)

Figure 3：

The decision of standardisation of TD-SCDMA

6.3 Comparison with the Korean case： (not good to compare... but why not say the approach from the Korean Case?) I was asked to do this by other friends

Examining the case of TD-SCDMA in China with CDMA in Korea, the paper concludes two points. First, the government plays a crucial role in the decision of standardisation, instead of technology or market as path-dependence suggests. In the case of Korea's CDMA, the government decided to give up the dominant WCDMA technology and chose the CDMA technology instead. This was against network effect or inter-comparability rationality and it was a challenge to install base and switch costs. Taking into account the Korean industrial foundation and advantage the Korean government decided to use the domestic market as a test bed for the development of the domestic industry. This way the Korean industry would have a basic guarantee for a market. The Korean manufacturers would have a comparatively safer development environment by using this standard since CDMA technology was a closed technology and the market would be closed to outside influence. This decision eventually helped speed up the growth of the Korean telecom market and it became the second largest CDMA market next to USA. The strategy also supported Samsung and LG to become world class companies. Although there was the difference that Korea applied the foreign technology CDMA and China used the self-innovated TD-SCDMA, the motivation behind the standard decision was similar. The decision indicated that technology is not the only concern of standard-setting, not even the key concern. Standard-setting acts as a tool for national industry development and it is destined to be influenced and controlled by many factors. Particularly latecomer countries have been set outside the arena of the standards battle and they have to use other means to leverage the competition for standard-setting. Only this way can latecomer countries use standardisation as a tool to serve national industry development and eventually achieve the goal of technology catch up. In this discussion it is confirmed that to latecomer countries government interference is one of the most effective measures among a variety of choices.

In the case of Wire the Korean government played as the principal actor similar to the Chinese government's role as the general coordinator of the new standard. As Park and Han (2011) pointed out, WiBro was not a government supported project but a pure collaboration between public institutes and private companies. This implied the deep involvement the private and public in the development of this project. The same way the Chinese government postponed the launching of the standard, the Korean government postponed the marketing activities to await maturity of the technology and also supported the development by financial grants and favourable regulations. The Korean government even actively involved itself in the R&D process on a task group-level, coordinating research assignments between companies and public institutes. The role of the Korean government as an active general coordinator and final decision maker could not have been played by any other actors. Again the authors find that in a latecomer economy the standard-setting is no longer the business of one particular company; it is the mission of an entire industry. The assignment to mobilise resources from the entire industry could only be completed by government, as latecomers usually do not have one or more MNC(s) to lead the industry. Despite certain companies having achieved some degree of catch up in terms of technology advancement and market domination, they are far too small to undertake the mission. The research confirms that the "political forces largely influence standard-setting" (David and Steinmueller, 1996) is true in a latecomer's catch up-pattern. In addition, the government provides massive influence and support in R&D activities to secure the ultimate goal of industry catch up.

7. Summary

In this paper, the researchers have discussed the standard-setting process in the framework of latecomer countries. It has reviewed the TD-SCDMA standard-setting and technology development process on basis of independent innovation policy. The paper has used two standardisation cases in Korea in the perspectives of decision making and government support. Based on these discussions the primary conclusion is that for a latecomer country, the standard-setting might be more constrained by political and economic concerns and technology would no longer be decisive, although it is certainly necessary. The role of standardisation is more like a means or a tool for a latecomer country to leverage its industry development. The "technological development occurs along a single predetermined trajectory" as proposed and insisted on by the neo-classical paradigm might suit a mature technological system in developed countries. The process of standard-setting is a very complicated process with many vested interests. However to a smart government from a latecomer country, there is one simple goal even for the most complicated project—that is to facilitate the domestic industry's technology catch up. China and Korea are both approaching this goal. The achievements are reflected in the considerable development of telecom giants such as Huawei, ZTE, Samsung, LG etc., on the world market after more than ten years of standardisation projects. As mentioned above when it comes to latecomer countries, only China and Korea can successfully use standardisation to leverage a domestic industry's catch up (ITU, 2007). The paper's summary on these patterns in the cases of China and Korea provides a further insight into the standardisation as a catch up tool in latecomer countries:

1） The latecomer catch up theory introduces three windows of opportunity, including a new techno-economic paradigm and government regulation. When these two windows are presented simultaneously to latecomer countries the probability of success is higher than usual. In the cases discussed, the Chinese and as well as the Korean governments used the two opportunities: taking advantage of the transition time of technology life cycle and provided major support, regulations, and interventions by the governments. The opportunity is composed of techno-economic and government regulation perspectives. Furthermore, this strategy may be regarded as an expression of techno-nationalism (Yamada, 2000): the government commits itself to promote domestic technical innovation, public-private R&D collaboration and attempts to replace the old standard with a new one even though it may involve high costs and high risk (Naughton & Segal, 2003). The Chinese independent innovation policy may be seen as an implementation of techno-nationalism. Therefore it is concluded that in the cases of China and Korea, there are multiple windows under techno-nationalism.

2） Path-dependencies promoted by neo classical-economics and other concepts, including network effect and install base, are influential factors in standard-setting, but they are not crucial factors of the decision and setting of latecomer countries' standardisation. The superiority of a technology is the basic condition of standardisation, but often the most advanced technology cannot be selected and implemented as a successful standardisation. This becomes more distinct in latecomer countries. From the discussion on China and Korea, this research derives that in latecomer countries the best guarantee of a successful standardisation comes from two quartertones is an abundant market resource and the other is powerful government support. The government uses industrial policy to help improve the competitive position of domestic firms, especially for the self-developed innovation to become more mature and commercially viable. One might say that these factors make up for the deficiencies of latecomers in terms of technology. The interesting point is, that after these latecomer countries had deployed related standardisation and initially realised the industry catch up, those elements in standardisation economics including install base, path-dependence, inter-compatibility and network effect etc. started to show effect when these standards were in the process of upgrading. For example, when the Chinese network was transformed from 3G (TD-SCDMA) to 4G (LEG) and the Korean CDMA technology was transformed from 3G to 4G, they all considered the available network and the potential switching costs for the end users. The upgraded standardisation met the dual requirements: firstly to follow the trend of technology evolution, secondly to promote domestic industry development. From the experience of these latecomer countries, the authors conclude that: government plays a rather crucial role in the standard-setting during technology change. However when a similar technology upgrades along the same trajectory, technology becomes the primary concern.

In conclusion, a smart government for a latecomer country apply standard-setting as the tool to achieve technology catch up under a national strategy. It is not a blind obedience to the trends of developed countries or mainstream technologies. In order to promote the development of local industries, the government uses the domestic market as a test bed for domestic manufactures' innovation. On a short term basis, it may influence the end user's welfare (for instance, delayed deployment of a new technology), but in a long term perspective it will benefit the catching up of domestic industries and building up of national innovation competencies. These results have been demonstrated through the dramatic development of the telecom industries in both countries central to this paper. From the cases of TD-SCDMA in China and. WiBro and CDMA2000 in Korea, the paper also establishes that it is an advantage, if a latecomer country have the capability to propose a self-innovated standardisation, though it is not a prerequisite. The WiBro and CDMA2000 case in Korea also realised a successful standard-setting and industry catch up by developing country. This indicates that it is not whether to adopt a foreign or a domestically-made standardisation. To a smart government, the most important factor is to choose a suitable standardisation to drive local industry's catch up and to design and implement a set of efficient policies to support this ambition. The policy learning for emerging catch up economies is the capability, competence and innovative openness to combine systematically both domestic and global standards to promote the industrialisation base of their economies.

References:

Amsden, A.H. (2001): The rise of the rest: Challenges to the west from late-industrializing economies. Oxford: Oxford University Press.

Antonelli, C. (1997): The economics of path-dependence in industrial organisation. International Journal of Industrial Organisation, 15(6), 643–676.

Antonelli, C. (1998): Localized technological change and the evolution of standards as economic institutions. In A. D. Chandler Jr.

Archibugi, D., & Michie, J. (1997): Technology, globalization and economic performance. Cambridge: Cambridge University Press.

Beijing Chenbao (2004): The 20 years development of Chinese communication industry memo. Oct.,2nd. (in Chinese)

Chen Jiguo (2004): The reflection about China telecom reform. Esoftbank (http://esoftbank.com.cn/wz/71_8587.html)

Chen Zhili (2005): Strengthen the independent innovation and promote sustainable development. China Soft Science, No.9. (in Chinese)

Choung, J.Y. (1998): Patterns of innovation in Korea and Taiwan. IEEE Transactions on Engineering Management, 45(4), 357–365.

Choung, J. Y., Hwang, H. R., Choi, J. H., & Rim, M. H. (2000): Transition of latecomer firms from technology users to technology generators: Korean semiconductor firms. World Development, 28(5), 969–982.

Dalum, B., Pedersen, C., and Villumsen, G. Technological Life Cycles (2002): Regional Clusters Facing Disruption. DRUID Working Paper 2002-10.

David, A. Paul, and Steinmueller, W. Edward (1996): Standards, Trade, and Competition in the Emerging Global Information Infrastructure Environment. Telecommunications policy 20 (No. 10:817-30).

David, P. A., & Steinmueller, E. (1994): Economics and compatibility standards and competition in telecommunications networks. Information Economics and Policy, 3– 4(6), 217–242.

Dosi, G. (1982): Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technological change. Research Policy, 11.

Dosi, G., Freeman, C., Nelson, R. R., Silverberg, G., & Soete, L. (Eds.). (1988): Technical change and economic theory. Pinter Publisher, London and New York.

Eisenhardt, K. M. (1989): Building theories from case study research. Academy of Management Review, 14(4), 532–550. New York: Columbia University Press.

Ernst, D. (2009): A new geography of knowledge in the electronics industry? Asia's role in global innovation networks. East-West Center, Honolulu, Hawaii. Policy Studies, 54, 1–65.

Farrell, J., and Saloner, G. Competition, Compatibility, and Standards (1986): The Economics of Horses, Penguins, and Lemmings. University of California at Berkeley Economics Working Papers No. 8610.

Fu, X.(2014), Chiana's Path to Innovation, Cambridge University Press, UK

Glaser, B. G., & Strauss, A. L. (1967): The discovery of grounded theory. NY: The Aldine Publishing Company.

ITU (2007): Bridging the standardisation gap. International Telecommunications Union Coucil information document (C07/EP/08), International Telecommunications Union.

Jho, W. (2007): Global political economy of technology standardisation: a case study of the Korean mobile telecommunications market. Telecommunications Policy, 31, 124–138.

Liu Jiajia & Tylecote Andrew (2009): Corporate Governance and Technological Capability Development: Three Case Studies in the Chinese Auto Industry. Industry and Innovation, 16:4-5, 525-544.

Li Jizhen & Pu Xin (2009): Technology Evolution in China's Color TV Industry, Industry and Innovation, Vol. 16, Nos. 4–5, 479–497, August–October 2009.

Kennedy, S. (2006): The political economy of standards coalitions: Explaining China's involvement in high-tech standards wars. Asia Policy, 2, 41–62.

KISDI (2003): 2003 trends of information and communications industry-1. Seoul: Korea Information Society Development Institute (in Korean).

Lee, Keun and John A. Mathews (2011): Upgrading in the Same Industry and Successive Entries in New Industries for Sustained Catch-up. E. Amann, J. Cantwell and M. Bell, Forthcoming in a Book on the Innovative Firms.

Lee, Keun and Tae Young Park (2010): Catching-up or Leapfrogging in Indian It Service Sector: Windows of Opportunity, Path-Creating and Moving up the Value-Chain in Tcs, Infosys, and Wipro. Asialics Conference.

Lee, Keun; Chaisung Lim and Wichin Song (2005): Emerging Digital Technology as a Window of Opportunity and Technological Leapfrogging: Catch-up in Digital Tv by the Korean Firms". International Journal of Technology Management, 29, 40-63.

Lee, Keun; Sunil Mani and Qing Mu (2011): Explaining Divergent Stories of Catch-up in the Telecommunication Equipment Industry in Brazil, China, India, and Korea. F. Malerba and R. R. Nelson, Catching-up in Sectoral Systems of Innovation. Oxford University Press.

Liang Xi , Lin Lei & Wu Guisheng (2009): Evolution of the Chinese Automobile Industry from a Sectoral System of Innovation Perspective. Industry and Innovation, 16:4-5, 463-478. Industry and Innovation, Vol. 16, Nos. 4–5, 463–478, August–October 2009.

Liao Xuelian (2005): Independent innovation and national competitiveness. Special Economic Zone (No.12: 355-356). (in Chinese)

Lu Feng, Feng Kaidong, Cao Wei (2005): China Independent telecom standardisation report by Beijing University. Sina Tech. (http://tech.sina.com.cn/t/2005-09-29/0004731647.shtml)

Ludovico Alcorta, Mark Tomlinson & An Tong Liang (2009): Knowledge Generation and Innovation in Manufacturing Firms in China, Industry and Innovation, 16:4-5, 435-461

Lyytinen K., Robey D. (1999):.Learning Failure in Information System Development. Information Systems Journal, vol. 9, No 2, pp. 85-101.

MacKenzie, D. A., & Wajcman, J. (Eds.). (1985): The social shaping of technology. Milton Keynes: Open University Press.

MIC (2003): National informatization whitepaper. National Computerization Agency, Seoul (in Korean).

Naughton Barry and Segal Adam (2003):.China in Search of a Workable Model: Technology Development in the New Millennium. In William Keller and Richard Samuels, eds., Crisis and Innovation: Asian Technology after the Millennium, New York: Cambridge University Press.

Nelson, R., & Winter, S. (1982): An evolutionary theory of economic change. Cambridge, MA: Harvard University Press.

Park, Tae-Young, and Han, Hoon (2011): How Could Korea Succeeded in Complex Product & System (CoPS)? Three Case Studies in Korean Telecommunication Systems. Graduate School of Business, Chonnam National University, The Global Network for the Economics of Learning, Innovation, and Competence Building Systems (Globelics), Argentina.

Peng Jimin (2006): To improve the ability of independent innovation idea. Economic Research Reference (No.1:32-43). (in Chinese)

Perez, Carlota and Luc Soete (1988): Catching-up in Technology: Entry Barriers and Windows of Opportunity. G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete, Technical Change and Economic Theory. London: Pinter Publishers, 458-79.

Pierre Vialle, Junjie Song, Jian Zhang (2012): Competing with dominant global standards in a catching-up context. The case of mobile standards in China, Telecommunications Policy 36, 832–846.

Gao Ping, Yu Jiang, Lyytinen Kalle (2014): Government in standardisation in the catching-up context: Case of China's mobile system, Telecommunications Policy 38, 200–209.

Ren Leyi (2005): Understanding impaction to operators and manufacturers: 3G frequency allocation. Telecom World

Richard P. Suttmeier and Yao Xiangkui (2004): China post-WTO technology policy: standards, software, and changing nature of techno-nationalism. The national bureau of Asia research, University Way NE, Washington.

Rosen Daniel H (2003): Low-Tech Bed, High-Tech Dreams. China Economic Quarterly, Q4, pp. 20–40.

Science and Technology Daily (2013): TD-SCDMA built the confidence for the Chinese science and technology. The Feb., 6th.

Sina Tech (2005): Internal meeting finalized in telecom TD-SCDMA networking. Dec., 26th. (in Chinese)

Strauss, A., & Corbin, J. (2008): Basics of qualitative research techniques and procedures for developing grounded theory (2nd ed.). London: Sage Publications.

Sun Yinglan (2005): The strategic orientation of independent innovation. Outlook Weekly (No. 11: 13-15). (in Chinese)

Suttmeier, R. P., & Yao, X. (2004): China's post-WTO technology policy: standards, software and the changing nature of techno-nationalism. Special report of the National Bureau of Asia Research, USA. (http://www.nbr.org/publications/issue.aspx?id=61S)

Suttmeier, R.P., Yao, X., & Tan, Z. (2006): Standards of power? Technology, institutions and politics in the development of China's national standards strategy. Special report of the National Bureau of Asia Research, USA. (http://nbr.org/publications/issue.aspx?id=78S)

Tushman, M., and Rosenkopf, L. (1992): Organizational Determinants of Technological Change: Towards Sociology of Technological Evolution. Research in Organizational Behavior 14: 311-47.

Tyson, L., & Zysman, J. (1989): Developmental strategy and production innovation in Japan. In Johnson, et al. (Eds.), Politics and productivity: The real story of why Japan works (pp. 59–140). Cambridge: Ballinger.

Ure, J. (2006): China standards and IPR chapter. Telecommunications Research Project Papers. University of Hong Kong. Available online from (www.trp.trpc.com.hk/papers/2006/china_ipr_stds_2006.pdf)

Utterback, J. M. (1994): Mastering the Dynamics of Innovation. Cambridge, MA: Harvard Business School Press.

West, J. (2001): Qualcomm's standards strategy. In Paper presented at the standardisation and innovation in information technology. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=968556&tag=1S.

Whasun Jho (2007): Global political economy of technology standardisation: A case of the Korean mobile telecommunications market. Telecommunications Policy 31 (2007) 124–138.

Williams, R., & Edge, D. (1996): The social shaping of technology. In W. H. Dutton (Ed.), Information and communications technologies. London: Oxford University Press.

Wu,Xiaobo Ma Rufei & Xu Guannan (2009): Accelerating Secondary Innovation through Organizational Learning: A Case Study and Theoretical Analysis. Industry and Innovation, 16:4-5, 389-409.

Xin Jinba (2006): Indigenous technology innovation fulfills today's Huawei and ZTE. CNET News, the Oct.27th. (in Chinese)

Gao Xudong, Liu Jianxin (2012): Catching up through the development of technology standard: The case of TD-SCDMA in China. Telecommunications Policy 36 (2012) 531–545.

Yamada (2000): Neo-Techno-Nationalism: How and Why It Grows. Columbia International Affairs Online.

Yang Jun (2006): China's manufacture is approaching to a critical point. Nan Feng Chuang. Vol. 8. (in Chinese)

Yin, R. K. (1989): Case Study Research: Design and Methods. Newbury Park, Sage Publications.

Zhou Huan (2011): Where is the origination of innovation for state-owned company? People Daily, the Sep., 30th.

- (3GPP) 3G's partner project
- (CATT)China Academy of Telecommunication Technology

- (CDMA2000) Code Division Multiple Access
- (FDD) Frequency-Division Duplex
- (GSM) 2G standardisation, Global System of Mobile
- (GSM)Global System of Mobile
- (LTE TDD)Long Term Evolution, Time-Division Duplex
- (MII) Chinese Ministry of Information Industry
- (MST) Ministry of Science and Technology
- (NMT)Nordic Mobile Telephony
- (TDD)Time-Division Duplex
- (TD-LTE)TD-Long Term Evolution
- (TD-SCDMA) Time Division-Synchronous Code Division Multiple Access
- (TTA)Telecommunications Technology Association
- (WCDMA) Wideband Code Division Synchronous Address
- (WiBro) Wireless Broadband access service
- Datang: a Chinese telecommunications company, the major developer of TD-SCDMA
- Huawei: a leading Chinese telecommunications company for infrastructure and handset equipment, ranked No.2 in the world by 2013
- ZTE: a leading Chinese telecommunications company for infrastructure and handset equipment, ranked No.4 in the world by 2013