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Market- and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication

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Abstract

The existing literature on industrial standards almost exclusively focuses on pure market competition; this paper shows how and why both governments and firms have had a strong effect on the creation of global standards in the mobile communication industry through a hybrid system of committees and markets. According to our model, governments can and did influence forecasted and actual installed base for systems in the mobile communications industry through their influence on product demand (e.g., by determining the amount of competition in the market) and the number of and degree of openness in the standards. In particular, the choice of a single standard (by either a large single country or region) dramatically and instantaneously increased the forecast for the standard's domestic installed base, thus causing other countries to also adopt the standard.

Keywords: Industry standards; Mobile communication; Global standards

1. Introduction

It is widely recognized that the creation of industry standards has a large effect on competition in industries. Once a standard is established, customers can benefit from the reduced market uncertainty and lower costs of the products that are based on the standard. Firms who create the winning standards reap substantial rewards compared to firms that back the losing standards. Further, it is recognized that an early installed base and an open policy increase the chances that a product or service will become an industry standard.

However, research questions still remain in how to create an early installed base particularly where both markets and committees play a role in standard setting. In our study, we look at the telecommunica-

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tions industry, an industry where both markets and committees play a role. There are few empirical studies of this industry and the interaction of firms and governments are not well understood (Besen and Saloner, 1988). Further it has been noted that the telecommunication industry presents paradigmatic cases of standard setting in large technological systems (David and Steinmueller, 1994). This industry is therefore an important setting for understanding the idiosyncrasies of standard setting processes (Antonelli, 1994) as well as setting a base line for generalizations on standards setting in other industries (David, 1995). In our study, we will show how international mobile telecommunications standards have emerged through a hybrid process where both firms and governments have used committee and market mechanisms.

At the national level governments can determine the mix and role of market or committee mechanisms at work in the setting of telecommunications standards. At the global level, no single overarching governance structure for setting standards exists. This is partly because international standard setting bodies cannot enforce standards. Further no single national government can impose by fiat an international standard. However, market mechanisms through increasing returns to scale have caused the emergence of global standards in spite of the initial tendency for many countries to select national champions in committees. In particular, the choice of a single open standard by a large country (e.g., the US) or region (e.g., Europe) causes the forecasted installed base to increase, making the standard more attractive to non-aligned firms. Further, the greater the openness in the standard, the greater the number of firms that can act as agents of diffusion in convincing non-aligned third party governments to adopt the standard as their own. As the "bandwagon" gains momentum with a large percentage of third party government adopting the standard, even the countries that promoted alternative systems end up adopting the global standard or a portion of the standard.

This paper first discusses previous research on industrial standards. Second, it summarizes the evolution of mobile communication standards and the characteristics of the standards that became "global" standards. In particular, the key role that governments and firms played in a hybrid standard setting process is described. We will focus particular attention on how committee and market mechanisms were used in the creation of open standards and an early installed base. We summarize this hybrid process in a model of forecasted installed base and use this model to understand the competition between various third-generation mobile communication standards.

2. Previous research

The industrial standard's literature treats the emergence of a standard as problematic. This is particularly true in the case of de facto standards where the markets as opposed to standard setting organizations choose standards. With de facto standards, products are commercialized before standardization occurs while with de jure standards the products are commercialized after the standards are determined (Asaba, 1995; Besen and Farrell, 1994; Farrell and Saloner, 1992; Khazam and Mowery, 1994).

Much of the research on standards competition focuses on the pure market competition in the selection of de facto standards (David and Greenstein, 1990; Grindley, 1995). Two important findings have emerged from this research. First, independent firms negotiate the exchange of technology in an attempt to create "bandwagons" to develop products based on this technology (Farrell and Saloner, 1985). Price performance mechanisms and increasing returns to scale drive installed base and thus the choice of industrial standards (Arthur, 1989). Further, it is recognized that the choice of an open or closed policy plays a major role in the competition between standards because this policy can effect the installed base (Asaba, 1995; Grindley, 1995). Firms that adopt an open policy rather than a closed policy are more likely to obtain an early installed base for their products. An open policy is more likely to attract producers of complementary products and customers who may not want to become dependent on a single firm (Farrell and Saloner, 1986; Farrell and Gallini, 1988; Hayashi, 1992). Because of network externality effects, products that obtain an early installed base are more likely to become industry standards than other products (Katz and Shapiro, 1985; 1986).[2]

Second, market mechanism do not always succeed in setting a standard and that alternative mechanisms, such as committees and hybrid arrangements that combine markets and committees have advantages over pure market mechanism (Farrell and Saloner, 1988; David, 1995; Besen, 1995). It has been argued that it is often difficult for a single firm to create a standard (Farrell and Saloner, 1986). This has been determined both conceptually (Farrell and Saloner, 1988) and shown empirically. In studies of the radio (Berg, 1989) and TV broadcasting industries (Crane, 1979; Pelkman and Bueters, 1986), no single standard emerged. Farrell and Saloner (1988) demonstrated conceptually that the hybrid arrangement of committee and market would out-perform either pure standard setting mechanism. Few empirical studies of their findings have been done, particularly in an international setting. Our work can be considered an extension of Farrell and Saloner (1988) in that we empirically examine a hybrid process at work in setting international telecommunications standards.

There also exists research on committee-generated standards. This research is mostly done from the standpoint of whether the committee work results in the establishment of a standard. Much of this work has been case study based and has focused on how "anticipatory standards" are set (David and Greenstein, 1990). From these studies a number of institutional factors have been cited as playing a role in whether a standard is successfully chosen or not.

Since committees generally operate on a consensus basis in deciding on standards, institutional factors that improved the possibility of consensus resulted in standards being chosen (Sirbu and Zwimpfer, 1985; Besen and Johnson, 1986; Weiss and Sirbu, 1990). The extent to which the technology and market were known and product development was imminent helped to result in a standard being chosen by reducing uncertainty (Sirbu and Zwimpfer, 1985; Besen and Johnson, 1986; Weiss and Sirbu, 1990). The extent that firms were able to form coalitions to support one standard or another also facilitated consensus (Sirbu and Zwimpfer, 1985; Weiss and Sirbu, 1990). Cooperation among rivals in establishing a coalition may have been facilitated by the ease of licensing, and other strategic considerations (Antonelli, 1994; Axlerod et al., 1995; Foray, 1995; Methe et al., 1997, 1998). We agree with these studies and also argue that the degree of openness in the standard will impact cooperation among rivals. These coalitions may arise in a process similar to the bandwagon effect through the direct and indirect effects of network externalities (Rofles,1974; Oren and Smith,1981; Farrell and Saloner, 1985).

Studies have found weaknesses in the committee based standard setting process as well (David and Greenstein, 1990). Committee derived standards tend to support current or known technologies over emergent or new technologies (Sirbu and Zwimpfer, 1985). And since their deliberations are often only understood by technical experts (David and Greenstein, 1990), users are often unable to influence the standard setting process. David (1986, 1987) found that government based committees had very narrow windows of opportunity to influence the standard setting process. These windows often occurred at times when the committee had the least amount of information available, rending them "blind giants" (David, 1986). Movement away from consensus rule and the inclusion of users may be ways around the "blind giant" problem. Of particular note for this study have been the moves by the European Technology Standards Institute (ETSI) to avoid these problems by streamlining its decision-making pro-

[2] For products in which network externalities operate, market share becomes a measure of quality and a rising market share increases the product's charm (Grindley, 1995). When products require interchangeability, network externalities become even more important (Greenstein, 1990). For example, although ATT originally had higher rates than the competition in the early 1900s, the ability to make long-distance and overseas calls increased the number of people with whom a user could communicate and thus increased the value of a subscription to ATT (Asaba, 1995).
Indirect effects operate through complementary products (Katz and Shapiro, 1985; Hayashi, 1992). For example, in a study of the Japanese personal computer industry, Methe et al. (1997) showed that NEC was able to set up a proprietary standard by leveraging the amount of software available to its PC-98 hardware. In particular, if there are economies of scale as there are with software, the price reductions of software provide substantial positive feedback to the value of the hardware. Also, software producers produce software for the most popular computers and vice versa (Conner and Rumelt, 1991), increasing the initial positive feedback effects.

cess. ETSI has moved away from consensus rule to a strong majority rule (71 percent) and has opened up its membership to include a wider group of telecommunication stakeholders, in order to speed up it decision making process and assure inter-operability (David and Steinmueller, 1994). However, it has been noted that the inclusion of users in committees increases the problem of sorting through a wide variety of preferences for technical standards unless some kind of anticipatory or meta-standard can be developed (Foray, 1995).

Our understanding of the committee process is still limited, however. No studies exist that examine the difference in behavior between anticipatory standards and ones where a de facto standard already exists. Further, no research has been conducted on how committees perform when confronted with the need to update and revise standards because of technological change (David and Greenstein, 1990) or what is the role of national committees in the international market place.

Conceptually it was determined that committees are more likely to arrive at a standard, but committees also tend to take longer in those deliberations before a standard is set (Farrell and Saloner, 1988). Farrell and Saloner, (1988) have suggested, however, that a hybrid system that used both the market and committee mechanism results in better performance. The availability of multiple pathways to determine a standard, result in standards being set by the hybrid system more often than just by the market and more rapidly than just by the committee (Farrell and Saloner, 1988). Farrell and Saloner's work however is constrained by several assumptions. Committees were not able to develop compromise standards (David and Greenstein, 1990) and markets were modeled using a market leadership assumption, without the possibility of coalitions (Axlerod et al., 1995). Foray (1995) has also noted that unless certain conditions are met, such as using the committee to set either an anticipatory standard or a meta-standard, it would be unlikely that committees would outpace the market. Both Foray's (1995) and Farrell and Saloner's (1988) work are conceptual and have not been examined empirically. However, Farrell and Saloner's work is seen as a useful beginning for further study (David, 1995). We empirically examine the role of markets and committees in an international industry confronted with rapid technological change. We do this through our empirical examination of the standard setting process within the mobile telecommunications industry.

3. Research methodology

Research has been conducted on technology management in the mobile communications industry since 1993 using the multiple case-study approach (Eisenhardt, 1989; Yin, 1989). Beginning in 1993, literature searches and telephone interviews with US telecommunication-related firms were conducted on the evolution of mobile communication standards. Beginning in 1996, interviews were carried out in Japan with Japanese, European, and US suppliers of mobile communication services, infrastructure, and phones. Between 1995 and early 1999 more than 100 interviews have been carried out with 19 Japanese, 3 US, and 6 European firms in Japan, the US, and Europe.

The topics addressed in these interviews focused on three main areas and were tailored to the interviewee's area of knowledge. The three main themes discussed were: (1) the evolution of standards including their performance and the performance of products compatible with those standards; (2) why certain standards have become global standards; (3) the evolution of market shares and the reasons for the changes in market shares in phones and infrastructure. Simultaneously, computer searches have been carried out on several Japanese, US, and European newspapers and other archival sources.

4. Evolution of global mobile communication standards

The mobile telephone industry was chosen for a number of reasons. It is an international industry, characterized by multinational firms and national governments. It is a complex technology that has undergone several generations. Each generation has resulted in new products. Consequently, the standards setting process is a complex one both within a technological generation and between generations.

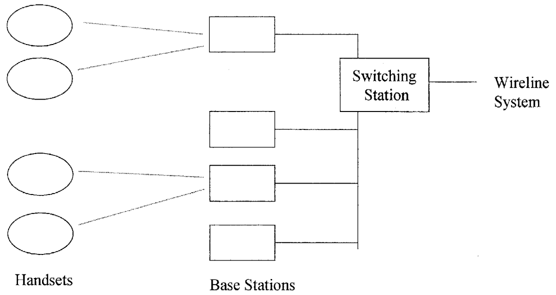

Fig. 1. Outline of a typical mobile communication system.

A typical mobile communication system is outlined in Fig. 1. Voices are transmitted between the handsets and the base stations via analog or digital signals using a variety of frequency bands (typically between 450 and 2200 MHz). The switching stations transfer calls between different base stations (calls between mobile phones) and between a mobile and wireline system (calls between mobile and fixed line phones). Further, they also transfer the control for a call between base stations as users move between areas that are controlled by different base stations. Within the base stations, base station controllers manage the allocation of frequencies for each call.

Carriers manage these mobile communication systems along with a variety of other technical systems that are needed to provide mobile communication service (e.g., network management systems). Infrastructure suppliers provide the base stations, switching equipment, and network management systems. Handset suppliers provide the handsets. Although many firms supply both infrastructure and handsets, it is uncommon for infrastructure or handset suppliers to invest in or be involved in the management of carriers.[3] Mobile communication standards define some or all of the interfaces that are shown in Fig. 1.

4.1. Technological change in the mobile telecommunication industry

Table 1 shows the evolution of three generations of mobile communication standards in the countries that contain the world's leading producers of telecommunication products. The major advantage of digital systems (second generation) over analog systems (first generation) is in voice quality and in the level of efficiency which with they use the frequency spectrum. Since frequency spectrum is a limited resource, frequency spectrum efficiency is important. Digital systems also generally have better voice quality and data transmission capabilities. Low mobility digital systems, such as PHS, are a low-cost version of second generation digital systems. They are cheaper to install than conventional digital systems in densely populated areas[4] but the phones cannot be used in fast moving vehicles. Thus, they have been mostly considered applicable to densely populated areas in Asia. Third generation systems are expected to include higher than existing frequency spectrum efficiencies, better voice quality, and much higher than existing data transmission rates (greater than 1 Mbps) than second-generation cellular systems along with multi-media capability and global roaming.

In countries where a single standard was not chosen, the most widely used standards are shown in Table 1. For example, although a single digital standard was not adopted in North America, DAMPS, GSM, and IS95 CDMA are the most widely used digital standards. DAMPS is a digitalized version of the analog standard AMPS, and DAMPS, GSM, and IS95 CDMA are all used in the new personal communication services that were started in the US in 1996, 1997 and 1998. Several of the standards are very similar. Since the only difference between

[3] Motorola is the main exception. It has invested in a number of service providers Iridium that was expected to provide mobile communication services from everywhere in the world.

[4] The cost effectiveness of PHS is debatable considering the deficits being run by the PHS operators. The PHS operators are unfortunately dependent on NTT's wireline system, which is one if not the most expensive wireline system in the industrialized world. As a result, the PHS operators pay half their revenues to NTT. Nevertheless, there is widespread agreement that the capital costs for PHS are lower than that for existing cellular systems in high-density areas. Not only are switching stations not needed but PHS base stations are much less expensive than existing cellular base stations. For example, a PHS base station that covers a 100-m radius can handle three calls and costs about $2000 to implement. A cellular base station that can handle 100 calls costs about (covers an area with a radius of 1 km) $1M. Therefore, the base station cost per potential call is $600 for PHS and $10,000 for cellular. In low-density areas, where coverage not capacity is the issue, cellular systems have lower capital costs.

Table 1
Evolution of mobile communication standards in major countries and year in which service began

Country	First generation analog cellular	Second generation digital cellular	Third generation digital cellular	Low mobility cellular
US	AMPS (1983)	DAMPS (1992), GSM (1995), CDMAOne (1996)	Various standards	None
Japan	NTT (1979), TACS (1989)	PDC (1993), CDMAOne (1998)	Wide-band CDMA (2001)	PHS (1995)
Scandinavia	NMT (1981)	GSM (1992)	Wide-band CDMA	None
Great Britain	TACS (1984)	GSM (1992)	Wide-band CDMA	CT-1
Italy	RTMS (1985), TACS (1989)	GSM (1992)	Wide-band CDMA	None
France	RC2000 (1985), NMT (1989)	GSM (1992)	Wide-band CDMA	None
Germany	CNETZ (1985)	GSM (1992)	Wide-band CDMA	None

Source: Meurling and Jeans (1994), Paetsche (1993) and Garrard (1998).

AMPS and TACS are their channel spacing; they are often referred to as the same standard in this paper. Although PDC, DAMPS and GSM are all based on TDMA technology, there are many more differences between these three standards than between the AMPS and TACS standards.

4.2. Definition of a "global" standard

Much of the literature on standards defines the existence of a standard in terms of which method is chosen for determining the standard (David and Greenstein, 1990). For committee-based standards, a de jura standard exists. However, there are important differences between international and domestic standards. Although the International Telegraph and Telephone Consultative Committee (CCITT) and International Telecommunications Union (ITU) exist as international standards committees, they do not have the authority to set international standards and can only recommend these to national governments (David 1995). National governments can set the domestic standards.

For market-based standards, the de facto holder of the majority of market share is usually said to be the standard. However, if a country, such as the US with a large market sets a standard, then it may appear that that standard holds the majority market share and is the de facto standard for the global market. Consequently, we argue that for a standard to be a global standard, the number of countries adopting that standard as well as its market share are important.

4.3. Global standards in the mobile telecommunications industry

Table 2 shows the evolution of mobile communication global standards. AMPS, GSM, and to some extent NMT can be defined as global standards (asterisks placed next to these standards) since a large number of countries have adopted them and they have acquired a significant fraction of the subscribers. In the case of NMT, although there are only 5 million subscribers to systems based on the NMT standard, 6 countries had introduced NMT systems before services based on AMPS were started. Thirty-six countries had introduced NMT systems by the end of 1998. Since the firms whose countries were the sources of these standards have supplied a large fraction of the infrastructure and phones for these systems, the firms have benefited by having their country's standards become global standards (Funk, 1998). Data for DAMPS, IS95 CDMA, PHS, and PDC are included in Table 2 for comparative purposes.

Fig. 2 shows the number of countries that started services based on the so-called "global standards" for each year between 1981 and 1997. As shown in Fig. 2, in 1987, the number of countries beginning services based on AMPS and TACS surpassed NMT; a situation that has continued until today. In 1994,

Table 2
The evolution of global standards

Generation of technology	Communication standard	The standard's country or region of origin	Number of adopting countries (mid-1998)	Number and percent of each generation's subscribers as of mid-1998	
First generation analog cellular	AMPS[a]	North America (1983)	85	80.0	80%
	TACS[a]	Britain (1985)	28	15.0	15%
	NMT[a]	Scandinavia (1981)	39	5.0	5%
Second generation digital cellular	GSM[a]	Europe (1992)	110	100.0	62%
	DAMPS	US (1993)	35	18.5	12%
	CDMAOne	US and Korea (1996)	15	12.0	7%
	PDC	Japan (1993)	1	30.0	19%
Low mobility digital cellular	PHS	Japan (1995)	1	6.0	98%
Third generation digital cellular	Wide-band CDMA	Japan (2001)			

Source: Garrard (1998) and Telecommunication (1997).
[a] Global standards.

the number of countries adopting GSM for the first time passed AMPS and TACS and this situation is expected to continue for several years.

The general trend from NMT to AMPS/TACS to GSM can also be found in an analysis of most regions. In the mid-1980s, four Asian countries

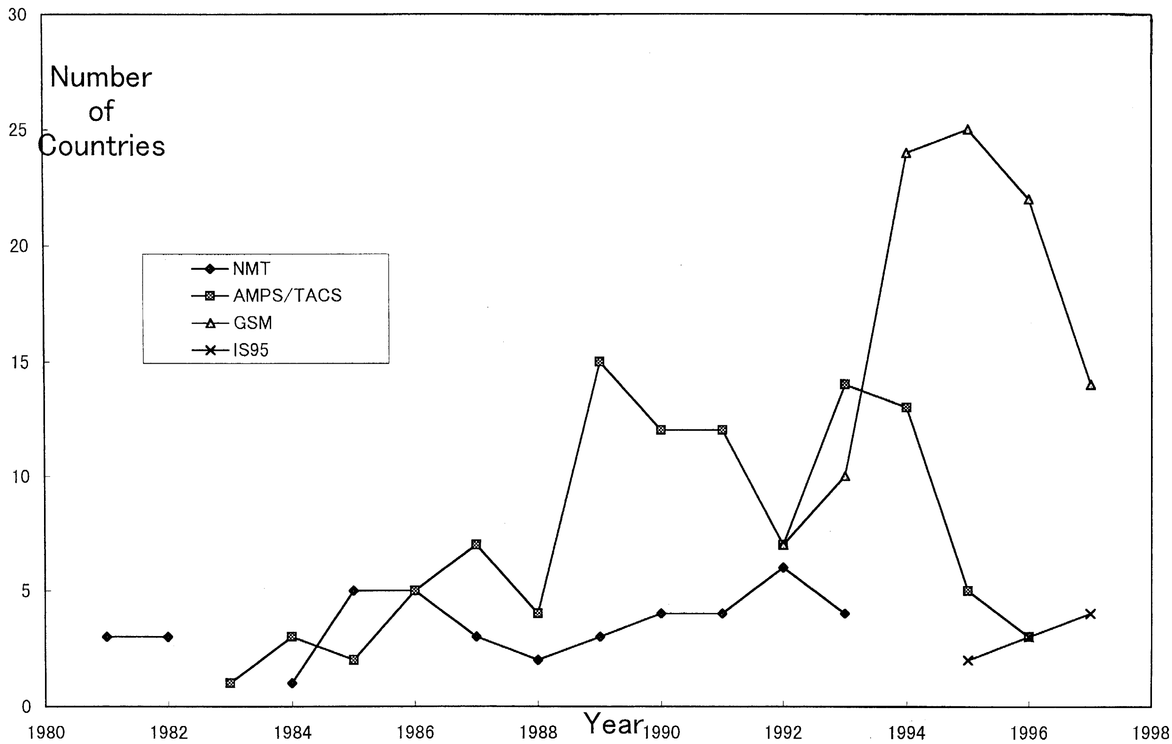

Fig. 2. The number of countries starting services based on the major standards by year.

Table 3
Selected information for global and non-global standards

Generation of technology	System	Introduction date	The standard's country or region of origin	In country or region of origin soon after introduction		Degree of openness
				Number of subscribers (1000s)	Penetration rate (%)	
First generation analog systems	AMPS	1983	US	680 (1986)	0.27 (1986)	High
	NMT	1981	Scandinavia	330	1.5	High
	TACS	1984	UK	122	0.18	High
	CNETZ	1986	West Germany	17	0.03	Low
	RC2000	1985	France	10	0.02	Low
	NTT	1979	Japan	75	0.06	Low
	RTMS	1985	Italy	4	0.00	Low
Second generation digital systems	DAMPS	1992	US	3.5 (1992)	< 0.1 (1992)	High
				80 (1993)	0.5 (1993)	
				400 (1994)	1.6 (1994)	
	GSM	1992	Western Europe	500 (1992)	0.20 (1992)	High
				1400 (1993)	0.56 (1993)	
				4700 (1994)	1.9 (1994)	
	PDC	1993	Japan	< 10 (1993)	< 0.01 (1993)	Low
				200 (1994)	0.50 (1994)	
	CDMAOne	1995	US and Korea	1100 (1996)	0.37 (1996)	Low
				7400 (1997)	2.5 (1997)	
Low mobility digital cellular	PHS	1995	Japan	4900 (1996)	3.8 (1996)	Medium
				6900 (1997)	5.5 (1997)	
	CT-2	1994	Hong Kong	175 (1996)	< 0.1 (1996)	High

Source: Garrard (1998), Telecommunication (1997) and Senmoto (1997).

adopted NMT versus two for AMPS or TACS while between 1988 and 1993, 12 countries adopted either AMPS or TACS. From 1994 onwards, 17 Asian countries adopted GSM versus only 2 countries for AMPS and TACS. In Africa, four (all in North Africa) countries adopted NMT in the 1980s versus three countries for TACS. Between 1990 and 1993, 5 countries adopted AMPS or TACS and after 1994, 17 countries adopted GSM against 2 for TACS or AMPS. In the Middle East (which overlaps with Africa), 4 countries adopted NMT versus 4 for AMPS and TACS. From 1994, however, 11 countries have adopted GSM versus none for NMT and AMPS/TACS.

South and Central America and Europe have slightly different diffusion patterns than Asia and Africa. Almost all of the South and Central American (including the Caribbean) countries initially adopted the US AMPS for historical rather than political reasons. Similar to wireline standards where South and Central American countries have for the most part adopted US standards, virtually all of the South and Central America countries also decided to allocate the same frequency band (800 MHz) as the United States to mobile communication services.[5] This includes Cuba and Nicaragua who clearly would have preferred not to support an important US policy.

European countries have primarily emphasized NMT and GSM for technical as opposed to political reasons. Only Great Britain, Ireland, Spain, Austria, and Malta adopted the AMPS/TACS (in this case TACS) standard. In Western Europe, this is probably due to the early success of NMT (11 countries

[5] Personal communication with Ahti Vaisanen, Vice President of Third Generation Technology, Nokia Mobile Phones, December 12, 1997.

Table 4
Openness: the number of initial sponsors[a] per standard

Generation of technology	Standard	Initial sponsors	
		Service providers	Manufacturers
Analog	NTT	NTT	NEC, Fujitsu
	NMT[b]	Four Scandinavian PTTs	> 10 firms from Europe, the US, and Japan
	AMPS[b,c]	> 50 service providers	> 10 firms from Europe, the US, and Japan
	CNETZ	Deutsche Telecom	Siemens, PKI
	RC2000	France Telecom	Matra
	RTMS	Italy's PTT (SPI)	Italtel, Telettra
	MATSE	None	Alcatel and Philips
Digital	GSM[b]	13 European PTTs	> 10 firms from Europe and the US
	DAMPS	All members of CTIA	> 10 firms from Europe, the US and Japan
	PDC	NTT Docomo	NEC, Fujitsu, Motorola, Lucent, Ericsson
	PHS	NTT Personal, DDI Pocket, Astel	> 10 Japanese firms
	CDMAOne[d]	Initially (early 1990s), none	Initially (early 1990s) Qualcomm
	PACS	None	Hughes
Third generation	Docomo W-CDMA	> 10 service providers from Japan, the US, Asia, and Europe	> 10 firms from Japan, the US, Asia, and Europe
	TD-CDMA	None	> 10 firms from Japan, Europe, and the US
	CDMAOne 2000	Initially (May 1997), none	Initially (May 1997), Qualcomm, Motorola, Lucent, Nortel

[a] Sponsors are defined as the participants in the standard setting process.
[b] Global standards.
[c] Although the FCC defined the specifications, many firms submitted proposals and were the initial providers of service, phones, and infrastructure.
[d] Qualcomm had licensed its technology to 14 service providers and 16 manufacturers by mid-1996 (Garrard, 1998).

adopted it during the 1980s) and the adoption of unique standards by France, Germany, and Italy. The emphasis on NMT and GSM is even more pronounced in Eastern Europe and the old Soviet republics (at least the northern ones) where systems based on NMT 450 were installed even in the early 1990s (see Fig. 2). However, the emphasis on NMT 450 does not appear to be due to trade and political ties between early adopters of NMT (e.g., Finland and Austria) and Eastern Europe. Instead, it was due to the military's control of the 800 and 900 MHz bands (which prevented the adoption of AMPS and TACS), the restrictions on exports to Eastern European countries, and the wide coverage (at the expense of subscriber capacity) that can be easily achieved with the 450 MHz frequency, and export restrictions for GSM. When these systems were being planned, most of the carriers (many of whom had Western European and US partners) believed that the potential for mobile communication services was small in these areas and there were restrictions on the export of western technology to Eastern Europe.[6]

5. Factors behind the creation of global standards

Similar to other research on industrial standards, the systems that have become global standards were able to achieve high early installed bases and they had a high degree of openness. As shown in Table 3, NMT, AMPS, and GSM were able to achieve much higher levels of installed base and they had much higher levels of openness than other systems that were being considered at the same time as these

[6] Personal communication with Olav Stang, President of Nokia Mobile Phones Japan and former President of Nokia Mobile Phones, Eastern Europe.

systems. These "open" systems had open published standards, open standard setting processes in which both domestic and foreign firms could participate, the inexpensive licensing of technology, and a large number of sponsors (see Table 4). Also like other products, product and service introduction dates (i.e., service start dates), prices (i.e., handset prices and service charges), and per capita incomes have had a large effect on installed base.[7] Unlike other products that have been the subject of industrial standards research however, a hybrid system of government and market mechanisms has played a strong role in the choice of global standards. The following sections describe this role.

5.1. First generation, the diffusion of NMT: the role of market and committee

The Scandinavian companies and Ministries of Telecommunications (MPTs) had been cooperating on the development of NMT since the 1950s. The companies and MPTs believed there was a large potential market for mobile communication due to the relative success of pre-cellular systems and more fundamentally due to the difficulty of providing wireline service to the popular summer resorts in the mountains and islands surrounding the major cities (Hulten and Molleryd, 1995). More than 20 Scandinavian and non-Scandinavian companies produced an open standard in which services were started in the 4 major Scandinavian countries in 1981 and 1982. Further, the choice of a single standard by Scandinavia and the high forecasts of installed base due to the adoption of a single standard in Scandinavia caused several other countries to immediately adopt the standard. For example, Spain decided to adopt NMT in early 1982 (services were started in June 1982) and the Netherlands, Belgium, and Italy were expected to quickly follow at that time (Jonquieres and Betts, 1982).

The strong early growth in subscribers in the NMT services also drove the adoption of NMT by other countries. The open standard and the government's liberalization of the handset market allowed competition to occur between manufacturers and handset prices dropped quickly. Further, partly through government encouragement, service prices were also set fairly low. By the end of 1983, there were more than 75,000 subscribers, which was more than any other standard in use at that time. Even at the end of 1984, there were still almost as many subscribers (150,000) as there were in the US (170,000) and more than five times the number of subscribers in Japan (40,000). By the end of 1987, 20 countries had started services based on the NMT service (Paetsche, 1993).

5.2. The creation of the first generation global standard: AMPS

The US government in the form of the Federal Communications Commission (FCC) and the US Judicial System played major roles in the creation of AMPS and its acquisition of an early installed base. Initially, the US was slower than Scandinavia to start mobile communication services due to the reluctance of the FCC to allocate spectrum for the new services and debates about the optimal number of operators per area. Partly due to the Modified Final Judgement which required AT&T to divest itself of the Regional Bell Operating Companies, a duopoly was introduced in each region, the AMPS standard was opened to the public, and handset sales were liberalized (Paetsche, 1993). The FCC, through proposals from firms, was the final judge on the technical specifications in the AMPS standard.

The decision in 1982 by the US to adopt a single standard caused many other countries to choose AMPS over NMT. For example, it caused Canada to immediately and Korea soon after to adopt AMPS and Great Britain immediately (in February 1993) and Hong Kong soon after to adopt a modified version of AMPS, called TACS. These countries predicted that the adoption of a single standard by the US, with its large population and high per capita income would cause the number of AMPS subscribers to grow rapidly and low cost handsets to appear. Great Britain's carriers wanted to adopt the AMPS standard in order to benefit from the potential

[7] Handset prices, service charges, and per capita income were found to explain about 77% of the variation in subscriber growth in the 1980s (Paetsche, 1993).

economies of scale in handsets. However, since AMPS was not perfectly compatible with the frequencies allocated to mobile communication in Great Britain, British carriers adopted a version of AMPS that was modified for the British market (TACS). North America and Great Britain subsequently experienced falling service charges through competition between carriers, which was also introduced into their wireline sectors almost simultaneously. Handset prices fell as the number of subscribers increased. Although the penetration rates did not rise as fast as in Scandinavia, the large populations of the US and Great Britain caused the number of total AMPS and TACS subscribers to pass the total number of NMT subscribers in 1986 (Meurling and Jeans, 1994; Paetsche, 1993). This was about the time that the number of countries starting AMPS- or TACS-based services in a year passed the number of countries starting NMT-based services in a year.

The Japanese, German, French, and Italian governments took very different approaches to mobile communication than did the US and Scandinavia. Although each of the governments from these countries showed more concern for the future competitiveness of their manufacturers than the US and Scandinavian governments, their attempts to protect as opposed to open the standards and the lack of competition contributed towards the eventual opposite result. These countries did not experience falling handset prices and service charges (Paetsche, 1993) and thus there was very little growth in subscribers. Handset prices did not drop in these countries due to the adoption of unique and relatively closed standards. Service charges did not drop due to a lack of competition and a monopolistic approach towards pricing and investment. Unlike the Scandinavian carriers, the carriers in these countries took a very cautious approach in capital spending and user fees (Paetsche, 1993).

For example, although services based on the Japanese NTT standard were started in 1979 by NTT 2 years before NMT services were started in Sweden, no other country began commercial services based on the Japanese standard. NTT used a proprietary system that had been developed by itself and a small number of Japanese suppliers. Further, there was almost no growth in subscribers until competition was introduced in the late 1980s and early 1990s. Japan's Ministry of Posts and Telecommunications (MPT) originally licensed NTT's mobile communications service in order to provide seven positions for MPT officials. Neither the MPT nor NTT believed there was a large market for mobile communication services in Japan and thus NTT did install many base stations and both the MPT and NTT agreed to set user fees at high levels. The MPT wanted to set the fees high in order to minimize the number of complaints and prevent people from subscribing who could not afford the service, and it rented the phones because it thought the purchase of phones would confuse users (Wakabayashi, 1994).

In Germany and France, however, more important than the lack of competition was the lack of leadership on the part of both governments and firms. Due to the success of Siemens and Alcatel in wireline switches, it would have been natural to expect these companies and their respective countries to also be the leaders in mobile communication. However, the governments were unable to overcome the rivalries between the various firms and create a unified analog system. While Alcatel, Siemens, Matra, Philips, and Thomson were each developing different systems in the early 1980s, their governments attempted to forge a compromise between themselves and also with Great Britain before it chose to adopt TACS. In late 1984 the German and French governments finally gave up and allowed Siemens and Matra to install their proprietary systems (Marsh, 1984; Financial Times, 1985, 1986).

Nevertheless, the attempt by French and German governments to use domestic standard setting as a way to promote national champions, was almost meaningless. By the end of 1984, there were more than 150,000 NMT subscribers in Scandinavia and 170,000 AMPS subscribers in the US. Neither France nor Germany had this many subscribers until the end of 1989. Although France and Germany did not realize it in 1984, the global analog standards had already been chosen when they were trying to create analog systems in 1984 that would provide their manufacturing firms with an advantage. Their firms would probably have been much more successful than they have been in the analog era (and possibly also in the digital era) if Germany and France had been an early adopter of either the NMT or TACS systems.

5.3. Second generation, the diffusion of GSM: the role of market and committee

In examining the second-generation standard setting process, we look at the roles of both governments and firms in setting the standard, as with the first generation. In GSM, the initial momentum came from Conference European Posts and Telecommunications (CEPT), German and French firms, and the European Commission. The CEPT allocated spectrum for GSM in 1978 and organized the first GSM meeting in 1982. After their failure in creating a global analog standard, the German and the French firms were determined to create a digital system that would provide their firms with an advantage. Their efforts were aided by the European Commission (EC), which was trying to create an economically integrated Europe. The EC recognized that the implementation of a single digital standard would be an essential part of an economically integrated Europe that then had five analog standards. The CEPT's and European Commission's activities resulted in the formal acceptance of a GSM system, its implementation by the European Council of Ministers in June 1987, and the signing of the Memorandum of Understanding (MOU) in September 1987. In the MOU, carriers from 13 countries agreed to start services based on the GSM standard in 1991 (Garrard, 1998).

The standard was created in the European Technology Standards Institute (ETSI), which contained government, manufacturer, and carrier representatives. Although there was competition between some manufacturers in the analog era, service providers still held domestic monopolies and many manufacturers had exclusive relationships with these service providers. Further, the European manufacturers made it more difficult for foreign manufacturers to enter the market by requiring participants to have a research and development facility in Europe. Thus, most carriers and some manufacturers probably perceived that cooperation in ETSI did not pose large risks of entry or lost opportunities in other markets.

Most of these European countries also began to award licenses in some cases to three service providers in the late 1980s and early 1990s. The large number of signers to the MOU coupled with the plans to introduce competition convinced many other countries that there would be a large installed base for GSM. When services were started in 1992, the first non-European countries decided to adopt GSM and in 1994 the number of countries adopting GSM for the first time passed AMPS and TACS. By the end of 1994, 24 non-European countries and 17 European countries had started services based on GSM.

On the other hand, the Japanese and US governments did not take the necessary leadership to create a successful digital standard. By the time Japan and the US were installing their digital systems, GSM had already become the de facto digital system. Further, like the analog era, Japan's government played too strong a role in defining the Japanese digital standard (PDC). The Japanese government allowed its national carrier, NTT Docomo to create a proprietary system. Although a set of specifications was published for the air interface, no specifications have been published for the network interface and even the air interface is far less defined than the GSM standard. This lack of openness discouraged other countries from adopting the standard and slowed down the diffusion of the standard to other countries through market mechanisms.

Within the US, an initial over-reliance on committee mechanisms and a subsequent over-reliance on market mechanisms prevented US digital systems from becoming global digital standards. When the US CTIA (Cellular Telecommunications Industry Association) was comparing various digital proposals in 1989 there were no plans for introducing new licenses for the new technologies. Thus, the CTIA chose a digitalized version of AMPS called DAMPS that would enable a gradual transition of existing service providers to digital standards. The result was that the introduction of DAMPS was left to the existing service providers who initially only installed it on a limited basis as a capacity enhancement technique.

By the time licenses were being awarded for the Personal Communication Services,[8] two new technologies for these frequency bands had emerged: IS95 CDMA and GSM. Although strong leadership could have enabled the US to choose a single stan-

[8] The US auctioned off a large number of new frequencies between 1994 and 1997 in several stages.

dard, the US relied too much on market mechanisms and there are now three digital standards (DAMPS, IS95 CDMA, and GSM) being used in the US. This created a large amount of uncertainty in the US and abroad. Other countries were afraid to adopt one of the US digital standards for fear that the other standard would eventually become the dominant US standard.

There are four reasons why the US did not choose a single digital standard. First, the fundamental differences between IS95 CDMA and DAMPS made it more difficult to achieve any type of compromise between the two standards. While IS95 is based on CDMA (code division multiple access) technology, DAMPS is based on TDMA (time division multiple access). Second, the large technical uncertainty in IS95 CDMA caused many carriers to stick with DAMPS or adopt GSM instead of opting for IS95 CDMA.

Third, Qualcomm adopted a very closed policy and misled a number of companies about the extent to which it would open IS95. Although Qualcomm set fairly reasonable fees initially for the patents concerning infrastructure, these patent fees were raised after several firms purchased licenses. Of greater importance, Qualcomm has set such high patent fees for the critical chips that are used in the handsets that it was able to control almost 100% of the US handset market (through its joint venture with Sony) well into 1998. This is one reason why Motorola's share of the US market dropped substantially in 1997 and 1998. Further, the price of the IS95 handsets as of mid-1998 was still three times the price of handsets that were available from US carriers who used different digital systems. This has naturally discouraged other carriers and countries from adopting IS95 CDMA.

Fourth, there was also no process or desire on the part of the federal government to select a single standard; this was in spite of the benefits the US enjoyed with the selection of a single analog standard. In the early 1990s, it became widely accepted that the success of the US personal computer industry (and in particular Microsoft and Intel) was due to the unbridled competition between multiple standards. Thus, the US Federal Government's and the cellular industry belief in competition between multiple standards became even stronger during the 1990s. The US government, service providers, and manufacturers underestimated the effect that the choice of a single standard by a large country like the US has on the forecasted installed base for the standard.

For example, if the US government had been able to create an agreement between US cellular operators and US manufacturers concerning the choice of IS95 CDMA as the US digital standard in return for low licensing fees for IS95 CDMA from Qualcomm, US consumers and manufacturers would have benefited. The choice of IS95 CDMA by the US probably would have caused most providers of AMPS service to adopt IS95 CDMA in South America, Asia, and Africa. It may have even caused some late entrants to the European market to adopt IS95 CDMA.

Further, the lack of a single digital standard and the continuing lack of desire and process for creating a third generation standard have placed the US at a competitive disadvantage in the third generation market. We return to this subject after discussing another failed candidate for a global standard: Japan's PHS technology.

5.4. Low mobility second generation systems: the lack of diffusion in PHS

Low mobility digital systems represent a special form of second generation system. The attempt by the Japanese MPT to make PHS a global standard also illustrates the principles related to the hybrid mechanisms for setting a standard. Although the initial idea to create a system for high-density Asian countries can be considered bold and innovative, the policies the Japanese MPT adopted during the actual standard setting and implementation significantly reduced the chances for PHS success. Similar to the behavior often attributed to Japan's Ministry of International Trade and Industry (Prestowitz, 1988; Johnson, 1982), the MPT delayed the opening of the standard in order to give Japanese manufacturers an advantage. Thus, foreign firms were not invited to participate in the standard setting process and the system specifications were not made public until 1 year after service was started in July 1995. Quite naturally, most foreign manufacturers, including industry leaders such as Ericsson, Motorola, and Nokia criticized PHS. This has made it difficult for Japanese manufacturers to convince foreign carriers to adopt

PHS particularly when many of these foreign carriers are major customers of firms like Ericsson, Motorola, and Nokia.

Second, the Japanese government allowed NTT, who is still partly owned by the Japanese government, to control key aspects of PHS. This is a major reason why two of Japan's three PHS carriers are not expected to become profitable in the near future and these losses discourage other countries from adopting PHS. Since PHS is built on top of NTT's public system, PHS carriers are very dependent on NTT which is the most expensive and in many ways the least innovative provider of wireline service in the industrialized world, for connections to the wireline and cellular systems (Telecommunication, 1997).

6. Model of forecasted installed base and open standards, how national government actions effects the emergence of global standards

The above examples demonstrate the effect that governments have had on the choice of global standard standards. The decision making process of both governments and equipment firms is key to the establishment of a global standard. The primary actors are the national governments that have equipment manufacturing firms and the firms themselves. However, another set of key actors is national governments that do not have equipment firms but do wish to establish a mobile phone system. The primary concern of these customers is service cost and uncertainty over which standard will win out. The actions taken by the primary actors can directly effect the concerns of these customers through their impact on forecasted installed base.

Fig. 3 summarizes our model of how the government and firms can influence forecasted installed base and thus the creation of global standards. The variables shown in this model are widely utilized in microeconomic models and those models presented in the literature on industrial standards. Forecasted installed base for a given product/system in a given country is a function of the overall penetration rate for the product type times the share held by the product in that country. Thus, installed base for this particular product can be calculated by summing this product over each individual country.

The penetration rate for a particular product type in a particular country is a function of demand and supply including product price and performance and consumer income. In general, both governments and firms influence supply and demand. In the specific case of mobile communication (shown in the right hand side of Fig. 3), governments and firms can use either a market-based, committee-based or a hybrid system to determine start-up dates, handset prices, and service charges. In addition to the obvious role

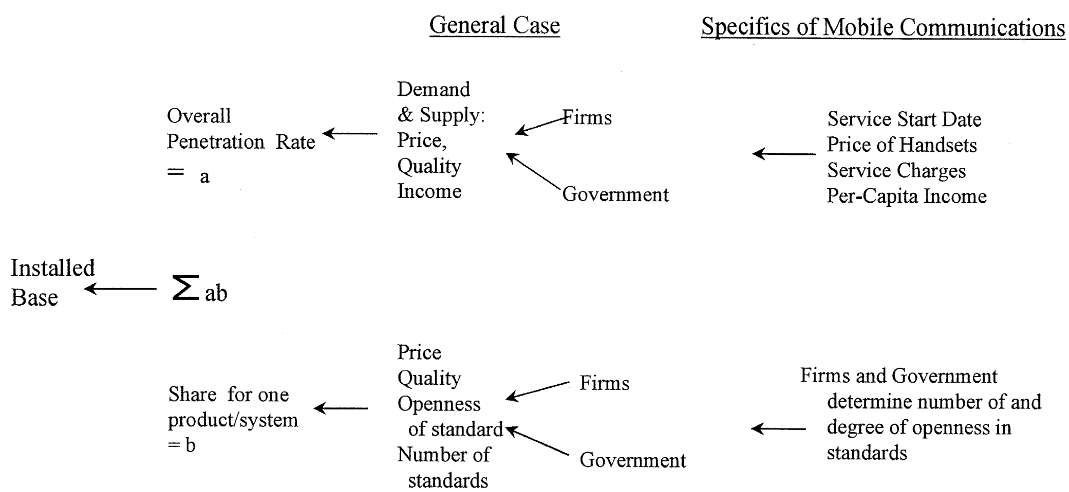

Fig. 3. Basic factors that influence installed base for a specific product/system.

that firms play in introducing new products, governments can effect start-up dates through their licensing of frequency spectrum. They can also effect service charges through the degree of competition they introduce and their approval of prices in the case of a regulated monopoly.

The share for one specific product/system is determined by its relative price and quality, the number of competing standards in the country, and the standard's relative degree of openness. Governments and firms can determine either using a market-based, committee-based or a hybrid approach, the number and degree of openness in the standard. Using solely market mechanisms, a large number of standards will increase the possibility that the "technically best standard" will emerge. However, a large number of standards also increases uncertainty in the market and decreases the forecasted installed base for any single standard. Consumers fear that they may be "orphaned" by choosing the "wrong" system while prices may not drop to any large extent because the market remains fragmented.

Governments and firms acting in committees can reduce this uncertainty. Committees tend to pick one technology as a standard, reducing the amount of uncertainty presented to the customer. Thus, a single standard can be presented, which increases the forecasted installed base for that standard in one country. However, for the country's or region's standard to become global it must be open to both domestic and foreign firms. The greater the openness in the standard, the greater the number of firms that can act as agents of diffusion in convincing third party governments to adopt the standard as their own. This increases the forecasted installed base for that standard and begins the bandwagon in the global market.

Global mobile communication standards were created by governments and firms who more effectively managed these variables by not relying too much on either market or committee-based mechanisms. Rather, they used a hybrid of both mechanisms. First, they expanded the overall penetration rate for the product type by creating a situation where prices fall. Scandinavia in NMT, the US in AMPS, and Europe in GSM were able to achieve falling handset, infrastructure, and service prices through the creation of a single open standard and the liberalization of the handset market. The Scandinavian countries were able to achieve falling service charges during the early years of NMT without introducing competition on a large scale, but the US, the UK, and Europe relied on competition to achieve falling prices in AMPS, TACS, and GSM services. These falling prices and forecasts for further falling prices caused other countries to adopt the standards.

Some of the losing standards relied too heavily on committee-based mechanisms. Japan, Germany, and France allowed their national carriers to control the specifications for the standards and act as a monopoly in setting prices. The lack of openness in the standard reduced competition in infrastructure and handsets and thus prevented their prices along with service charges from falling.

Second, and more importantly, governments and firms can influence the creation of global standards through their efforts to adopt a single-open standard. When Scandinavia (NMT), the US (AMPS), and Europe (GSM) announced their plans to adopt one single-open standard, the forecasted installed bases for these systems rose dramatically. These forecasts for installed base continued to rise as the countries awarded licenses to multiple service providers, started services that were based on the single standards and the number of subscribers grew as prices fell. This created the "bandwagon" effect that is often referred to in the standards setting literature. However, this "bandwagon" was not created by a single dominant actor, but by the interplay of one or several governments and firms; that is, through a combination of committee- and market-based actions.

These firms also included firms that were not from the sponsoring governments. This helped to increase the legitimacy of these systems to third party governments in addition to merely increasing the number of agents of diffusion. For example, Motorola and Mitsubishi were agents of diffusion for NMT, Ericsson was an agent of diffusion for AMPS and TACS, and Motorola and recently Nortel and Lucent have been agents of diffusion for GSM.

This adoption of a single-open standard also explains the evolution from NMT to AMPS and GSM. The decision by a very large and rich country, the US to adopt a single-open standard caused many countries to adopt AMPS instead of NMT, which had already diffused to many small countries. The decision by 13 European countries in 1987 to adopt GSM also caused interest in GSM to increase significantly. Within 2 years of starting GSM-based services in Europe in 1992, 29 other countries had also started GSM-based services. If Europe in mass had not decided to adopt a single digital standard, there would have been a great deal of confusion in Europe over mobile communication technologies and Europe would probably have moved more slowly to digital systems, perhaps as slow as the US.

Some of the losing standards relied too much on market-mechanisms or misuse of market mechanisms. In the US, the lack of market mechanisms when DAMPS was first selected as the digital standard in 1989 had changed to an over-emphasis on market mechanisms by the early 1990s; this prevented DAMPS or IS95 CDMA from acquiring a sufficiently high forecasted installed base. In the case of Japan's PHS system, the Japanese government and firms did not recognize that firms from several nations are needed to diffuse technology across national boundaries.

Interestingly, although the conventional literature stresses the actions of firms in the determination of which products become industrial standards, we have found that firms and even governments have not played *as active a role* during the diffusion stages (as opposed to the creation stage) of standards. For example, after the GSM standard setting process was established, an open standard was created, and competition between different carriers was introduced, European firms and governments have had very little impact on the diffusion of GSM. The leading suppliers of GSM infrastructure and handsets have not pushed GSM at the expense of other standards. For example, Ericsson, Motorola, and Nokia maintained their shares in the NMT, TACS, and AMPS markets and they also simultaneously became suppliers of products based on either or both the US (DAMPS) and Japanese (PDC) digital standards as GSM diffused.

This is only slightly less true in IS95 CDMA where obviously Qualcomm has only supported IS95 CDMA and to some extent Motorola has supported IS95 CDMA over GSM. While this has clearly hurt Motorola in Europe where its support of IS95 CDMA has angered many European carriers, it is not clear whether this has helped Motorola in IS95 CDMA.

European governments have also not had much effect on the diffusion of GSM through political or economic means. For example, between 1993 and 1996, the percent of former European colonies that started services based on GSM is not larger than the percent of all countries which started GSM as opposed to another standard.[9]

7. Third generation systems: the role of market and committee

As of mid-1999, it appears that NTT Docomo's system called Wide-band CDMA (W-CDMA) will become the global standard for third generation systems. In February 1998 the European Technology Standards Institute (ETSI) voted to adopt this system and more than 20 Asian countries had also decided to adopt the system by that time. Although the outcome for a third generation standard is still too early to determine, this addresses how the Japanese standard was adopted by the Europeans. This is particularly interesting since the Japanese were not considered to be in the running for a potential third generation technology by most industry observers until early 1997.

In 1992, the members of the International Telephone Union (ITU) voted to allocate frequencies for a third generation mobile communication system. However, the US, Europe, and Japan each adopted very different philosophies about how such a third generation system should be developed and chosen. Europe set aside the allocated frequencies and planned to select a system (in ETSI) in the late 1990s and propose this system to the ITU. It also planned to award licenses for third generation services. As GSM began to diffuse throughout the world in the mid-1990s, most Europeans in the mobile communication field expected Europe would propose an enhanced version of GSM and that it would be accepted by the ITU.

[9] Between 1993 and 1996, 45 countries adopted GSM and 30 adopted AMPS or TACS. Of the former European colonies, 23 of 32 former British Colonies, 5 of 9 former French colonies, 1 of 9 former Spanish colonies, and 1 of 3 former Dutch colonies adopted GSM as opposed to AMPS or TACS.

The US used the frequencies allocated by the ITU to third generation systems for its Personal Communication Services (PCSs). Thus, it let the firms decide whether and when they would introduce third generation services. It expected that both the best second and third generation system would emerge from competition between various second and third generation systems. As systems based on IS95 CDMA began demonstrating their superior voice quality, data transmission, and use of the frequency spectrum in 1995 and 1996, most Americans in the mobile communication field expected that IS95 CDMA would become the de facto third generation standard.

Japan adopted a strategy that was somewhat similar to Europe's strategy. Like Europe, it allocated frequencies for third generation services and it created a committee in 1992 whose task was to define the Japanese proposal to the ITU. The major difference between Japan and Europe was that NTT Docomo who indirectly was largely owned by the Japanese government was expected to dominate the third generation standard-setting process as it had done in the first and second generations. NTT Docomo had more than 50% of the subscribers, it had access to NTT's well funded (by Japanese tax dollars) research programs, and it was planning to operate services overseas (as a result of changes in NTT's charter). Importantly, it was being pressured by Japan's MPT to either create or adopt a global standard. Further, the Japanese pushed for an early start date and due to the large population densities and large penetration rates in Japan, NTT Docomo has repeatedly announced that it will install third generation systems very quickly in the major cities.

Still, by mid-1996, few participants in the global mobile communication field outside of Japan believed that NTT Docomo had a chance of creating a global standard. Although NTT Docomo was attracting some support from Asian carriers (Korean and Chinese), most Europeans still believed that an enhanced version of GSM would win while many Americans believed that IS95 CDMA would win. However, even the possibility that IS95 CDMA would win was a large concern to Ericsson and Nokia who had previously decided not to participate in the IS95 CDMA infrastructure market. Ericsson is the largest supplier of GSM and mobile communication infrastructure overall while Nokia is the second-largest supplier of GSM infrastructure. The choice of IS95 CDMA as a third generation standard would have been a major loss to these firms.

Ericsson and Nokia saw NTT Docomo's efforts as a way to increase their chances of success in the third-generation market. Not only would collaboration with NTT Docomo enable them to participate on the creation of the standard, Ericsson and Nokia held an important trump card: Europe was planning to choose a single standard in late 1997 and award licenses for these services a few years later. Ericsson and Nokia used this trump card to convince NTT Docomo to adopt the evolution path of the GSM network interface in place of Docomo's proposed ISDN interface; this was announced in March 1997. This was a major victory for Ericsson and Nokia in that it enabled them and other GSM infrastructure suppliers and users (i.e., carriers) to utilize a large amount of their existing technology in third generation systems. Naturally, this decision also increased the interest of GSM service providers (e.g., all of Europe's carriers) in Docomo's standard.

NTT's decision to adopt the GSM network interface can be interpreted as the creation of a committee-based mechanism that opened their standard to foreign firms to act as foreign agents of diffusion. This government committee action to set a single open standard in multiple regions pre-empted market actions in others. It did so by signaling that the Docomo's technical specifications could act as a standard for all third-generation mobile telecommunication systems. This action created the potential for the Docomo system to be used as a way of restricting the field of value of individual preferences of later adopters (Foray, 1995).

Simultaneously, NTT Docomo had been attempting to enlist the support of Asian carriers such as Korea Mobile Phone, China Telecom, Australia Telstra, and Singapore Telecom. In April 1997 it announced that it had invited carriers from North America (including AT&T), Great Britain, Sweden, France, Germany, Italy, Thailand, Malaysia, Indonesia, and New Zealand to participate in the development of a wide-band CDMA system. It also announced that it had invited Ericsson, Lucent, Fujitsu, NEC, and Matsushita to supply infrastructure and Motorola, Nokia, NEC, Matsushita, Mitsubishi, Sharp, and Toshiba to supply handsets for the experimental systems (Japan Industrial Journal, 1997).

With the announcement of an international development team and the decision to use the GSM network interface, private conversations revealed that Ericsson and Nokia would announce their support for NTT Docomo's system at a global mobile communication conference in Singapore in May 1997. This caused a four-firm US group consisting of Motorola, Qualcomm, Northern Telecom, and Lucent to belatedly announce their development of a wide-band version of IS95 CDMA. In fact, this decision was prepared so haphazardly that they failed to enlist the support of a single carrier before the announcement even though several carriers were angry that they were not consulted about the announcement.

Nevertheless, the US firms' proposal was too little and too late, the forecasted installed base for Docomo's system had already reached a critical mass. US firms argued that their proposed third generation system was compatible at the network interface with narrow-band IS95 CDMA and AMPS; thus it had the same advantages as a W-CDMA system that is compatible with the evolution of the GSM network interface. However, the US firms could not offer NTT Docomo or any other partner what European firms could offer since the US did not plan to choose a single standard for third generation systems or award new licenses for these services. NTT Docomo had decided very early to focus first on the European market and second on the US market since there would not be a US decision to adopt a single standard nor award new licenses. The result is that US firms have had very little negotiating power throughout the entire third-generation standard-setting process.

Following the announced support for Docomo's standard by Ericsson and Nokia, Docomo continued to receive support from additional carriers in Asian and European countries. This includes Japan Telecom in Japan (10/97) and carriers in Indonesia (9/97), the Philippines, Thailand, Italy (12/97), and Hong Kong (1/98). The support by Asian GSM carriers (many of whom were partially owned by European carriers) for the Docomo proposal eventually caused many European carriers to vote for Docomo's proposal.

Other European manufacturers (e.g., Siemens, Alcatel, Bosch, and Matra) were slower than the US firms to recognize the growing support for Docomo's standard and thus create coalitions. Throughout much of 1997 they believed that an enhanced GSM would be the eventual choice for a third generation system in Europe and in the ITU. However, in addition to their lack of CDMA technology like Ericsson and Nokia, they also held the same trump card as Ericsson and Nokia: Europe's plan to choose a single standard in late 1997. This enabled the European manufacturers to strike a compromise with the Ericsson and Nokia led proposal for the NTT Docomo system. The NTT wide-band CDMA system would be used for outdoor applications while TD-CDMA (a hybrid of TDMA and CDMA) would be used for indoor applications. Although the implications for this decision are still largely unknown, the compromise was perceived to be better than nothing. In January 1998, ETSI voted for this compromise solution by a narrow margin.

Interestingly, Motorola, Lucent, and Northern Telecom (along with its partner Matra) jointly proposed the TD-CDMA system with the European manufacturers. However, since they are relatively stronger in CDMA than TDMA, the compromise will probably be of little benefit to them. Apparently, their lack of negotiating power in the entire third generation process made them believe that they did not have another option.

The US failure to adopt a single digital standard reflects an inadequate process for choosing mobile communication standards. By deciding not to create a process for choosing a single standard, it precludes the choice of a single standard. Further, the existence of this fact reduces the negotiating power of US manufacturers and carriers since they are forced to negotiate independently with foreign manufacturers, carriers, and governments.

Korean manufacturers have also suffered from Europe's selection of the W-CDMA system. The Korean government agreed to implement IS95 CDMA by in large in return for favorable patent fees. The result has been a rapid growth in IS95 CDMA subscribers in Korea and as of mid-1998, there are still more IS95 CDMA subscribers in Korea than in the US. Further, Korean firms are suppliers of IS95 CDMA-based handsets and to some extent infrastructure in the world market. However, interestingly, due to patent battles with Qualcomm[10] and the expected success of the Docomo standard in third generation systems, the Korean government now publicly states that it made a mistake in the adoption of IS95 CDMA. One Korean carrier who installed an IS95 CDMA system has subsequently elected to install a system based on the Docomo standard.

8. Discussion

Our study of the standard setting process in the mobile telecommunication industry offers three conceptual contributions. First, we found that global standards emerged through a combination of both committee and market forces. Although the CCITT and ITU exist, these do not have the authority to impose an international standard. National governments do have that authority but it is limited to their domestic markets. Thus, although governments with equipment firms often initiated the standard setting process, these actions were confined to their domestic market and firms played an important role in diffusing the standard internationally, often through the formation of coalitions. Initially these coalitions were comprised of the initial sponsors (both firms and governments), but the successful coalitions were able to attract foreign equipment and service providers and in some cases foreign governments. By attracting a sufficient number of these firms and third-party governments, a bandwagon effect within the global market was generated.

It has been found that the inclusion of users in a committee can complicate and slow the process down, unless anticipatory standards can narrow the field of choices (Foray, 1995). NTT Docomo's action to set an open standard created the potential for having its technology considered as an anticipatory standard. Its technology was a viable candidate among the third-generation technologies and as a single standard would have dominated in Japan. But because NTT Docomo increased the attractiveness of its standard to foreign firms through adopting the GSM network interface, the Docomo standard was bridged to another important set of suppliers and users, the Europeans. These actions limited the "war of attribution game" that often has been used to characterize committee negotiations (Farrell and Saloner, 1988; David, 1995) by creating a potential anticipatory standard (Foray, 1995). ETSI was able to view the Docomo system as a way of narrowing individual preferences. This hybrid standard setting process hinged on the development of coalitions of users and suppliers, and the linking of these coalitions across national boundaries.

The initial size of these coalitions was important. Both the degree of openness in the standard and the number of standards adopted determined coalition size. We found that within each generation of technology, the national government that adopted a single standard and then made it open to both domestic and foreign firms increased the size of the initial coalition and thus enhanced its chances of becoming the global standard. Only through the combined actions of governments and firms using committee mechanisms to speed up the standard process did the market "bandwagon" effect then take over and establish a global standard.

The hybrid process of committees and markets plays an important role as the bandwagon effect begins to develop. To understand this, an important distinction should be made between governmental and industrial committees. Each is a form of collective action. Within the national boarders of a country, government-based committees can carry tremendous weight to support a national champion and set a standard, superceding the market. However, a regional-based committee, such as ETSI and even the ITU, is a form of collective action that must be supported by more than governments. These types of committees we term industrial committees,[11] because

[10] The Electronics and Telecommunications Research Institute (ETRI) of Korea claims that Qualcomm owes it royalties. In a 1991 agreement, Qualcomm agreed to pay 20% of the royalties that it receives from Korean firms that manufacture systems using the jointly developed technology to ETRI. However, ETRI claims that the agreement also applies to PCS frequencies (1900) and not just 800 MHz bands in Korea, foreign sales, and all Korean firms (not just Samsung, Lucky Goldstar, Hyundai, Maxon) (Dobbin, 1998).

[11] We wish to thank an anonymous reviewer for this suggestion.

of the role that firms from a variety of countries can play. There is an important link between governmental committees operating at a national level and industrial-based committees in promoting the diffusion of the standard to other country markets. This is because the extent of the openness and singularity of standards chosen in a single country can give firms from that country an advantage in building coalitions within the industrial-based committees. The process of attracting support from other firms or representatives within the industrial committees is made easier by the open standard.

Second, the mobile telecommunications market is also one characterized by rapid technological change and an evolution of both the technical characteristics that make up the standards and the standard setting process itself (Metcalf and Miles, 1994). Three generations of mobile telephone technologies currently co-exist. Unlike the case of CD replacing LP phonographic records or in the computer industry where each new generation of microprocessor replaces the current generation quickly, this process of technological obsolescence has not happened quickly with mobile telecommunication systems. This may be in part due to the large investment in infrastructure that service providers must create. We found that governments played or are playing a critical role in launching the first, second and third generation technologies. However, we also found that neither governments nor equipment firms had incentives to eliminate the previous generation technology to make way for the newer generation. New service providers played the critical role in starting and thus encouraging the existing providers to also start the new services. Nevertheless, it is possible that some of the older generations will persist for an extended period of time (Metcalf and Miles, 1994).

The lag created presents some interesting features of inter-generational technology competition. This is particularly evident in the third generation technology. How firms and governments use the committee mechanisms in the hybrid process has become even more evident with the existence of technological change and inter-generational competition. An over-reliance on market mechanisms, in the US, to determine a second-generation standard has most likely lost US firms the race also in the third-generation race barring significant government actions. While the actions of Qualcomm in promoting its IS95 CDMA standard are justifiable in terms of attempting to maximize profits from proprietary systems, these actions have stunted the development of strong coalitions. Without committee-based actions to jump-start the process, market mechanisms have failed to coalesce around a second or third-generation standard within the US.

Third, we found that learning has occurred with the experience that firms and governments have gained with each generation. This is particularly evident in how the role that coalitions play has change over time as well. We found that the European and Japanese coalitions of firms for the third generation were aimed at influencing the selection process of standard setting committees, which in turn effected the forecasted installed base. By understanding that committee actions can be effective means to jump-start the move in the market to the next generation, firms have attempted to pre-empt pure market-based coalitions from having an effect.

This is one reason why committee action was faster than the market in determining a standard in the case of both the second-and third-generation technologies. Because of the smaller market incentives in the US for either a second or third generation standard, none have been forthcoming. Equipment firms had been making profits off of the existing technologies and service providers had little incentive to make substantial new investments. In the US, the government could have stepped in to force a choice but did not. To a lesser extent, but not critically so, these same market conditions exist in Japan and Europe, but governments there did force a choice. Without the actions of committees, the market may be slower in setting a standard when technological change occurs where substantial investment in infrastructure is also needed.

What are the down sides to government involvement in standards? Clearly, government involvement does not always work. Even in the mobile field, many governments chose standards that were not successful. Governments can still act as “blind giants”. However, confronted with technological change in markets where substantial infrastructure investments are necessary, firms operating only with market incentives can become “paralyzed giants” through fragmentation and over competition among standards (David, 1995). In such cases, it may be better that some standard be chosen by committee, even if a better one would have emerged more slowly from an extended market competition.

Of course, we are assuming that governments will always take the perspective of attempting to provide advantages to national firms in this international competition. Consequently, there is a very subtle role for government to play. It must support a single open standard that will create the positive externalities, which will expand the market. Even though firms from other countries will benefit from such a situation, its own domestics firms will also benefit. Inter-firm or inter-coalition competition will ultimately determine which company will reap the most profits.

9. Conclusions

The telecommunication industry is an industry that is rapidly globalizing because of market forces. However, it is an industry where governments, through committee actions, can still set national telecommunication standards. As such any setting of global telecommunication standards must rely on a hybrid process of market and committee actions. This paper uses a model of forecasted installed base to describe how and why governments have played a very strong role in the creation of global mobile communication standards. While the existing literature on industrial standards almost exclusively focuses on pure market competition, this paper shows how governments can influence forecasted installed base and thus have a strong effect on the creation of global standards. According to our model, governments can and did influence forecasted and actual installed base for systems in the mobile communications industry through their influence on product demand (e.g., by determining the amount of competition in the market) and the number of and degree of openness in the standards. In particular, the choice of a single standard (by either a large single country or region) dramatically and instantaneously increased the forecast for the standard's domestic installed base, thus causing other countries to also adopt the standard. Nevertheless, there is still a great deal of remaining research on industrial standards. By demonstrating a possible role for governments in the successful creation of global standards, our paper actually broadens the possible avenues of research in the industrial standards field.

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