THE NATIONAL BUREAU *of* ASIAN RESEARCH
Trade, Economic, and Energy Affairs

Diminishing Returns to High-Tech Standards Wars: China's Strategies in Mobile Communications Technology

Tomoo Marukawa

TOMOO MARUKAWA is Professor of Chinese Economy at the University of Tokyo. He can be reached at <marukawa@iss.u-tokyo.ac.jp>.

EXECUTIVE SUMMARY

This working paper reviews the competition between various technology standards for mobile communications and the strategies that China has adopted in this competition. It finds that the returns from winning the standards wars have diminished.

Main Argument

Technology standards are often regarded as having a strategic importance in high-tech industries. The Chinese government has been influenced by this theory and has attempted to develop its own high-tech standards. By reviewing the history of mobile communications technology, this paper finds that the expected market size and the switching cost between different technology standards determines the intensity of the standards wars. When the switching cost is high, the potential returns from victory are huge, so the war will be fought hard. But if the switching cost decreases, winning or losing a standards war will have little influence on a firm's or a nation's success in high-tech industries. In the case of mobile communications technology, the progress in integrated circuits (IC) technology has reduced the switching cost to a minimum level.

Policy Implications

- If the switching cost between different technology standards is high, then the competition between standards will have strategic implications for the success of the parties involved in the creation of those standards.
- The history of mobile communications technology suggests that in high-tech industries in which the core technology is encapsulated in ICs, the switching cost will decrease along with the technological progress of ICs. This will reduce the importance of standards wars.
- China belatedly joined the war between various technology standards in mobile communications, but by the time it became involved, the importance of the standards wars in mobile communications was already decreasing. China's recent policy of favoring indigenous standards will have little positive impact on its domestic industries and little negative impact on foreign industries.

Technology standards are often regarded as having a strategic importance in high-tech industries. Technology standards are a set of characteristics or quantities that describe features of a product, and in the context of high-tech products (such as cell phones or personal computers), they are what assures a product's compatibility with other associated products (such as software or hardware like printers). The strategies of exploiting standard-setting for the benefit of a firm have been discussed extensively in countries that have taken an interest in developing high-tech industries, including the United States, Japan, South Korea, China, and various countries across Europe. As the outcome of the competition between computer operating systems in the 1990s shows, the competition between technology standards has an impact not only on the destiny of the technologies themselves but also on the destiny of a whole body of associated products, services, and even firms associated with them.

Being aware of the implications of technology standards, China began its attempt to manipulate technology standards in high-tech industries at the beginning of the 21st century.[1] By exploring the technology standards wars in mobile communications, this paper, however, argues that the returns from winning standards wars are diminishing. Technological progress makes victory or defeat in high-tech standards wars less and less important in determining a firm's or a national industry's success. China has succeeded in evolving from being just a user to one of the creators of international technology standards in mobile communications. The irony for China, however, is that the value of creating such standards has already diminished. China and many scholars have been misguided by the perception of technology standards that was formed by experiences in global high-tech industries during the 1980s and 1990s. That perception needs to be reexamined in light of today's technology.

To explore these issues, this paper will focus on the recent development of mobile communications technology. Section one discusses the factors that give rise to standards wars. Section two shows the impact of technology standards on the competitiveness of national industries during the first two generations of mobile communications, a period when technology standards did matter. Section three shows the wane of standards wars in mobile communications in the 21st century and discusses the reasons behind this, followed by a conclusion.

---

[1] China's efforts to develop its own high-tech standards are extensively discussed in Richard P. Suttmeier, Xiangkui Yao, and Alex Zixiang Tan, "Standards of Power? Technology, Institutions, and Politics in the Development of China's National Standards Strategy," National Bureau of Asian Research (NBR), NBR Special Report, no.10, June 2006.

Determinants of Standards Wars

Before showing why the importance of high-tech standards wars is decreasing, this paper first reviews why they have previously been regarded as important. Generally, three properties of high-tech products have shaped the intensity of their standards wars:

- First, some products have network externalities. This means that their perceived utility is shaped by the size of the network of products that share a common technology standard with them.[2] An example of network externalities is the case of videocassette recorders (VCR). There were two competing technologies of VCRs during the 1980s, Betamax and VHS. Technologically speaking, neither one had an absolute advantage over the other. But eventually VHS had an overwhelming victory over Beta, mainly because more VCR manufacturers supplied VHS machines and more titles of prerecorded cassettes were available for VHS than Betamax.
- Second, the user of a product that belongs to a losing network must either incur the cost of switching to products that belong to the dominant network or content themselves with smaller network externalities than those who associate with the dominant standard.[3]
- Third, the potential user's choice of which network to join will be influenced by their expectations about the ultimate size of that network. If government policies can influence consumer expectations, then they can be used to foster a certain network over another. For example, there are currently five digital television broadcast standards in the world, but national governments usually support only one of them. The decision made by the Japanese government to select ISDB as the national standard has resulted in the monopoly of ISDB-compatible television sets in Japan.

The first and third abovementioned properties of the high-tech product market will remain unchanged in the future, even with technological progress. High-tech products will have little value if they have few complementary products and services that share the same technology standard. Likewise, anticipated market size will impact consumer decisions about whether or not

[2] Michael L. Katz and Carl Shapiro, "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy* 94, no.4 (1986): 822–41.

[3] Stanley M. Besen and Joseph Farrell, "Choosing How to Compete: Strategies and Tactics in Standardization," *Journal of Economic Perspectives* 8, no.2 (1994): 117–31.

to join a particular network and also shape how firms and governments respond to a potential arena of competition. If the expected size of the market that will be lost due to losing a standards war is small, firms and governments will not be interested in fighting such a war.

However, the second property—the cost of switching—may change with technological progress. If the switching cost decreases to a very low level, so that consumers can move between two or more different standards without incurring costs, then the rewards from winning a standards war for a firm will be small, because the firm cannot keep the consumers captive within the network.[4]

An example of an intense standards war in which all of these three properties exist is the competition between technology standards for personal computers (PC) during the 1980s and 1990s. In the case of the Japanese PC market, there were nine major standards during 1980s, and each of them was supported by a network of hardware and software.[5] Switching from one standard to another was very costly because a user had to repurchase all the hardware and software. With the spread of Microsoft's Windows in the mid-1990s, all but one of the nine standards (Apple's Macintosh) disappeared from the Japanese market.

A situation in which the first and third properties of network products still hold but the second property (i.e., the switching cost) is unimportant[6] can be illustrated by the case of electrical power plugs and sockets. Travelers to foreign countries often find that the shape of electrical power sockets is different from the shape used in their home country, making their electric razor or hair dryer useless without the means to adapt their plugs to the socket. However, frequent travelers to foreign countries know that the cost of switching from one type of plug to another is low. Adapters that enable electric goods to be plugged into different types of sockets are cheap and easily found. The low cost of switching between different types of plugs has

---

[4] The discussions above can be formulated into a function that determines the intensity of a standards war:
[Intensity of a standards war] = F[(switching cost)×(expected market size)]×E

In this formulation, E is a dummy variable that takes "1" if network externalities exist and "0" otherwise. In the following discussion, it is taken for granted that the former is the case (E=1), so it is omitted.

[5] Tomofumi Takamatsu, "Opungaka hyojunka suishin no tameno joken" [The Conditions for Promoting Open Standardization], in *Defakuto sutandado no honshitsu* [The Nature of De Facto Standards], ed. Junjiro Shintaku, Yoshinobu Konomi, and Takashi Shibata (Tokyo: Yuhikaku, 2000).

[6] A low switching cost implies that the degree of "skewness" of the rewards from the outcome of standards wars—namely the difference between winning and losing the wars—is low, as described in the model developed by Besen and Farrell, "Choosing How to Compete."

reduced firms' and governments' interest in waging a standards war for expanding the share of a certain kind of plug. As a result of such indifference, there are fourteen different types of plugs and sockets currently used in the world, and even the unification of plug types within a single country is seldom achieved. International standardization of plugs was once discussed but there is now little hope for the global unification of plug shapes in the future.[7]

With the abovementioned function and discussions in mind, the following sections analyze the changes in the global competition between technology standards in mobile communications, an area in which China has become an increasingly important player.

When Technology Standards Mattered: The First and Second Generations of Mobile Communications

First Generation (1G) Technology

From the start of mobile telecommunications service in 1979 until the mid-1990s, analog cellular technology was used in transmitting voice signals. This period is called the "first generation." During 1G, major developed countries conducted research and development independently and adopted their own standards for mobile communications. Japan's dominant mobile network operator, Nippon Telegraph and Telephone (NTT, later NTT DoCoMo), adopted a proprietary standard it developed on its own. U.S. operators adopted the AMPS standard developed by the American companies Motorola and AT&T; Italy, Germany, and France also had their own standards.[8] Consequently, developed countries' markets were fragmented, with each country having its own national standard. The exception was in the Scandinavian countries, where the mobile network operators of Sweden, Norway, Finland, and Denmark adopted a common regional standard: NMT. Having a unified standard, the handsets and infrastructure were compatible across all four countries and consumers could enjoy roaming capabilities in any part of the region.[9] Judging from the outcome, competition between technology standards during

---

[7] The facts and data on electrical plugs and sockets derive from International Electrotechnical Commission's World Plugs website, http://www.iec.ch/worldplugs.

[8] Jeffrey L. Funk, *Global Competition between and within Standards: The Case of Mobile Phones* (Basingstoke: Palgrave, 2002).

[9] Dan Steinbock, *Wireless Horizon: Strategy and Competition in the Worldwide Mobile Marketplace* (New York: AMACOM, 2003).

the first generation was relatively moderate. The U.S.-led standard outcompeted the other 1G standards; it accounted for 60% of worldwide mobile subscribers in 1988 and was adopted by mobile network operators in 80 countries by the end of 1993. But the Scandinavian NMT was also fairly successful, being introduced in 36 countries by the end of 1993 and accounting for 20% of worldwide subscribers.[10] Japan's NTT system was the least successful among the first three 1G standards, being adopted by only two Japanese operators. But still it remained the dominant standard in Japan, and both Motorola and the Office of the U.S. Trade Representative pressed the Japanese government hard on expanding the penetration of AMPS into the Japanese market. Other Asian countries were merely customers of the technology made by developed countries during 1G and chose either NMT or AMPS.

Let us consider the two factors that have been hypothesized to influence the intensity of standards wars. The switching cost was very high during 1G because dual- or multiple-mode handsets—which could be used in the networks of two or more technologies—were few until the 1990s. Mobile users had to buy another handset when they wanted to move from one network to another; they even had to change their phone numbers.

In terms of the expected market size, 1G mobile communications services attracted 102 million subscribers worldwide at their peak in 1997. This is not a small number for a high-tech product, but it is dwarfed by the 3.5 billion subscribers to 2G services worldwide in 2009. It was widely recognized that the volume of the 1G service market had a limit due to technical reasons: phone calls that could be made simultaneously in a certain area were limited in 1G networks. With such technical features in mind, it is likely that firms and governments did not expect that 1G technology would create a big market compared to later technologies.

With a high switching cost and small expected market size, the competition between standards during 1G was moderate compared to later generations. The AMPS and NMT camps were relatively aggressive in marketing their technology abroad, but the other camps did not join the scramble for overseas markets. AMPS prevailed over NMT, but it was not an overwhelming victory.

The lesson that can be drawn from 1G is that a national government's policy can influence the outcomes of global competition. The success of AMPS during 1G can be attributed to the U.S.

[10] Funk, *Global Competition between and within Standards*, 43–44, 55.

government's decision to adopt it as the sole standard in the United States. With this decision, the AMPS camp created the largest installed base for a 1G standard in the world, which made their technology competitive in the global market. Japan's failure in marketing NTT's technology overseas stems from the fact that, under the pressure from the United States, the Japanese government failed to unify domestic technology standards, splitting in two its small domestic market.

Second Generation (2G) Technology

In June 1992, the first network using GSM technology started operation in Germany, marking the start of the second generation of mobile communications. The impact of 2G technology was immense. During the first ten years of 2G, worldwide subscribers of mobile services grew from 23 million in 1992 to 1.1 billion in 2002. There were more than 4.4 billion 2G subscribers in 2013, and the number was still increasing.[11]

Plenty of strategies and tactics were employed in the competition between various 2G standards. The most successful strategy was the creation of a pan-European 2G standard, GSM. The decision to create it was made in 1982 by the European Conference of Posts and Telecommunications, which comprised the telecom administrations of 26 European countries. The United States, the birthplace of the most successful 1G technology, took a free-competition policy during 2G, allowing network operators to choose whatever technology they liked.[12] As a result, several different 2G technologies, such as DAMPS, iDEN, CDMA, and Europe's GSM, were adopted by U.S. operators. Japan, learning lessons from 1G, tried to set a unified national standard and market it to other countries. In 1991, Japan's Ministry of Posts and Telecommunications (MPT) decided that a proprietary standard developed by NTT would be the national standard for 2G services, and named it PDC. The MPT worked aggressively to cultivate foreign markets by holding seminars to introduce PDC to Asian operators and publicize that the standard had higher frequency spectrum efficiency than GSM. However, no operator outside Japan adopted it. South Korea, hoping to change from being a mere customer of mobile communications technology to being a creator, teamed up with the U.S. company Qualcomm to

[11] The data is derived from GSM Association and Global mobile suppliers association.

[12] Funk, *Global Competition between and within Standards*, 72–76.

help develop its CDMA technology. A research institute under the Korean Ministry of Information and Communication organized a research team with major Korean electronics manufacturers and developed base stations, switches, and handsets for CDMA. Korea also decided to make CDMA the national standard for 2G at a very early stage, and prohibited domestic operators from adopting other technologies.[13]

As the theory on network externalities predicts, the technology that was expected to have the largest installed base—Europe's GSM—attracted the largest number of customers. With 26 European countries promising to get on the bandwagon right from the start, while U.S. and Japanese standards gained scarce support outside their countries, many non-European operators decided to adopt GSM from an early stage (including, as mentioned above, some operators in the United States). As of 2002, mobile service operators in 174 countries and regions had adopted GSM, with 809 million subscribers in total, accounting for 75% of 2G subscribers worldwide. CDMA, though suffering from delay—its first commercial launch was three years later than GSM—became the second most successful 2G standard, attracting 114 million subscribers by the end of 2002, mainly because of its technological superiority in data transmission speed and frequency spectrum efficiency. Japan's PDC failed to attract any foreign operators, though it became the dominant 2G standard in Japan, having 56 million subscribers by the end of 2002.

The overwhelming success of GSM, the moderate success of CDMA, and the failure of PDC had a serious consequence on the market for mobile handsets. Manufacturers that had participated in the process of making GSM, such as Nokia, Motorola, and Ericsson, succeeded in acquiring large shares in the global mobile handset market, and Korean manufacturers that had participated in the development of CDMA also emerged rapidly as major mobile handset producers, while the shares of Japanese manufacturers declined. In 2004, Nokia's share in the global mobile handset market was 32.4%, followed by Motorola (14.5%), Samsung (12.1%), LG (6.7%), and SonyEricsson (6.3%). There were three Japanese manufacturers among the top five in global handset sales in 1990, but in 2004 even the Japanese manufacturer with the largest

[13] Makoto Abe, "Kankoku keitai denwa tanmatsu sangyo no seicho" [The Growth of Korean Mobile Phone Handset Industry], in *Higashi Ajia no IT kiki sangyo* [The IT Machinery Industries in East Asia], ed. Ken Imai and Momoko Kawakami (Tokyo: Institute of Developing Economies, 2006); and KDDI Research Institute. *Komyunikeshon no kokusai chiseigaku: mobairu tsushin hen sono 2* [The International Geopolitics of Communications: Mobile Communications] (Tokyo: KDDI Research Institute, 2004).

share had only 2.3%.[14]

It was not that Japanese manufacturers avoided the GSM market. Some Japanese manufacturers developed GSM-compatible handsets and tried to sell them in Europe and China. Their competitiveness, however, was seriously impaired by not participating in the creation of GSM technology.[15] First, they had to pay substantial licensing fees, which amounted to 6%–10% of the price of the handsets, to the patent holders of GSM. Secondly, although the developers of GSM published the specifications of the technology, the details of GSM technology were not easily accessible to outsiders and were also upgraded several times, making it difficult and costly for outsiders to catch up. With these disadvantages in mind, firms and even the Chinese government started thinking of creating their own standards and waging war against other competing standards.

With the appearance of dual-mode handsets during the 1990s, the cost of switching from some technologies to others was reduced. During the transition period from 1G to 2G, some dual-mode handsets were launched by U.S. and Japanese operators, who thought that such handsets were needed to attract consumers to their 2G services, as operators gradually switched over their networks and coverage would have otherwise remained incomplete. However, these handsets were not welcomed by mobile users because they were heavier, more expensive, and had shorter battery life than single-mode handsets.[16] Consequently, the switching cost for consumers was reduced but still high during the 1990s.

The size of the market expected to be created by 2G was at least several times larger than 1G because 2G involved a major breakthrough in overcoming the capacity limitations of 1G. By digitalizing and compressing voice signals, 2G services can accommodate several times more traffic than 1G within a given frequency spectrum. But few people expected that the 2G market would be as big as 4.4 billion subscribers and still growing even in the 22nd year since its debut.

---

[14] Here I do not count SonyEricsson, a joint venture created by Sony and Ericsson, as a “Japanese manufacturer,” because a large part of their sales in 2004 was the legacy of Ericsson.

[15] Masanori Yasumoto. “Gurobaruna keitaidenwa meka no kyosoryoku” [The Competitiveness of Global Mobile Phone Makers], in *Keitai denwa sangyo no shinka purosesu*, ed. in Tomoo Marukawa and Masanori Yasumoto [The Evolution Process of the Mobile Phone Industry] (Tokyo: Yuhikaku, 2010), 100–103.

[16] Funk, *Global Competition between and within Standards*, 73–74; and Yasukazu Sugiyama and Yoshi Takatsuki, “Keitaidenwa nimo henkaku no nami” [The Revolutionary Waves in Mobile Communications], *Nikkei Communication*, June 15, 1998, 106–11; and “Kyojin ni idomu” [Challenging the Giant], *Nihon kogyo shimbun*, April 15, 1999.

The Emergence of China in 2G

China was merely a consumer of technologies designed by companies from developed countries at the start of 2G. In 1993, China's dominant mobile network operator, China Mobile, and the second-largest mobile carrier, China Unicom, decided to adopt GSM. In 2002, China Unicom started operating a CDMA network along with its GSM network.[17]

During the 1990s, China harbored an ambition to change itself from the consumer of technologies and hardware for mobile communications to a creator of them. The first project was the development of indigenous-brand mobile handsets. Until 1998, China's mobile handset market was occupied by international brands such as Nokia, Motorola, and Ericsson. In 1992, a research team for the development of a GSM handset was organized at an institute affiliated with the Chinese government. After six years of hard work, its first mobile handset was produced in 1998.[18] The Ministry of Information Industry (MII) convened domestic household electronics manufacturers and transferred the technology developed at the institute to them. In addition, MII promulgated a mobile handset industrial policy in 1999, which introduced a licensing system for handset production, offered R&D subsidies to domestic manufacturers, prohibited new entry of foreign manufacturers, and obliged foreign-invested manufacturers to achieve a high level of local content and to export more than 60% of their production.

This very protectionist policy had an immediate impact. The share of domestic-brand handsets, which was zero in 1998, climbed up from 3% in 1999 to 10% in 2000 and then to 55% in 2003. In that year, a domestic manufacturer named Bird ranked first in the sales volume of mobile handsets in China.[19] Interestingly, while Japanese manufacturers—even with their long experience in handset development and production—failed to penetrate the GSM handset market, Chinese new entrants easily expanded their market shares in China and some of them even exceeded global giants. One factor that impaired the competitiveness of Japanese manufacturers

---

[17] Some Chinese commentators suggest that the Chinese government made this decision under diplomatic pressure from the United States. Libai Liu, "TD-LAS-CDMA, Minzu yidong tongxin chanye de jiyu" [TD-LAS-CDMA, The Chances for a National Mobile Communication Industry], *Yidong tongxin*, November 2001.

[18] Jingming Shiu and Ken Imai, "Keitai denwa sangyo ni okeru suichoku bungyo no suishinsha" [The Drivers of Vertical Division of Labor in the Mobile Phone Industry], in Marukawa and Yasumoto, *Keitai denwa sangyo no shinka purosesu*, 204–5.

[19] Tomoo Marukawa, *Gendai chugoku no sangyo* [Contemporary Chinese Industries] (Tokyo: Chuo koron shinsha, 2007), 108–9.

was absent in the case of Chinese firms: license fees. According to the author's interviews with people working for Chinese handset manufacturers, Chinese manufacturers were not paying license fees for using GSM technology, and there was a tacit agreement with the patent holders of GSM that, as long as these manufacturers did not export their handsets to other countries, they would be exempted from paying license fees.

The success of Chinese manufacturers, however, was short-lived. Soon after 2003, the combined market share of domestic-brand handsets fell to less than 50% and the dominance of international brands in the Chinese mobile market revived. The reasons for the failure of Chinese manufacturers to maintain their leading positions in the domestic market were as follows: first, they could not match global giants like Nokia in price competition because the latter, with a production volume tens or a hundred times larger than Chinese manufacturers, could enjoy economy of scale in production, parts procurement, and product development; second, lacking core competence, the big domestic manufacturers like Bird were challenged continuously by new entrants—including the numerous guerrilla (*shanzhai*) handset manufacturers—into the domestic mobile handset market, leading to the rapid decline of the former. Through the experience of a failed attempt to foster domestic mobile phone industry by protectionism, MII came to realize that without controlling the "core technology" there was little hope to become an important part of the global mobile communications industry. Therefore, China started to pour its resources into developing a global standard of 3G mobile communications, which will be discussed in the next section.

The impact of winning the standards wars became more evident during 2G than during 1G. The success of Europe's GSM and the firms that supported the standard was overwhelming, while Japanese mobile manufacturers that supported a losing standard—Japan's PDC—became marginalized in the global market. GSM's success and the failure of PDC and DAMPS have also shown that governmental policy can influence the outcome of a standards war. Without the support of the U.S. government, DAMPS ended up being a marginal technology standard, though it was the successor of the most successful 1G standard, AMPS. PDC did enjoy the support of the Japanese government, but the support was not tactical enough to induce other countries to adopt it. GSM's success cannot be separated from the will of European Union members to have a common technology standard, which influenced the expectations of mobile service operators around the world.

The Wane of the High-Tech Standards Wars: The Third and Fourth Generations of Mobile Communications

Third Generation (3G) Technology

The third and fourth generations of mobile communications are similar to 2G in that they digitalize voice and other signals, but they transmit this data at a much faster speed. 3G is defined by the technologies that can transmit data at a speed of 144 kbps (kilobits per second) to 2 Mbps (megabits per second), and 4G is defined by those that can transmit data at a speed of 50–100 Mbps. The technologies that stand in between the two are called “3.9G” by some network operators and “4G” by some others.

Since the returns from winning a technology standards war for a manufacturer and a nation’s industry were huge during 2G, all parties acted very strategically at the start of 3G. The Japanese took the lesson of being isolated during 1G and 2G very seriously. Japan’s Ministry of Posts and Telecommunications pressed NTT DoCoMo to either create or adopt an international standard. This led NTT DoCoMo to join hands with Nokia and Ericsson to propose W-CDMA as a candidate for the 3G standard.[20] To make the adoption of W-CDMA easy for network operators that had operated GSM networks, W-CDMA shared the same core network standard with GSM. This decision triggered the creators of CDMA technology to propose their own 3G standard, with North American manufacturers including Motorola and Qualcomm putting CDMA2000 forward. The Korean government, meanwhile, urged its domestic network operators to adopt both W-CDMA and CDMA2000 to avoid isolation.

During 1G and 2G, the International Telecommunications Union (ITU) did not interfere with the decisions of governments on the choice of technology standards, but it took a different approach towards 3G. ITU tried to determine a single global standard for 3G to facilitate international roaming at the beginning, but because the two major competing camps would not compromise, it ended up recommending five different standards as the “global standard” for 3G, including W-CDMA, CDMA2000, EDGE, TD-SCDMA, and DECT. EDGE was later regarded as an enhanced version of GSM and not as a part of 3G, and DECT has been used mainly for cordless phones, leaving W-CDMA, CDMA2000, and TD-SCDMA in the global competition for 3G markets.

---

[20] Funk, *Global Competition between and within Standards*, 78–84

TD-SCDMA is a transmission technology developed by an institute under China's MII, combining together the technologies developed by Siemens and some Chinese-American engineers. The Chinese government used this technology, which was apparently different from other 3G standards, to break into the competition for the next global standard. While its rivals—W-CDMA and CDMA2000—competed for more international support from service operators and equipment manufacturers, the Chinese government basically relied on infant industry protection measures—insulating the domestic market from foreign competition—to make TD-SCDMA successful.

First, China's MII prepared a fund of 700 million renminbi for the development of TD-SCDMA. The fund was provided to the members of the TD-SCDMA Industry Alliance, which consisted of Chinese electronics manufacturers that took part in the manufacturing of handsets and network equipment, and members paid the money as license fees to Datang, a state-owned enterprise established for the development of TD-SCDMA technology.[21] Second, MII's allocation of frequency spectrum in 2002 favored TD-SCDMA. It allocated 180MHz to W-CDMA and CDMA2000 combined and 155MHz to TD-SCDMA. Third, MII did not allow domestic operators to begin offering 3G service using W-CDMA and CDMA2000 until TD-SCDMA technology was ready for commercial use. Because of this policy, 3G service in China did not start until 2009, eight years after W-CDMA was first put into commercial use elsewhere. Fourth, MII obliged the dominant operator, China Mobile, to provide 3G service using TD-SCDMA. China Mobile, with its huge subscriber base on a GSM network, preferred W-CDMA, because of its commonalities with GSM, but this preference was denied by MII.[22] Fifth, MII tried to involve international manufacturers such as Nokia, Samsung, LG, Siemens, and Texas Instruments in the development of TD-SCDMA technology to make use of their expertise and to create international support for the standard.

In spite of these tactics promoting TD-SCDMA, the standard's subscriber base grew slowly at the beginning. As shown in **Table 1**, more than 70% of 2G subscribers in China have been customers of China Mobile. Considering the network externalities of this huge subscriber

[21] Jing Liu, "TD chanye lianmeng chenggong mijue" [The Secret of the Success of TD Industry Alliance], *Zhongguo dianzi bao*, December 6, 2007.

[22] Arthur Kroeber, "China's Push to Innovate in Information Technology," in *Innovation with Chinese Characteristics—High-Tech Research in China*, ed. Linda Jakobson (Basingstoke: Palgrave Macmillan, 2007)

base, China Mobile could have attracted a similar percentage of 3G subscribers in China. However, Table 1 shows that until the end of 2012, China Mobile's share of 3G subscribers hovered around 40%, while its 2G subscribers continued to increase. One reason for this sluggish 3G growth was the scarcity of handsets for the TD-SCDMA network, while there were already many handset models for W-CDMA and CDMA2000 networks.

Table 1 Number of subscribers of 2G and 3G services in China

(Million)

Operator	China Mobile		China Unicom		China Telecom	
	GSM(2G)	TD-SCDMA(3G)	GSM(2G)	W-CDMA(3G)	CDMA(2G)	CDMA2000(3G)
End of 2009	518.9	3.4	144.8	2.7	52.0	4.1
End of 2010	563.3	20.7	153.4	14.1	78.2	12.3
End of 2011	598.4	51.2	159.6	40.0	90.2	36.3
End of 2012	622.4	87.9	162.9	76.5	91.6	69.1
End of 2013	575.6	191.6	158.4	122.6	82.5	103.1

(Source) Websites of China Mobile, China Unicom, and China Telecom

But in 2013 the number of subscribers to TD-SCDMA doubled and its share of 3G services increased rapidly, while China Mobile's 2G subscribers decreased for the first time. The 2013 announcement by China Mobile that the company would soon start operating its 4G network and the launch of Apple's iPhone in its 3G and 4G networks may also have contributed to this rapid growth.

The irony of the war over the global technology standard for 3G is that, although the parties involved employed various strategies and tactics to win the war, none of the standards has actually won yet. Although W-CDMA had the highest share among all three standards at the end of 2011 with 945 million subscribers, its share of global mobile service subscribers was only 16%. CDMA2000 had an 11% share with 626 million subscribers, while TD-SCDMA had 0.9% with 51 million subscribers.[23] The transition from 2G to 3G has been very slow compared to the transition from 1G to 2G. In 2002, the tenth year since the transition from 1G to 2G began, 2G subscribers accounted for 95% of global mobile subscribers and 1G subscribers had decreased to

[23] Data on global mobile subscriptions derive from the Ericsson Mobility Report, available at http://www.ericsson.com/mobility-report. However, the figure for CDMA2000 derives from CDMA Development Group's website.

less than 2%. By contrast, in 2011, the tenth year since the transition from 2G to 3G began, 3G accounted for only 28% of global mobile subscribers, whereas 2G accounted for 71% and its subscriber base was still growing. Judging from this trend, it is doubtful whether 3G technologies can eventually take over all the global market from 2G. It is likely that 2G will coexist with 3G and 4G even beyond 2020 as a low-end variety of mobile service.

There are significant differences in the transition from 2G to 3G between countries. In Japan, all 2G subscribers switched to 3G services by 2012, but in Western Europe, 3G services had attracted only 30% of mobile users by March 2010 while the rest continued to use 2G services. Since only a minority were using 3G services, European mobile service operators built the infrastructure for 3G telecommunication in only a limited number of places, such as the centers of big cities, while covering the rest of their service area with 2G infrastructure to save on investment costs. Therefore, European operators need to provide 3G subscribers with dual-mode handsets, which can be used in both 2G and 3G networks. Progress in integrated circuits (IC) technology made it possible for manufacturers to develop handsets that could be used in several different kinds of networks without sacrificing their price competitiveness. The handover from the 2G network to 3G network operates automatically so that users are not aware of it. There are also some handsets that can be used in more than one 3G technology, such as CDMA2000 and W-CDMA. Technological progress has reduced the switching cost from one standard to another to a negligible level.

Given the low switching cost, it would be unwise for the patent holder of a certain 3G technology standard to demand high licensing fees for using its patent because that would make the 3G service or handset expensive and induce consumers to migrate to other services that employ cheaper technology. Therefore, patent holders cannot expect to make a lot of money out of their ownership of 3G patents. This decrease in switching cost has eroded the returns of winning a standards war. The success of Apple's iPhone, which had a 12.5% share and ranked second in the global smartphone market in the third quarter of 2013, shows that technology standards matter little in the current competition between mobile handset brands. Apple is a latecomer in the mobile phone business, taking no part in the development of 2G, 3G, and 4G standards, and yet it is currently far more successful than Nokia, which has always been at the core of mobile technology development. Having been defeated in the smartphone market by Apple, Nokia decided to sell its mobile phone business to Microsoft in September 2013.

The Fourth Generation

Because of the consequences of the war over the 3G global standard, most industry and governments' interest in waging another war over 4G has decreased drastically. This explains why both the W-CDMA camp and CDMA2000 camp have decided to jointly support LTE as the standard for the next generation.

China, however, is not getting on the bandwagon. The Chinese government has supported the development of TD-LTE, a high speed version of TD-SCDMA, employing similar tactics as the ones it used in promoting TD-SCDMA, including subsidies to R&D[24] and giving priority to TD-LTE in licensing network operators to offer 4G services. TD-LTE is expected to be a little more successful than TD-SCDMA because it has already been adopted by 23 network operators in 18 countries as of October 2013.[25] While these figures are dwarfed by the achievement of LTE (260 operators in 95 countries by the end of 2013), the users of TD-LTE will not feel so inconvenienced as users of previous minority standards such as Japan's PDC during 2G. The handsets that are used in China Mobile's TD-LTE network, for example, are "quintuple-mode" handsets that can be used in TD-LTE, LTE, TD-SCDMA, W-CDMA, and GSM networks. The network externalities that TD-LTE subscribers enjoy will not be less than those of LTE subscribers even if TD-LTE loses the standards war against LTE, because, with a quintuple-mode handset, they can use the LTE network or others in areas that are not covered by TD-LTE.

More broadly, the competition between standards in 4G may not be a competition over territories because some operators have decided to adopt both LTE and TD-LTE. For example, Softbank, a Japanese network operator, runs both TD-LTE[26] and LTE services because the company wants to divert the heavy traffic of mobile communication into two networks. It is reported that China Unicom is also planning to deploy both TD-LTE and LTE networks.

When multiple-mode handsets become the rule and operators around the world deploy

[24] Hou Yunlong, "Fagaiwei gouhua 4G chanye fazhan luxiantu" [National Development and Reform Committee designs the Roadmap for 4G Industry], *Jingji cankao bao*, October 9, 2013.

[25] Jiang Jiadai, "Zhongyidong 1332 yi ziben kaizhi tuidao xiabannian" [The 133.2 Billion Capital Expenses by China Mobile Will be Postponed until the Latter Half of the Year], *21shiji jingji baodao*, August 16, 2013; and Liu Fangyuan, "Zhongyidong mingnian tui qianyuan 4G shouji" [China Mobile Will Start Selling 1000-Renminbi 4G Mobile Phones Next Year], *21shiji jingji baodao*, December 4, 2013.

[26] Strictly speaking, the technology that Softbank has adopted is AXGP, which is perfectly compatible with TD-LTE but slightly different.

patchy networks, winning or losing a standards war will have little influence on the welfare of consumers and the success of a firm or a nation's industry. Subscribers to a losing network can still enjoy network externalities without incurring a switching cost. Patent holders of a technology standard cannot charge high license fees because operators and consumers can easily migrate to other technologies. The suppliers of handsets for a certain standard will benefit from the expansion of its market, but suppliers cannot confine themselves to a certain technology because the market demands multiple-mode handsets. It will also be unwise to enclose a certain technology within a nation's industry, because the network will lose its attraction. Mobile operators that adopt a certain technology will be motivated to invite foreign manufacturers to share the technology and supply new equipment to the network to enhance its attractiveness to consumers. The launch of Apple's iPhone for China Mobile's TD-LTE network illustrates such motivations. Under these circumstances, a governmental policy that favors a certain standard over others will make little sense as an industrial policy.

It is consequently a puzzle why the Chinese government still favors TD-LTE. Perhaps the Chinese government is trying to make up for the failure of TD-SCDMA by reaping the fruit of previous development efforts from the success of its successor. Or perhaps the Chinese government is so trapped in the technology standards war paradigm shaped by experiences during the 1980s and 1990s that it still believes that winning the war will promote the development of indigenous manufacturers. It is unlikely that China will promote a technology standard that is limited to domestic firms, because if it wants the standard to survive global competition, it is crucial to have foreign firms share the technology and increase the supply of complementary hardware and software. Therefore, even if the Chinese government persists in supporting TD-LTE, it will not result in the loss of market opportunities for foreign firms.

Conclusion

Conventional theory on the competition between technology standards presupposes a high switching cost between standards, meaning that the networks based on those standards are mutually exclusive. However, the history of technology progress in mobile communications suggests that the switching cost decreases over time. If the switching cost is low, the relationship between various technology standards can be complementary as well as competitive. Therefore, the intensity of the competition between standards will also decrease. This paper examined this hypothetical relationship between switching costs, expected market size, and the intensity of the competition between standards in the case of mobile communications. **Table 2** summarizes the result of the analysis.

Table 2 The Relationship between Switching Cost, Expected Market Size, and the Intensity of Standards War

Generations	Switching Cost	Expected market size	Intensity of Standards War
1G	very high	<102 million	moderate
2G	high	<4.4 billion	high
3G	low	>1.6 billion	high
4G	very low	>2.5 billion?	very low

(Source) The Author

During 1G, the switching cost was very high, but the intensity of the standards war was moderate, judging by the tactics that were employed and the outcome of the competition. This can be explained by the small size of the expected market, since the expected size of 1G was likely smaller than its actual peak volume of 102 million subscribers. During 2G, the fight between GSM (Europe), PDC (Japan), and CDMA (South Korea and the United States) was intense, various tactics were employed by the parties involved, and GSM's victory was overwhelming. This can be explained by the high switching cost and the huge expected market size, although nobody would have forecast that the GSM market would be as big as 4.4 billion subscribers. During the early stage of 3G, the fight between W-CDMA (Europe and Japan), CDMA2000 (North America), and TD-SCDMA (China) was intense. This fact appears to contradict our hypothesis, yet can be explained by the fact that the switching cost decreased rapidly and unexpectedly due to the rapid progress of IC technology. In the current 4G era, the switching cost has decreased even further, and the standards war between developed countries has ceased. The Chinese government's policy to wage another war in 4G is outdated and will have little positive impact on China's domestic industry and little negative impact on foreign industries.

While this discussion has been confined to the case of mobile communications, the decrease of switching cost between technology standards may occur in any industry if the features of its standards can be digitally encoded and written into ICs. In mobile communications and other industries that have this property, it is likely that standards wars will soon come to an end. The end of standards wars does not mean the global unification of technology standards but rather the coexistence of several standards—as in the case of electrical power plugs—without a battle for market share among them.

List of Abbreviations

1G	first generation
2G	second generation
3G	third generation
4G	fourth generation
AMPS	advanced mobile phone system
AXGP	advanced eXtended global platform
CDMA	code division multiple access
DAMPS	digital advanced mobile phone system
DECT	digital enhanced cordless telecommunications
EDGE	enhanced data rates for GSM evolution
GSM	global system for mobile communications
IC	integrated circuit
iDEN	integrated digital enhanced network
ITU	international telecommunications union
LTE	long term evolution
NMT	Nordic mobile telephony
PDC	Pacific digital cellular or personal digital cellular
TD-LTE	time division LTE
TD-SCDMA	time division synchronous code division multiple access
W-CDMA	wideband code division multiple access