Paper to be presented at the

35th DRUID Celebration Conference 2013, Barcelona, Spain, June 17-19

The institutional rigidities in the transition phase from catch-up to forging ahead: The case of ICT systems innovation in Korea

Jae-Yong CHOUNG
Korea Advanced Institute of Science and Technology
Department of Management Science
innovation@kaist.ac.kr

Hye-Ran HWANG
Daejeon Development Institute
Dept. of City Management
twinmum@naver.com

Abstract

The emergence of globally competitive latecomers with frontier technologies requests the new theoretical approaches on technological capabilities of latecomer countries. Since the capabilities for developing new products and processes are different from the one with which imitates and assimilates existing products and processes, it requires profound change both in technological and organizational capabilities. Moreover, institutional context and policy environments within which the innovation actors interact have to be changed in accordance with the technological and organizational change. The aim of this paper is to explore the institutional rigidities of emerging economies in the transition period from imitators to innovators, based on the case studies of ICT system development in Korea. Based on the in-depth case studies of the three ICT systems, WiBro, T-DMB, IMT 2000, this paper shows that institutional aspects are more relevant than reliance on technology centric development strategy particularly during the transition period. Therefore, it emphasizes the importance of establishing institutional capabilities to overcome latecomer disadvantages in the global market. This paper will address the transitional issues at national level, details of some institutional elements essential for upgrading beyond catch-up stage. It will be argued that delays in facilitating new institutional arrangements and new relationship among innovators in transition inevitably hamper their transition to innovation and creation in technology-intensive large ICT systems.

Jelcodes:O38,P41

The institutional rigidities in the transition phase from catch-up to forging ahead: The case of an innovation policy of ICT systems in Korea

ABSTRACT

The emergence of globally competitive latecomers with frontier technologies requests the new theoretical approaches on technological capabilities of latecomer countries. Since the capabilities for developing new products and processes are different from the one with which imitates and assimilates existing products and processes, it requires profound change both in technological and organizational capabilities. Moreover, institutional context and policy environments within which the innovation actors interact have to be changed in accordance with the technological and organizational change. The aim of this paper is to explore the institutional rigidities of emerging economies in the transition period from imitators to innovators, based on the case studies of ICT system development in Korea. Based on the in-depth case studies of the three ICT systems, WiBro, T-DMB, IMT 2000, this paper shows that institutional aspects are more relevant than reliance on technology centric development strategy particularly during the transition period. Therefore, it emphasizes the importance of establishing institutional capabilities to overcome latecomer disadvantages in the global market. This paper will address the transitional issues at national level, details of some institutional elements essential for upgrading beyond catch-up stage. It will be argued that delays in facilitating new institutional arrangements and new relationship among innovators in transition inevitably hamper their transition to innovation and creation in technology-intensive large ICT systems.

Keywords: Korea, Transition, Complex Products, Institutional capability

1. INTRODUCTION

Research studies on the innovation in the emerging economies have traditionally attributed the country's accelerated industrial advance to the rapid learning and adaptation of foreign technologies (e.g. Lall, 1992; Hobday, 1995; Kim, 1997; Bell & Pavitt, 1997). The government, corporations, and organizations in the regions first adopted foreign technologies, and then accumulated technological capabilities through assimilation and learning processes.

However, in recent days, some of Asian emerging economies become global innovation leaders in selected industrial sectors. Countries such as Korea, Taiwan, Singapore and China showed outstanding performance in many technological sectors, such as semiconductor memory, flat panel displays, shipbuilding, and automobiles. Firms in these regions start to produce new products and processes on the basis of endogenous innovation capabilities.

The emergence of globally competitive latecomers with frontier technologies requests the new theoretical approaches on technological capabilities of latecomer countries. There have been discussions on the challenges of technologically advanced emerging economies both in the firm level (Kim, 1997; Hobday, 1995; Hobday, Rush and Bessant, 2004; Ernst, Mathew, 2002) and national system level (Dodgson et.a., 2008; Dodgson, 2010). These studies recognized the importance of firm level innovation strategies which are favorable for accessing global knowledge (Chen,S.-H., 2006; Hobday, 1995; Ernst,2005) and more coherent national innovation systems providing the capacity to be important international sources of innovative products and processes (Dodgson, 2010; McKinsey, 2005; Sigurdson, 2005).

Since the capabilities for developing new products and processes are different from the one with which imitates and assimilates existing products and processes, it requires profound change both in technological and organizational capabilities for latecomer firms (Figueiredo,2010; Dantas & Bell, 2009) . Moreover, institutional context and policy environments within which the innovation actors interact have to be changed in accordance with the technological and organizational change. In some cases, the very nature of organizational capabilities turns out to be rigidities to adapt to a new product development and to a new competition environment (Leonard-Barton, 2007; Hwang, H.-R., 1999).

The aim of this paper is to explore the institutional rigidities of emerging economies in the transition period from imitators to innovators, based on the case studies of IT system development in Korea. The paper starts from the two intertwined questions: First, why Korean IT system developers showed a low performance in the global market even though it achieved successful in-house technological development. Second, what were the main institutional rigidities taking place in the transition period to challenge to the global leadership both in the aspects of technology and market?

The Korean ICT system development cases represent the importance of non-technological factors, such as organizational and institutional aspects, in the transition period of emerging economies. Since the late 1990s, Korea has taken on the new challenge of establishing itself as a global leader by executing a series of national development projects for large technology systems. These efforts have led to successful Korean advances in areas such as telecommunications, nuclear energy, satellite technology, and aero technology. These cases show that innovation activities in Korea are pursuing depth and width towards technology complexity and system integration.

So far, the successful cases of developing technology-intensive large systems are telecommunication systems, such as CDMA (Code Division Multiple Access) mobile wireless, with which Korea have become a world leader in the ICT industry. With these early successes, Korean firms and organizations gained the confidence and expertise to develop and implement other large-scale ICT system projects such as WiBro (Mobile WiMAX), IMT-2000, and T-DMB (Terrestrial Digital Multimedia Broadcasting) technologies. Some of these "homegrown" Korean systems have been transformed into global standards. Despite their technological superiority, however, new large-scale ICT systems have suffered from low market performance in the global market. For instance, in 2006, there were high expectations attached to the commercial launch of WiBro, a wireless broadband Internet technology, but since then the number of national subscribers and the overall revenue has not substantially increased, and the system has not made a dent in the international market (Dong-A Ilbo, 2009). Meanwhile, licenses for IMT-2000, a third-generation (3G) wireless technology, were first issued in 2000 but full services were not launched until 2007 (Digital Times, 2007). T-DMB, a digital terrestrial television standard which offers a greater coverage area and higher signal quality for mobile terminals, was commercialized in 2005, but had yet to turn profitable in 2009 (MK Economy, 2009).

Why did these superior technologies fail to break through in the international commercial market? To address this question, we must investigate which barriers need to be overcome for successful implementation of new large-scale ICT systems and products, particularly during the transition period from catch-up to frontier.

Traditional studies on development stage of technological catch-up in latecomer countries have been mainly based on Product Life Cycle (PLC) theory. Lee et al. (1988) and Kim (1997) have expanded this traditional approach, arguing that technological catch-up follows a reverse pattern than that of the product life cycle from entry into the mature stage, accumulating technological capabilities through assimilation and improvement and then proceeding to develop a new product in the fluid stage. However, the traditional wisdom has some limitations with respect to transitional issues. Basically, it assumed the automatic transition of evolutionary process based on capability accumulation. Moreover, the role of institution and relationships between innovation actors in the evolutionary process are

hardly considered. However, as the Korean case demonstrates, these institutional rigidities hampered the successful transition to frontier and attainment of satisfactory market performance in ICT complex systems although they achieved technological knowledge creation.

Based on the in-depth case studies of the three ICT systems, WiBro, T-DMB, IMT 2000, this paper shows that institutional aspects are more relevant than reliance on technology centric development strategy particularly during the transition period. Therefore, it emphasizes the importance of establishing institutional capabilities to overcome latecomer disadvantages in the global market. This paper will address the transitional issues at national level, details of some institutional elements essential for upgrading beyond catch-up stage. It will be argued that delays in facilitating new institutional arrangements and new relationship among innovators in transition inevitably hamper their transition to innovation and creation in technology-intensive large ICT systems.

In the second section, we review the research on catch-up theories with respect to the roles of institutions in the transitional stage of technological development and diffusion. In the third section, we present an analytical framework based on the identification of four factors which have been shown to inhibit the transitional capabilities of companies and institutions in the ICT industry. Particularly, the institutional elements are selected in accordance with the institutional routine which has accumulated in the catch-up period. It will present how the very nature of institutional routines in the successful catch-up period turned out to be impediments in the transition period to technological leadership. The fourth section examines three specific cases of ICT systems development in Korea — WiBro, IMT-2000, and T-DMB—in order to identify possible reasons for their low rates of diffusion. Conclusions and policy implications are discussed in the fifth and final section.

2. Theoretical Background

2.1 Catch-up regime and institution

The role of institutions becomes salient in the transition process of latecomer countries to innovative activities as well as in the development of complex and highly integrative system products. There is a growing body of research which emphasizes the importance of the institutional context in explaining innovation activities within national systems (e.g. Lundvall, 1992; Nelson, 1993; Freeman, 1987) and latecomer economic success (e.g. World Bank, 1993; Mathews, 1998; Nelson, 2007). This institutional context triggered more comprehensive research examining the role of institutions in helping or hindering the global advance of latecomer countries.

Particularly, the success of East Asian emerging economies has been attributed to 'developmental state'(Amsden, 1989), which guided market (Wade, 1990) to overcome technological and market deficiencies. It is indicated that developmental states in East Asian economies played critical role of facilitation economic development through providing incentive to incentives for innovation and reducing the risk to investment (Evans, 1995) as a distinctive institutional capacity. However, as the latecomer countries faces more complex and advanced capabilities to adapt frontier arena of competition environment, the role of public policy and the relationship between private and public sector has to be changed. In this regard, the changing role of the state becomes a salient factor to transform the economy to achieve technological and market leadership in the global market.

Developmental state theories suggest three main characteristics of instituional arrangement in East Asian countries. First, the existence of strong state which provide the vision of future growth. In Korea, central government provided the vision for export oriented growth strategy and heavy industry centered industrialization. Based on the guidance of central government, market participants concentrated their resource and capabilities on the strategically selected arena. In addition, it is indicated that the importance of 'pilot agency' for the planning and implementation of economic policy (Johnson, 1982; Haggard, Kim and Moon, 1991). In the catch-up period, particularly in the Korean case, the role of pilot agency was critical in the policy planning and implementation. The planning of heavy industry-based development was highly centralized in Economy Planning Board (EPB), the most orthodox Korean governmental body. EPB functioned as a 'control tower' for the planning and forging the consensus within the government ministries.

Second, it is indicated the selective industrial policies had been important. Developmental states selected and nurtured on the strategic industries which have high growth potential. Through the various policy instruments, including not only export subsidies, tax exemption, tariff, but also financial supports and the supervision of entry and exit of firms, the states formed a 'controlled competition environment'.In the catch-up period, the level of technological and market risk was relatively low since the development focus put on the learning and assimilating existing technologies that its technological and market potential was proved already.Through the control and guided consensus by pilot agency, the collective coherence among government ministries was accomplished in this period[1]. The centralized structure of policy planning and formulation positively corresponded to policy regime of ‘the selective support of economic actor and targeting of strategic industries’ with

[1] In addition to the developmental states, Evans(1995) identified "predatory states", characterized by rent-seeking activities of the state and "intermediate states" that lack of bureaucratic capacity and embedded autonomy.

which enabled fast catch-up and rapid economic growth. Centralized and selective industrial policy produced outstanding performance since it enabled to allocate limited resources to a few selected national champions.

Third, the structural features of 'developmental state' are distinguished in terms of the existence of strong and competent bureaucracy with collective coherence (Evans, 1995). It is indicated that "the state's effectiveness emerges not from its own inherent capacity but from the complexity and stability of its interactions with market players" (Samuels, 1987; Evans, 1995) in successful East Asian developmental states. Amsden emphasized the autonomy of government as the governments assigned the certain level of exports performances to private sector in return for support subsidies(Amsden, 1989). However, post developmental theorists emphasizes the relationship between private sector and the government as represented from the term of 'embedded autonomy' (Evans, 1995) with which focused on the information sharing and policy coordination between bureaucrats and leading domestic capitalists.

Public-provate relationships in the catch-up period of Korea were characterized by the hierachical and centrally governed policy planning system, selective resource allocation system and embedded autonomy. The system functioned as a effective instituional mechanisms for rapid learning and creating outstanding economic performance in the catch-up perod. However, the developmental states with embedded autonomy face great challenge in the transition period. Internally, as the economic actors diversified and accumulated the capabilities. In the technological perspective, a few large latecomer firms face direct competition with large multinational firms. The importance of upgrading of innovation capabilities to develop new products and processes and the creating of original technology has incresed as the possibilities of imitation disappered. With the high uncertainty of technological environment, the increasing capabilities of private sector requests the changes of policy regime.

2.2. System failure in the transition period

Often, new technologies are poorly accommodated by prevailing institutional structures and require policy and institutional reform to enact effective development. Leonard-Barton (1992) suggested that the core competencies of firms can become core rigidities in the face of technological change. The above discussion could be interpreted in the context of 'core institutional capabilities' at the national level, where they may become 'core institutional rigidities' during a transition period. The organizational rigidities and institutional delays turn out to be critical impediment in transition from

imitators to innovators in the global market. Consequently, the delayed institutional change during the transition phase will be one of the main issues in the research arena of developmental theory. This notion somewhat coincides with 'institutional inertia' by Lundvall et.al (2006), analyzing failures in a few Asian national innovation systems in transition. Another example is brought forward by Hung and Whittington (2000), who demonstrated the mismatch between the HDD sector and the Taiwanese national system as a source of its failure. Similarly, a detailed case study of software industry in Japan provides evidence that institutions can be too embedded in the national character to resist adaptability (Anchordoguy, 2000). In this Japanese case study, the persistence of industrial policy and organization were major issues, among others.

Recent arguments on the rationale for policy intervention in innovation policy focues on system failure. Woolthius (2005) summarize the four major types of system failure; infra failure, institutional failure, network failure and capability failure. Although the argument provide the sound understanding base for system failure, it has limitation to explore the system failure in the transition process in the developing context. It requires to develop the dynamic perspective to investigate the lock-in and transformational failure in the process of transition from catch-up to post catch-up.

In order to investigate the system failure from the perspective of transion, the arguments of socio-technical system provide a sound starting point. Weber & Roracher (2012) catigorized system failure in relation to the transition as follows; directionality failure, demand articulation failure, policy co-ordination failure and reflexivity failure.

We will expand the arguments on the transitional failure in terms of developing countries context. Particularly, we will focus on the organizational and institutional lock-in to understand the mechanisms of transitional failure. It suggests that the transitional failure in the process of post catch-up closely related to the organizational and institutional lock-in of catching-up system.

3. **Conceptual Framework**

To understand the transitional failure, it requires how the mechanisms of lock-in persist in the changing environments. This paper focused on the three aspects of lock-in mechanisms; policy directionality, inter-organizational coordination and public-private relationship.

Policy Directionality

Innovation policies play critical roles in the innovation process by directing the creation, selection, and diffusion of technologies. During the catch-up period, technology policy typically focuses more on the improvement of technologies, whereas during the transition phase, the concern of technology policy shifts to selecting the most promising of various technological endeavors, eliminating technological uncertainties, and obtaining technological superiority over competitors. Leadership strategy inherently involves the definition of new markets and the implementation of new technological choices.

Whereas the role of government in the catch-up period focused on the targeting of existing technologies / products with high potential and resource mobilization on the selective sectors, it requires different role and capabilities of government in the transition phase to challenge global leadership. In the transition period, the concern of technology policy shifts to co-ordinate competing stakeholders with different technological visions, to reduce uncertainty coming from new technological knowledge and to set the new rules of games in the emerging market.

As Nelson (2007) points out that the formation of new institutions or the renovation of old institutions for new purposes, may be the most difficult step of the post catch-up period. As technological needs simultaneously become more prevalent and more complex, it is imperative that countries nurture diverse sources for technology as well as the capability to integrate the various participants of the technology development process. Rapidly changing technological needs may lead to institutional and organizational mismatches, but such problems would seem to be unavoidable. Nelson (2007) identifies several other snags in the institutional overhaul process, including uncertainty about how to perfect new practices, the need for sophisticated learning through experience, and the continuous potential for failure. These factors indicate that there is a need for utmost awareness in the national system of future technology and market directions, opportunities and risks. The interactive learning between policy designers and industrial sectors is important to improve readiness for change in competition environment as well as to avoid institutional failure.

The inter-organizational co-ordination

The process of introducing programs, strengthening linkages, and forging a consensus between innovators can be very prolonged and unpopular. Setting up routines for integrative policy requires patience from all the involved parties since the process can initially weaken a system and its participants' positions.Latecomer countries require the institutional capability to define the rules for interactions between innovators and producers. This is particularly true during the transition phase, when it becomes critical for nations and industries to define standards and organize participation in the process of technological innovation.

Particularly in the case of ICT system, policy orientations satisfy disparate participants instead of providing optimal solutions. Moreover, the importance of the process of policy shaping increases as the number of innovators and the stakeholders in complex system products such as ICTs. This tendency emphasizes the importance of coordination capabilities among the various parties involved in the ICT systems development process. The production of ICT systems and products often involves a combination of various technology units and customized components, and this process requires high levels of interface among the participants. The roles of professional user groups are critical in the development process, which means that coordination between users and suppliers is also very important. In the case of ICT systems, the range of the policy arena is broad, from system development to service providing, which makes intra-ministerial coordination even more significant.

With ICT systems, users of specialized technologies are particularly important, and it is essential that they should be involved in the formulation of development strategies. During the catch-up stage, technology development strategies target improvement of existing technology and organization of private sector participation, but such capabilities tend to impede the flexible industrial dynamics required for ICT systems by creating tension between government-led, supply-side technology developers and user-led, demand-side technology needs.

Public-private relationship

During the catch-up period, public policies are often implemented independently using different instruments in order to foster the development of many industries simultaneously. The relative autonomy with targeted policy objectives may enable a government to achieve technological efficiency and competitiveness expediently.With strong policy instrument of resource mobilization and allocation to a few selected market actors, the govrnment achieved 'governed market' of private sector.

However,as the capabilities of private sector enhanced, the relationship between the government and private sector has to be changed. The role of governments shifts to market diffusion by setting up new rules, encouraging competition, and defining incentives for participants. In the early stages of the product cycle, it is important to reduce market uncertainties by gauging the demand for products and services through research at public institutions. The results of these studies can then be applied towards the creation of new rules and standards which reflect the needs and concerns of market participants. It is also vital for institutions to secure an early stage market via policy instruments such as public procurement.

The technology policies that largely support mass-produced goods (such as semiconductor memory)

include development of projections for procurement, funding R&D, establishing antitrust issues, fostering trade, manipulating taxes and generating manpower. While these issues are important for ICT systems products also, policies which encourage coordination among participants and support for commercialized standards in the global market are even more essential. It is critical for governments and institutions to adapt their policy areas in order to respond to environmental change in terms of product characteristics and developmental stages.

4. CASE ANALYSIS

The three cases discussed and analyzed in this section exemplify Korean success in ICT systems development. With the development of TDX and the world's first commercialization of second generation CDMA in 1996, Korea became one of the world leaders in ICTs. During the first decade of the 21st century, Korea continued its ascension among the leading national producers of technology by developing and commercializing new ICT Systems such as WiBro, IMT-2000, and T-DMB/TPEG.

All three of these systems were internationally recognized as successful examples of technological standards developed or contributed by a catch-up country. But irrespective of their quality, all three systems have suffered from limited market diffusion and low profitability.

Each of the case studies discusses only relevant elements identified in the framework for the reason that evidence for each element may not be relevant for each single case study. For instance, coordination is not discussed in the case of WiBro as there are no apparent inter-ministerial coordination issues.

4.1 Wireless Broadband (WiBro)

WiBro is a mobile wireless internet technology initiated and developed by Korea, beginning in 2001. It is compatible to its global counterpart WiMAX, with some additional mobility features. It was developed to overcome the limitations of previous communications networks, such as low transmission speed, high cost, limited content distribution, and sporadic coverage (Bang, 2003). In 2002, the Korean Ministry of Information and Communications (MIC) decided to use a vacant frequency range (once allocated to Wireless Local Loop (WLL) services) for "mobile internet." This decision prompted a public research institute called the Electronic and Telecommunications Research Institute (ETRI) to join with Samsung Electronics to explore the development of the technology under the project code "High Portable Internet" (HPI), which was later named WiBro (Hankyung Business Weekly, 2006). The technology was made compatible with WiMAX and eventually became

an international standard (IEEE802.16e), which was commercialized for the first time by KT (Korea Telecom) and SKT (SK Telecom) in Korea in 2006.

4.1.1. Formulation of new technology policy

In the case of WiBro, the self-inflicted pressure of being the first mobile wireless broadband network in the world resulted in isolation from the global roaming network of Mobile WiMAX. The bandwidth for WiBro was set at 8.75MHz at the 2.3GHz frequency range, which is different from the global trend of 10MHz at the 2.5GHz or 3.5GHz frequency. The problems of different frequency ranges can be solved through software, but bandwidth differences necessitate different or modified devices and equipment, a significant obstacle against achieving economies of scale. The bandwidth problem in Korea was initially caused by allocating three operators to the narrow 2.3GHz range. Since Korea was the first country to implemented, with other countries allocating spectrum later, some argue that the Korean government should not be blamed. However, by remaining captive to the goal of being the world's first, the Korean government surrendered its chance to coordinate with global players. Korea may have won the title of "the world's first commercialization of mobile wireless internet," but the victory came at the cost of market opportunity, as other countries elected to use a different frequency range and bandwidth. The discrepancy in frequency and bandwidth was immediately criticized during

WiBro's service launch in 2006, but the Korean government inexplicably waited until 2009 to begin the process of fixing this problem by switching to the 10MHz bandwidth at the 2.5GHz frequency range (ETNews, 2009).

4.1.2 Inter-organizational co-ordination

In order to create effective market conditions, institutions should design policies which provide economic benefits and incentives to promote rapid diffusion. When WiBro was first being implemented, the selection of carriers was a hot issue. There was a lot of debate surrounding how many carriers would be awarded and which carrier would be favored for wired vs. wireless services.

The MIC considered a number of proposals, which were divided by the number of WiBro network operators and the issue of whether to include MVNOs. Among the five proposals, considered, the MIC settled on the "three operators plan," thinking that increased competition between three providers would be optimal for accelerating market diffusion (INews, 2004). In 2005, the MIC granted licenses to three large companies -SKT (wireless), KT (wired), and Hanaro (wired) (INews,

2005).

In terms of proliferating market dynamics, these three carriers viewed WiBro much differently than did the government. Hanaro Telecom's existing business was broadband internet and local telephone service. In order to expand its business, Hanaro was planning to acquire Thrunet (a cable TV and internet operator). It had been involved in acquisition talks since 2003, and in December 2004 signed an MOU. Having telephone and cable networks, Hanaro was planning to establish a portfolio of various internet services. WiBro was to be another item in that portfolio, although it quickly got lost in the shuffle as Hanaro focused on its merger with Thrunet. WiBro required huge investments with no guaranteed returns, and the competition in the broadband internet was heating up as a new service provider (Powercom) entered the market. Therefore, a mere three months after being named as a WiBro provider, Hanaro opted to return its license in order to concentrate on its wired broadband internet business, for which the returns were comparatively clear and achievable (Digital Daily, 2005).

Meanwhile, SKT considered WiBro to be a complementary technology to its core business of 2G mobile services. The company was expanding into 3G technology, and even had aspirations of moving forward with 3.5G technology through HSDPA. Considering that WiBro offered voice communication using VoIP (Voice over Internet Protocol), and HSDPA offered mobile internet, SKT's involvement with WiBro seemed risky and redundant. Thus, the company objected to the use of VoIP and convinced the MIC not to allow it (Digital Times, 2006b). But SKT still remained reluctant to invest in WiBro, since they had already invested in 2G and 3G networks, and its 3G business had not yet reached a break-even point due to huge licensing fees. Moreover, if WiBro was fully commercialized, it would likely cannibalize revenue from 3G video calls. SKT finally postponed its investment plan in WiBro, essentially condemning the network to a limbo of limited coverage and low market diffusion.

The third licensee, KT, actively invested in WiBro, but they were not able to achieve enough economies of scale for the whole WiBro market. WiBro's market diffusion was also hampered by poor spectrum management, as allocated bandwidth channels had to be narrowed down to 8.75MHz to squeeze the three operators into a narrow range of available frequency (INews, 2008). The 2.3GHz range in Korea had only 100MHz capacity (vacated by the WLL service), which meant that less than 30MHz were allocated to each of the three operators. Those 30MHz then had to be divided into three channels with guard bands, leaving an available bandwidth of only 8.75MHz per channel (Kim, 2009). As mentioned earlier, the problems of frequency difference may be overcome by software solutions, but differences in bandwidth are a critical source of incompatibility. Due to such incompatibilities caused by the government's pluralistic approach, WiBro (and WiMAX) device and equipment manufacturers were not able to achieve economies of scale.

As mentioned earlier, WiBro development was initiated by the MIC in 2001 when a frequency range (2.3GHz) allocated to WLL (Wireless Local Loop) was returned. In July 2001, the MIC reached an agreement with mobile communications operators and device manufacturers to utilize the vacated 2.3GHz range for mobile internet (MIC, 2002). After almost three years worth of R&D headed by ETRI and Samsung, KT and SKT successfully launched WiBro services at 2.3GHz in 2006, making it the world's first commercial mobile broadband wireless network. However, Korea soon learned that there are sometimes disadvantages to being first, as the worldwide selection of frequency range for mobile internet services did not meet their expectations.

Whereas Korea used the 2.3GHz range, an increasing number of countries, including many countries with large markets, decided to use frequencies of 2.5GHz or above, as shown in Table 1. European countries selected 3.5GHz, but at that time they were targeting fixed WiMAX transmission instead of mobile. In order to expand the coverage of WiBro service, it was important to lower the prices of equipment through economies of scale. However, experts claimed that staying at 2.3GHz could be disadvantageous, as 2.5GHz had become a global trend (Digital Times, 2006). Setting 2.3GHz as a standard in Korea would not be a significant failure, considering that Korea was the first to commercialize WiBro, which meant that other countries would later implement mobile internet.

However, those other countries were flexible in allocating frequencies, allowing multiple frequency ranges or technology neutrality (Jeon, 2007b). In Korea, the 2.5GHz range was already being used by military communications and S-DMB (Satellite Digital Multimedia Broadcasting) (Digital Times, 2006). Rather than negotiating to acquire frequency flexibility, the government chose to adjust its strategy to the available frequency range. Since the commercialization of WiBro in June 2006, the problem has yet to be solved. After the then ruling party was replaced, the Korean government finally began to consider allocating the 2.5GHz range for WiBro, but this belated consideration only serves as evidence that the government's poor policy vision played a crucial role in the delayed diffusion of WiBro in Korea and abroad.

<Table 1 about here>

4.2 International Mobile Telecommunications-2000 (IMT-2000): 3rd Generation Wireless (3G)

The next case of Korean technology to be examined is IMT-2000 (International Mobile Telecommunications – 2000), which is a set of standards for third-generation (3G) mobile telecommunications which allow video calls with upgraded data transmission capacity. As global companies were collectively transitioning to 3G, Korea sought to follow up on their previous success with TDX and CDMA by entering the next-generation ICT fields. The plan was to launch IMT-2000 services in 2002 and to conquer the global mobile communication equipment market with the

synchronous IMT-2000, which was regarded as an advanced version of the homegrown CDMA technology which had been developed in collaboration with Qualcomm, a US firm. The plan looked viable because Korea's second-generation CDMA technology was considered superior to its competitors, leading to an impressive 30% share of the market. Most participants expected that share to increase with the more advanced 3G system, with Samsung forecasting a 40% share for IMT-2000 (Korea Economic Daily, 2000).

4.2.1. Formulation of new technology policy

The case of IMT-2000 exemplifies the possible perils of a poor forecast for demand and over-commitment to homegrown technologies. The MIC pushed the implementation of 3G mobile networks (IMT-2000) far ahead of the demand. During the period while Korea was considering the implementation of 3G mobile technology, many countries in the world believed that the demand for

3G would soon take off. European mobile service operators suffered from low ARPU (Average Revenue Per Unit) due to the technological limitation of 2G mobile technologies. In order to increase revenue, they required better technology, and new mobile technologies with higher data transmission rate were expected to bring new opportunities (Ha, 2001). The roadmap for 3G mobile services was born in this context, and world mobile operators prepared for a new technology. The future of the new mobile technology looked bright, and majority of operators selected asynchronous IMT-2000.

The Korean government also rushed into the global trend, accepting the global view on the next generation mobile technology and the emerging new Asynchronous IMT-2000 standard. However, the MIC believed that its mission was to nurture homegrown technologies and leading global ICT industries. This belief was based on the MIC's previous success in the 2G CDMA commercialization, which had a strong performance in the global market (ETRI, 2006). Samsung Electronics, which manufactured synchronous equipment, supported MIC, arguing that it could produce synchronous equipment for 3G technology that could be developed in time, forecasting the future of the synchronous IMT-2000 market positively. Meanwhile, LG Electronics, a Samsung competitor, had already been investing in asynchronous IMT-2000 (Korea Economic Daily, 2000). Therefore, the MIC considered a dual standards plan which accepts both homegrown synchronous and European asynchronous IMT-2000.

During the process of IMT-2000 implementation, the MIC strongly supported its CDMA technology (synchronous IMT-2000) and attempted world-first implementation of the technology. When NTT DoCoMo commercialized a competing technology (WCDMA) in 2001, the Korean government shifted into high gear to reduce the gap in WCDMA and to commercialize the world's first

synchronous IMT-2000. In 2000, two operators (SKT and KT) were selected as asynchronous IMT-2000 operators, and in 2001 LGT was licensed for synchronous IMT-2000. However, despite the MIC's promising forecast, global and domestic demand for WCDMA was stagnant for several years, and the operators were reluctant to increase investments. As market expectations became unclear LGT considered withdrawing from synchronous IMT-2000 and finally returned its license in 2006 (Munhwa Ilbo, 2006). LGT could find no reason to promote IMT-2000 when demand for 3G did not increase and 2G technology had advanced to the point of threatening 3G in terms of capabilities.

Thanks to the pressure to achieve "world's first" status, along with a flawed market forecast, Korea's homegrown 3G technology (synchronous IMT-2000) became extinct.

4.2.2. Inter-organizational coordination

The idea of IMT-2000 was to achieve worldwide wireless access by linking diverse systems and networks. For the next generation of mobile communications networks, equipment manufacturers and service operators attempted to integrate GSM (Global System for Mobile Communications) and CDMA, which had been evenly dividing the mobile communications business.. When the Korean government was considering IMT-2000 commercialization and licensing, there were two policy arguments: one advocated a third-generation on top of the homegrown CDMA-based technologies (synchronous IMT-2000) and the other sought to improve global competitiveness in mobile services (asynchronous, based on WCDMA) (INews, 2002). It was clear from an announcement by the MIC that Korea would pursue an IMT-2000 plan before market demand took off, since it seemed that success was inevitable based on the growth of CDMA-related industries. The MIC appeared to have the intention of sustaining the growth of the Korean ICT industry by nurturing the next generation of

CDMA technology (i.e. synchronous IMT-2000), but contrary to the government's plan, all the major operators expressed the view that they would prefer asynchronous over synchronous IMT-2000. Korea's major mobile communications operators, including SKT, KTF, and LGT, all argued that Korean mobile communications would lose the opportunity to achieve economies of scale and would be isolated in the global mobile communications industry if they did not align themselves with international technology trends.

This dissension from the private sector caused the MIC to change its stance, and it was announced that the government would not attempt to support any specific technology, letting the operators choose for themselves instead (MIC, 2000). However, in August 2000, the opposition party in the National Assembly accused their opponents of attempting to exert governmental influence during the technology standardization process for IMT-2000, and these allegations proved to be valid. On

October 10, 2000, the MIC announced that it was considering a mandate which would require at least one operator to use synchronous IMT-2000 (Weekly Dong-A, 2000). In February 2001, the new

Minister for the MIC identified CDMA2000 1x as the synchronous IMT-2000, which was commercialized in Korea for the first time in the world (Ilyosisa, 2002). By doing so, the MIC overturned the previous minister's identification of CDMA2000 EV-DV as third-generation (3G) synchronous IMT-2000 and CDMA2000 1x as 2.5G. The series of inconsistent signals from the government resulted in distrust in the mobile communications industry which became visible in the stock market as stock prices of asynchronous operators such as SKT and KT experienced severe fluctuation thereby discouraging investors and leading to a downward economic effect.

Journalists and industry practitioners agreed that the government was increasing uncertainty rather than decreasing it (Weekly Dong-A, 2000).

The policy failure surrounding IMT-2000 was due to the Korean government's inconsistent signals and inability to coordinate between stakeholders. Owing to the nature of competition in the Korean mobile communications industry, which is based largely on facilities and technology standards, the potential competitiveness of operators depends on which technology standard the government supports. The inconsistency in the MIC's position and the resultant discord between the state, the MIC, and the private sector led to increased uncertainty in the mobile communications business, which clearly had a negative effect on investor sentiments and customer confidence.

4.2.3 Public-Private Relationship

The development of IMT-2000 was similarly plagued by institutional pluralism and indecision, as the fierce debate over synchronous or asynchronous IMT-2000 eventually caused the government to adopt multiple standards and to pursue a mixed approach between two policy visions – technological leadership and market leadership.

The plan was to select three operators: one for synchronous IMT-2000, one for asynchronous, and one which could choose either of the two standards, depending on market demands. In October 2000, four operators submitted proposals for the IMT-2000 spectrum. All three of the major mobile operators applied for asynchronous, while the only applicant for synchronous was Hanaro Telecom, which had no previous experience in mobile communications operation. This imbalance conflicted with the MIC’s expectation that operators would prefer the synchronous system, which represented a natural evolutionary trajectory from previous CDMA technology. The MIC opted to issue asynchronous licenses to two operators (SKT and KTF), and to reject Hanaro Telecom’s application for a

synchronous license due to its lack of technological capability. The MIC then tried to persuade LGT (the lone operator whose application for an asynchronous license had been rejected) to opt for synchronous mobile operation by offering the company differentiated regulatory requirements, discounted subscription fees, and other advantages over the asynchronous operators. LGT initially refused the government's offer, but finally decided to begin synchronous mobile operation in 2001 (Korea Economic Daily, 2001).

This policy of asymmetric regulation was meant to promote leadership in both technology and services, but neither of those goals was realized. The commercial launch of asynchronous IMT-2000 was delayed, while synchronous IMT-2000 was outplayed in the market. The delay of asynchronous IMT-2000 was, of course, a global phenomenon which was inevitable, since the technology was not ready. However, industry practitioners still say that the Korean government cannot avoid the blame for this policy failure (INews, 2002). While the asynchronous operators were suffering from an economic downturn and a high financial burden due to the expensive frequency charge, the MIC enacted inequitable regulations and offered financial advantages to LGT, the synchronous operator. In addition, even after issuing the asynchronous licenses, the MIC persistently cajoled asynchronous operators to participate in the synchronous operation, resulting in low investment in the asynchronous operation.

While the government strongly supported LGT as the synchronous operator, it did not pay close attention to the technological development and equipment manufacturing in the synchronous IMT-2000. As soon as SKT and KTF were selected for the asynchronous IMT-2000, Samsung and Qualcomm each stopped manufacturing synchronous equipment. Even though LGT participated in the synchronous operation, the company could not carry out manufacturing while relying only on a handful of operators. Moreover, while Korean mobile operators were struggling for 3G mobile services, 2G technologies were progressing. For instance, the 2G system of CDMA2000 Revision A offered a data transmission rate which could have qualified for 3G mobile services. Finally, in 2006, LGT announced that it would return its IMT-2000 license and withdraw from the 3G mobile business (Munhwa Ilbo, 2006), choosing instead to begin offering 3G-level mobile service using CDMA2000 Revision A (2G technology). Once again, divided objectives led to policy visions which conflicted with and even obstructed one another, causing the government's policy to become diluted.

4.3 Terrestrial Digital Media Broadcasting (T-DMB) and Transport Protocol Expert Group (TPEG)

The third case, Digital Multimedia Broadcasting (DMB) is one of Korea's homegrown technologies.

It is an international standard based on ETSI's (European Telecommunications Standards Institute) digital radio broadcasting standard, called the Eureka-147 DAB system (World DMB Forum, 2009).

Whereas the DAB system is used primarily for audio-only services, DMB has focused on broadcasting and receiving moving images through mobile devices. There are two types of DMB, known as S-DMB and T-DMB, the latter of which was developed and commercialized for the first time by Koreans, according to the World DMB Forum. The technical potential of T-DMB was first explored during debates over digital television (DTV) standardization in Korea (Hankyoreh 21, 2005). DAB was selected for next-generation radio broadcasting in Korea, which signaled that the development and standardization for these systems were well under way. The enhanced function of T-DMB was achieved by employing a new multimedia encoding technology called MPEG4, which was largely developed by Korean scientists, as seen by the large number of US patents for the product (Choi and Choung, 2006).

4.3.1. Formulation of new technology policy

T-DMB is another case of a Korean technology whose long-term development was hindered by the obsession to become a "world's first" commercialization. DMB was first developed in Korea, but it was split into two factions—T-DMB (led by ETRI and Samsung) and S-DMB (led by SKT). While both technologies were initially developed in Korea, S-DMB was first commercialized in Japan (Korea Times, 2004). Stimulated by this, the Korean government tried to accelerate the commercialization of T-DMB, and the service was successfully launched in December 2005.

However, institutional adjustment was not quick enough to follow the technological implementation. As described previously, business models were not developed and regulations were not improved. Though T-DMB has been in service for four years now, the operators have not yet increased revenue and are still seeing deficits. The MIC's plan was to first implement and then to export equipment and devices to overseas markets, but the export of T-DMB has not yet occurred.

4.3.2. Inter-organizational Coordination; T-DMB and TPEG commercialization

Through its status as the government ministry for Korean ICT, the MIC was also intimately involved with the development and implementation of T-DMB. The standardization process for TDMB was supported by both the TTA (Telecommunications Technology Association), which is Korea's counterpart to the ETSI (European Telecommunications Standards Institute) and the ITU (International Telecommunication Union), while the ETRI, which is an MIC affiliate, played a key

role in R&D (ETRI, 2004). In addition, one national broadcaster—KBS (Korean Broadcasting System)—and several companies holding MPEG-4 patents (including Samsung) were active participants in this major developmental project.

Despite the successful technological development and commercialization of T-DMB, it has not produced a profit in any year since its implementation. This failure has been attributed to a weak business model and lack of impressive applications. TPEG (Transport Protocol Expert Group) emerged as a possible provider for such applications, but its development was significantly hindered by the participation of many different institutions and networks with diverging interests. TPEG's path to development and standardization has involved the following; a proposal from the MOCT (Ministry of Construction and Transportation) to advance the TTI (Traffic and Traveler Information) system; technological support from the MOCIE (Ministry of Commerce, Industry and Energy) and its subordinate institution, KETI (Korea Electronics Technology Institute); and the TTI-system operational experience of the broadcaster MBC.

Along with MOCIE, the involvement and expertise of MBC was most integral to the development of the specifications for the TPEG subordinate standard, CTT (Congestion and Travel-Time Information). Before working on TPEG, MBC developed an FM-DARC (Frequency Modulation Data Radio Channel) service system using FM Radio, and used this technology to launch a traffic information service called "Idio" in 1999. Based on the experience from Idio development and operation, MBC transformed its Idio service into CTI (Congestion Travel-time Information). CTI was then submitted to the international TPEG forum, and accepted as TPEG CTI in 2004 (Digital Times, 2004).

As reviewed above, T-DMB and TPEG were developed by two separate groups of networks, with T-DMB being led by the MIC, ETRI, and KBS, and TPEG being led by MOCIE, KETI, and MBC. These opposing sets of networks clashed and collided throughout every stage of T-DMB and TPEG implementation. Their conflict over market share was apparent during the operator selection stage, and became particularly fierce when the two parties attempted to implement TPEG on T-DMB. This process necessitated the development and implementation of a CAS (Conditional Access System), which would track the customer's TPEG service usage and bill them appropriately. No such system had yet been developed for DMB service, so KBS and MBC each took it upon themselves to create their own CAS solutions. MBC developed a CAS for TPEG (not for DMB) according to its strategy for the DMB market, while KBS independently developed a CAS which was specific to its TPEG service. The two solutions were incompatible, which led to a prolonged dispute between the two broadcasters and further delay for the implementation of TPEG for DMB. Ironically, the TPEG forum and TTA eventually rejected both proposals, and KBS independently implemented an initial charge

scheme without using CAS, with MBC soon following suit. By May 2007, about 50,000 users had subscribed to KBS TPEG, producing estimated revenue of about one million US dollars (Digital Daily, 2007). While the initial charge scheme finally gave the broadcasting companies some revenue, it was not enough to sustain their businesses. It is clear that the lack of coordination between the two sets of institutions was primarily responsible for the belated implementation of DMB and the low return on investment.

4.3.3 Public-Private Relationship

T-DMB was first commercialized in December 2005, but coverage was limited to the Seoul metropolitan area. In 2006, the selection process for operators offering national coverage became a hot issue. There were two proposals for national coverage: one which would divide the country into six regions and select a local broadcaster for each, and one which targeted nationwide T-DMB service (except for the Seoul metropolitan area) (Broadcasting Commission, 2006). The first plan was better for achieving localism, allowing local and small broadcasting companies to focus on regional markets.

The disadvantages were a lack of mobility across regions and uncertain profitability, since smaller broadcasting companies would find it difficult to achieve economies of scale. The second proposal guaranteed nationwide mobile reception of digital TV, and offered higher profitability and quality of multimedia services, based on the participation of larger broadcasting companies. However, this proposal had a disadvantage in the localization of services.

<Table 2 about here>

The selection between the two proposals was a difficult problem to solve due to the conflict between profitability and localism. From an economic point of view, regional T-DMB operators would have preferred profitability, but from a sociological point of view, the provision of local information to the public was more important. In October 2006, the Broadcasting Commission opted for a mix of the two proposals by selecting one nationwide broadcaster, and two local broadcasters for each of the six regions (Dong-A Ilbo, 2006). The compromised proposal was aimed at satisfying needs for both localism and mobility.

However, there has been criticism that too many broadcasters were selected for the single market. In 2005, six companies were selected for the Seoul Metropolitan area, and thirteen more were selected for regional operations in 2006. With a total of nineteen broadcasting companies operating in a single market, demand had not increased sufficiently. T-DMB operators are currently suffering from low revenue, and it does not seem there will be any reversal without some radical measures.

Clearly, T-DMB is a more advanced technology than DAB in terms of features and performance. T-DMB signals are compressed using MPEG4, which is a better compression technique and is not available through DAB equipment, whereas DAB signals compressed by MPEG2 still work on TDMB (World DMB Forum, 2009). In other words, T-DMB is reverse compatible with DAB.

Therefore Korea expected that T-DMB would be adopted by European countries where DAB infrastructure was already under installation, and T-DMB could be implemented without any extra cost. It seemed certain that T-DMB would replace DVB-H, so Korean institutions began to strategically plan how to develop and commercialize T-DMB in Korea, with the ultimate intention of penetrating the European market.

This goal seemed feasible, as European countries had already been promoting regional standardization of Eureka-147 family technologies, with which T-DMB was technologically competitive, in addition to being compatible with DAB. Therefore, T-DMB developers formed a competitive relationship against DVB-H and began promoting international standardization of T-DMB through ETSI. This standardization strategy was expected to support T-DMB institutionally even outside the Korean territory.

<Table 3 about here>

By December 2007, T-DMB was commercialized in three countries and being tested. A German broadcaster, MFD, adopted the standard in 2006 (Lim, 2006), which was a positive signal for T-DMB's eventual penetration into the European market. Based on this initial adoption, T-DMB developers expected the coverage would expand, but their ambitious plan soon encountered an obstruction. In July 2007, the European Commission (EC) announced that it would recommend the use of DVB-H by European countries (BBC, 2007). After this announcement, MDF decided to withdraw from the T-DMB business. The decision of the EC was suspected to be a political move to protect DVB-H against T-DMB, as became apparent during an interview with EC's Telecoms Commissioner Viviane Reading (BBC, 2007). This move could have been predicted, since DVB-H is a charged service which features technology developed by European telecommunications companies, while T-DMB is a free service which was developed primarily by government-funded research institutes and national broadcasting companies. From a political point of view, it seems natural that the EU would support the interests of its local companies.

This event has cast a shadow on the future of T-DMB, but new opportunities are still expected in

Norway and France. In 2008, Norway decided to introduce T-DMB for its digital TV broadcasting(Digital Times, 2008), causing Koreans to revisit their implementation plan for T-DMB. Notably, Norway is not a member of the EU, and thus has more freedom to choose a non-DVB-H standard than EU countries. This fact confirms that social or political dynamism in the global market is a significant consideration during international expansion.

5. CONCLUSION AND POLICY IMPLICATIONS

Despite visible technological superiority, Korean telecommunication systems have performed relatively poorly in the global market, as exemplified by the cases of WiBro, IMT-2000, and T-DMB.

This paper argues that the main reason for this less-than-stellar performance could be the delay of institutional shifts, which are required in response to environmental changes. In the case studies discussed, there was a clear mismatch between Korea's existing institutional capabilities, which were accumulated during the catch-up phase, and the types of institutional arrangements and organizational routines required to help the country attain a new status of global leader in technology and industry.

At first, public actors are prone to learning and developing some sort of core institutional competencies, especially in cases of previous successes. Success tends to reinforce the organization and routines for evaluation of new options, selection and implementations. Therefore, when development and diffusion of new ICT system demand new jurisdictions and controls over technological and market aspects, conflicts between public actors arise. In order to make the transition smoothly, coordination between multiple, and, in some cases, new networks is imperative for achieving common goals. This coordination should address issues about jurisdiction and control throughout the evaluation of opening options, selection and subsequent implementation plans for new ICT system. The Korean government and industrial institutions faced such a coordination failure in the cases of IMT-2000 and TDMB systems. The conflicts between intra-governmental departments had a crippling effect on both the domestic and international market. In addition, inconsistent policy visions aggravated the market uncertainties.

For example, in case of TDMB, a conflict between the MIC's service interests and MOCIE's equipment interests caused significant confusion among the market participants, and this dispute was augmented by departmental biases and a general lack of coordination from all the involved parties.

Secondly, another major failure during transition comes from the policy or technology strategy side. Inevitably, it takes some time to shift from institutions suitable for one set of industrial policies towards a different overall orientation. Korea's narrowly focused, supply-dominated technological

strategy prioritized the establishment of "world's first" technologies over more practical concerns like cooperation with market participants at the global level. Compliance with global standards of a domestically developed technology is essential for being a candidate for global market diffusion. However, irrespective of the standards approval which is somewhat predictable if the proposal is technologically compliant, diffusion requires more capabilities, such as interdependences of the systems, for example, or even the will to work together at regional levels. In a few cases, the Korean government showed an appalling lack of understanding of these aspects of global technology networks, where it should have pursued a user-based technology development on a global level instead of implementing a supply-based technology policy. On the contrary, on the domestic side, a balance between institutions focusing on user and technology at the same time can have important implications.

In the case of WiBro, the Korean government followed a user-centered institutional design, and lacked the capability to forecast about domestic technological markets and anticipate business possibilities. Specifically, the government underestimated the possible detriments of cannibalization which would occur within existing domestic markets with the launch of parallel services. The government further demonstrated its lack of understanding of the market by setting up inappropriate rules. Therefore, for simple products, gradual upgrading from supply side to user side policy design seems to be the appropriate pattern in line with PLC, but for ICT system there are no set rules. It may turn out differently, depending on the individual case and whether it involves the domestic or global level.

Finally, latecomer countries with a successful record of building technological capabilities may find it difficult to deploy institutional capabilities that are crucial for market creation. The closed nature of government decision focused on technological catch-up usually works well during early stages, but may fail to notice the emerging market needs both at domestic and global levels. Such a failure stems from the inability to elaborate newer (or somewhat invisible) possibilities while just evaluating more predictable options, which are results of regulatory and interventionist instruments during catch-up. As shown in the WiBro case, the Korean government insisted on the participation of several service providers, despite the limited size of the market. Similarly, in the case of IMT-2000, the Korean government was torn between a domestically developed standard and a globally dominant standard, and therefore tried to accommodate both. The decision to encourage LGT to become a synchronous IMT-2000 provider was driven by a latecomer's pride in a homegrown CDMA technology, and it predictably turned out to be a failure. This debacle of trying to shape the market based on a domestically developed standard demonstrated an incompetent long-term vision and understanding of domestic and global market dynamics.

In sum, during the catch-up phase, Korea successfully accumulated technological facilities and expertise, and simultaneously developed the institutional capabilities needed to complement those advances. These institutional capabilities, which were geared towards mass production, began with a highly concentrated decision-making system which enabled faster decisions in order to support accelerated learning in selected areas. Subsequently, the nation developed systems for policy planning and implementation within each functional unit, which facilitated the selection of strategic product groups and the correct allocation of resources. This sort of sectionalism functions well when concentrating resources on a strategic product. A third element was the supply-centered technological strategy, which supported fast learning under clear technological targets. This idea tends to be effective in allowing latecomers to quickly become equal with competitors within given technology options.

However, the institutional capabilities accumulated during the catch-up period have proven to be impediments in the transition phase. Moreover, such institutional capabilities have resulted in some damaging mismatches in the ICT system markets, which have different characteristics from the mass production markets where Korea is competitive. In the case of system level transitions in late industrializing countries, these findings support the notions of nonattendance or mismanagement of 'reverse salient' in the making, along with 'institutional inertia'.

We propose that there are at least three elements which must be part of new institutional capabilities in order to promote an effective response to changes within the industrial environment, including a paradigm shift for catch-up and ICT system markets. First, there is the element of coordination capability, which is critical for organizing and integrating between inter- and intra-government departments. Second, a user-driven technology strategy must consider technological complexity and market creation beginning in the planning stage. The third element is market creation capability for institutionalizing technology standards and generating needs for new products. The institutional support for reducing technological and market uncertainties is important for all of the above elements in general.

It has been shown that institutional capabilities which are effective during the catch-up phase often become obstacles once a country's status on the global technological market changes. The institutional arrangement and organizational routines in the catch-up period support fast learning of existing technologies, thereby achieving competitiveness through adjustment and improvement.

However, these capabilities result in delays in setting standards and in the commercialization of newly developed technologies during the transition period. These results imply a long-term policy orientation, which contains a larger set of possible options of the future, and inter-organizational coordination is essential in order to provide flexibility for embracing environmental changes during

transition. In terms of policy objectives, dealing with technological complexity and uncertainties becomes more important than fast learning. Thus, a meta-level governmental integrated policy system may be required. Such a system should include feedback for policy education and re-education. The concept of "policy learning" is a key methodology to accumulate institutional capability within a new policy framework, and should serve as one of the future research areas for understanding the complex problems faced by newly industrialized or latecomer countries in the transition phase.

REFERENCES

Anchordoguy, M. (2000), 'Japan's software industry: a failure of institutions?', Research Policy, 29, pp.391-408.

Bang, H. C. (2003), 'Mobile Internet Technologies (2.3 GHz Range)', Radio Promotion, June 2003, Korea Radio Promotion Association, Retrieved from http://www.rapa.or.kr/data/book_issue_view.asp?idx=7&flag=2 [Text in Korean].

Bell, M. and Pavitt, K (1993), 'Technological accumulation and industrial growth: contrasts between developed and developing countries', Industrial and Corporate Change **2**, pp.157–210.

Broadcasting Commission (2006), Proceedings of Public Hearing for Regional DMB Operation, Korean Broadcasting Commission.

Choi, Y. and Choung, J-Y., (2006), 'A Successful MPEG Standardization of South Korea: Technological Catching-up with a Co-Evolutionary Innovation System', IAMOT 2006 Conference, Beijing, China.

Electronics and Telecommunications Research Institute [ETRI] (2004), 'The implications from international standardization of Korean T-DMB', ETRI Press Release, 8 Dec 2004. [Text in Korean].

Electronics and Telecommunications Research Institute [ETRI] (2006), The Thirty Years History of Electronics and Telecommunications Research Institute, ETRI, Daejeon. [Text in Korean].

Freeman, C. (1987), Technology and Economic Performance: Lessons from Japan, London: Pinter.

Ha, T. J. (2001), 'European Mobile Internet Marching towards 2.5G, EG Economy Weekly, 25 April.

Hobday, M. (1995), Innovation in East Asia: The Challenge to Japan, Aldershot: Edward Elgar.

Hobday, M., R. H, Rush and J. Bessant (2004), 'Approaching the Innovation Frontier in Korea: The transition phase to leadership', Research Policy, 33 (10), pp.1433-1457.

Jeon, S-Y. (2007), 'The Process of WiBro Standardization and Frequency-Technology Neutrality', Information and Communications Policy, 19(20), pp.41-45.

Kim, L. (1997), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Boston: MA: Harvard Business School Press.

Kim, Y. H. (2009), The Trend and Future of WiBro Business, National Assembly Research Service [Text in Korean].

Lall, S. (1992), 'Technological capabilities and industrialization', World Development, 20(2), pp.165-186.

Lee, J., Bae, Z and Choi, D-K, (1988), 'Technology Development Processes: A Model for a Developing Country with a Global Perspective', R&D Management, 18(3), pp.235-250.

Leonard-Barton, D. (1992). Core capabilities and core rigidities: A paradox in managing new product development. Strategic Management Journal, 13(S1), 111-125.

Lundvall, B-Å. (ed.) (1992), National Innovation Systems: Towards a Theory of Innovation and Interactive Learning, Pinter, London.

Lundvall, B-Å., Intarakumnerd, P. and Vang, J. (2006), *Asia's Innovation Systems in Transition*, Edward Elgar.

Mathews, J. (1998), 'Fashioning a New Korean Model Out of the Crisis: The Rebuilding of Institutional Capabilities', Cambridge Journal of Economics, vol. 22(6), pp.747-59, OUP.

Ministry of Information and Communications [MIC] (2000), IMT-2000 Plan, Ministry of Information and Communications, Seoul. [Text in Korean].

Ministry of Information and Communications [MIC] (2002), Mid to Long Term Plan for Frequency Utilization, Ministry of Information and Communications, Seoul, February 2002.

Nelson, R. (1994), 'The Co-evolution of technology, industrial structure, and supporting institution', Industrial and Corporate Change, vol.3, pp.47-64.

Nelson, R. (2007), 'The Changing Institutional Requirements for Technological and Economic Catch up', Int, J. Technological Learning, Innovation and Development, Vol.1, No. 1.

World Bank (1993), The East Asian Miracle: Economic Growth and Public Policy, Washington.

Zysman, J.(1996), "Nations, Institutions, and Technological Development," International Journal of Technology Management, Vol. 12, Nos. 3/4.

<News Articles and Web Resources>

BBC (2007), 'EU backs standard for mobile TV', BBC News, Retrieved from: http://news.bbc.co.uk/2/hi/technology/6902541.stm

Digital Daily (2005), '[WiBro] Hanaro's announcement on withdrawal from WiBro business', Digital

Daily, April 25, 2005.

Digital Daily (2007), ‘Initial charge – Small amount but large source of revenue’, Digital Daily, May 18, 2007.

Digital Times (2004), 'International standardization of Korean TPEG-CTI promotes application and devices export', Digital Times, 07 Jul 2004.

Digital Times (2006a), ‘WiBro frequency strategy needs to change’, Digital Times, May 30, 2006.

Digital Times (2006b), ‘Lame WiBro – until when?’, Digital Times, September 21, 2006.

Digital Times (2007), ‘Lessons from similar investments in WCDMA and WiBro’, Digital Times, November 6, 2007.

Digital Times (2008), ‘Norway selects Korean DMB’, Digital Times, 21 Aug 2008, [in Korean]

Dong-A Ilbo (2006), ‘Broadcasting commission suggests 2 TV channels for local T-DMB’, Dong-A Ilbo, October 24, 2006.

Dong-A Ilbo (2009), ‘WiBro, futile three years’, Dong-A Ilbo, April 6, 2009.

ETNews (2009), ‘Multiple frequency range for WiBro opens’, ETNews, August 10, 2009.

Hankyoreh21 (2005). ‘DMB, the great birth’, Hankyoreh21, April 8, 2005. [in Korean].

Ilyosisa (2002), ‘IMT-2000 policy drifts’, Ilyosisa, 321. [in Korean].

INews (2002), ‘Anatomy of people’s government communications policy – Operators selection for IMT-2000’, INews, October 27, 2002.

INews (2004), ‘3-operator plan likely for WiBro – MIC prepares 5 plans’, I News, 11 August 2004.

INews (2005), ‘WiBro licenses to KT, SKT, and Hanaro Telecom’, INews, January 20, 2005.

INews (2008), ‘Lee vs. Hyung, Debate over WiBro frequency allocation’, INews, December 22, 2008.

Korea Economic Daily (2000), ‘Lacking government’s view, and selfish operators – Difficulties in IMT-2000’, The Korea Economic Daily, October 4, 2000.

Korea Economic Daily (2001), ‘LG Telecom wins synchronous license’, The Korea Economic Daily, August 27, 2001.

MK Economy (2009), ‘DMB business in dilemma’, MK Economy, 1999, April 1, 2009.

Munhwa Ilbo (2006), ‘LGT will not use the one trillion won frequency’, Munhwa Ilbo, July 5, 2006.

The Korea Times (2004), ‘Japan outpaces Korea in satellite mobile broadcast’, The Korea Times, October 4, 2004 [in Korean]

Weekly Dong-A (2000), ‘Inconsistent policy by MIC’, Weekly Dong-A, 26 October, 2000, pp.34-35.

World DMB Forum (2009), 'Introduction to DAB/DMB/DAB+', World DMB Forum Website, Retrieved from http://www.worlddab.org/technology

Table 1: Frequency ranges for Mobile WiMAX (and WiBro)

2.3 GHz (11 countries)	2.5 GHz (12 Countries)	3.5 GHz (20 Countries)
US, Canada, Hong Kong, Norway, Singapore, Vietnam, New Zealand, Malaysia, Taiwan, Indonesia, Korea	US, Canada, UK, Japan, Netherlands, Russia, Taiwan, Australia, Brazil, Venezuela, Mexico, South Africa, etc.	Canada, UK, France, Netherlands, Italy, Germany, India, Saudi, Brazil

Source: Ahn et. al. (2009)

Table 2: Comparison between 6-region and single region plans for T-DMB

Regional Division	Advantage	Disadvantage
6 Regions	- Realization of localism - Fair allocation of frequency	- Low mobility - Profitability uncertain
Single Region	- Higher profitability - High mobility - Multimedia service available	- Low localism

Source: Broadcasting Commission (2006)

Table 3: Practical launch of T-DMB

Mobile TV standard	Countries launched	No. of countries testing
DMB	Korea, Germany, China	11
DVB-H	Italy, Finland, Albania, Vietnam	24
MediaFlo	U.S.	2
OneSeg	Japan	

Source: MIC website