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Patterns of Imitation in the Adoption of Product Technologies: the Case of the Mobile Phone Industry

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Abstract of the PhD dissertation

Technology adoption processes have emerged as an important determinant of competitiveness in several industries (Zaltman, Ducan and Holbek, 1973). To maintain their competitiveness firms often monitor advances in product technology in relation to the adoption decisions of other firms in the industry (Abrahamson and Rosenkopf, 1993; O'Neill, Pouder and Buchholtz, 1998). Benchmarking against the rest of the industry gives the firm useful reference points when it comes to deciding which product technologies to adopt, when, and to what extent the product technology will be used in the product range (Fiegenbaum and Thomas, 1995; Greve, 1998). In this dissertation I explore how firms respond to the introduction of new product technologies by industry rivals. In particular I follow a longitudinal approach to investigate how quickly firms adopt technologies introduced by competitors and which industry benchmarks firms use when adopting new product technologies. The research site is the mobile phone industry.

Abstract della tesi di dottorato

L'adozione di una nuova tecnologia può fortemente influenzare la competitività del prodotto dell'impresa (Zaltman, Ducan and Holbek, 1973). Per mantenere la propria posizione competitiva spesso le imprese monitorano i processi di adozione e sviluppo di nuove tecnologie da parte dei competitor (Abrahamson and Rosenkopf, 1993; O'Neill, Pouder and Buchholtz, 1998). Confrontare le proprie scelte strategiche con quelle dei rivali è un modo per capire quali tecnologie adottare ed il momento più opportuno per adottarle (Fiegenbaum and Thomas, 1995; Greve, 1998). L'obiettivo di questa tesi è di capire come le imprese rispondono all'introduzione di nuove tecnologie di prodotto da parte dei rivali. Nello specifico si cercherà di capire quanto velocemente le imprese adottano le tecnologie introdotte dai rivali e quali imprese vengono utilizzate come benchmark nei processi di adozione di nuove tecnologie. Questi fenomeni verranno analizzati empiricamente nello specifico contesto dell'industria dei telefoni cellulari.

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Evolution of the Firms' Product Strategy over the Life Cycle of Fast Changing Technology-Based Industries: a Case Study of the Global Mobile Phone Industry

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Abstract

This paper adopts Industry Life Cycle approaches to better understand the changing rationales for product strategy development in the worldwide mobile phone industry. Based on both primary and secondary sources, we find that mobile phone manufacturers have changed their product strategy over the industry life cycle in response to various factors, such as the intense global competition and the need to rapidly respond to changes in technology and mass-consumer preferences. We also find that a sequence of dominant designs and technical standards in product innovations periodically emerged.

Keywords: mobile phone industry, product strategy, industry life cycle

1. Introduction

A wide number of manufacturing technology-based industries have evolved over time at an impressive speed, showing rapid transitions both in terms of product features and manufacturers' competitive dynamics. The mobile phone industry is undoubtedly one of most prominent examples. The global mobile phone industry has faced dramatic changes since its birth. Rapidly changing market dynamics such as increasing market penetration, intense cost competition, rapidly shrinking product life cycles and product customization, have continuously shaped the industry over time. Over the last two decades, the fast introduction of new product technologies and the propensity of demand towards products with rich and even "unrelated" features, has transformed the mobile phone in a multi-functional device. The function of the mobile phone has in fact expanded outside its traditional scope of providing pure telephone, or voice, capabilities to include an ever-growing number of features and applications. At first, in the 1980s, mobile phones expanded to be able to receive radio stations, but later, in the 2000s, with the convergence of the portable computers and mobile phones, and the introduction of high-speed wireless networks, consumers were able to download, upload, store and create music, video and photos on their mobiles. In this fast changing environment mobile phone manufacturers have constantly re-shaped their product strategies, introducing new product features, widening their product portfolio, outsourcing core and non-core activities, strongly re-drawing the relationships with all actors working in their ecosystem.

Despite the topic of competitive dynamics in the mobile phone industry has enjoyed significant development in the management literature, few scholars have used the Industry Life Cycle (ILC) framework as a tool to describe the evolution of mobile phone manufacturers' product strategy over time. The few empirical studies following this longitudinal approach have focused mainly on strategic alliances formation (Rice and Galvin,

2006) and mobile phone technologies and technical standards development over time (Steinbock, 2003; Agar, 2004; Hamil and Lasen, 2005), but few has been said on competitive and contingent factors affecting manufacturers' product strategy formation over the industry evolution. According to the ILC literature (Utterback and Abernathy, 1975; Utterback and Suarez, 1993; Klepper, 1996, 1997), changing in demand growth and technology have in fact implications for industry structure, competition, source of competitive advantage, and in turn on the rationales for product strategy development (Pessemier, 1982; Wind, 1982). Therefore different ways of manufacturing, innovating, distributing and promoting the product are often required through each stage of the industry evolution.

Based on both published material in newspapers, special magazines, manufacturers' annual reports and newsletters, and several interviews with product and marketing managers, with this paper we aim at understanding the main factors that have exercised influence on the global mobile phone manufacturers' product strategy development, from the introduction of the first analog handled device for business users in the 1980s, till the recent technological convergence, that has transformed the mobile phone in a mass-market multi-tasking product.

This paper is organized as follows: First, we briefly described how the product strategy and ILC issues have been linked in the management literature. Second, we illustrate the research methodology we have followed. Then, to review the chronological development of mobile phone manufacturers' product strategies in the Worldwide mobile phone industry, we divide the analysis in five time periods: 1980s, first and second half of the 1990s, first and second half of the 2000s, each of them linked to a specific stage of the mobile phone industry life cycle. Per each time period the main factors influencing the mobile phone manufacturers' product strategy are described. Finally, at the end of the paper a longitudinal overview of the entire analysis is presented.

2. Product strategy and the Industry Life Cycle

"Industry Life Cycle" (ILC) models aim at integrating technological, firm and industry evolution in terms of trajectories and outcomes that can be exogenously observed (Suarez and Utterback, 1995; Klepper, 1997). Although the term ILC is often used as a synonymous of Product Life Cycle (PLC), the latter takes a micro-level approach, and represents the course of the product sales and diffusion over time, while the former copes with more general categories related both to the consumer demand and to the firms supply. "Product strategy" deals with how the product is produced, designed, distributed, promoted and innovated over time (Pessemier, 1982; Wind, 1982). The firm's product strategy concept has been often described as part of the ILC framework: according with the ILC literature the firm's product strategy changes as the industry dynamics evolve over time. The ILC provides an invaluable perspective on the development of the firm's product strategy, as each phase of the life cycle – introduction, growth, shake-out, maturity and decline – has distinct characteristics that affect a firm's operation. Different product strategies are often required through each stage, as consumer attitudes and needs, the market concentration, and the firm's supply chain relationships change through the course of the industry evolution.

The *introductory* stage refers to the development and market introduction of a new product that gives birth to a new industry. In this stage sales of a product are usually relatively low, even after its technical problems have been ironed out, due to a number of marketing forces and consumer behavior factors (Pessemier, 1982). The major marketing obstacle to rapid introduction of a product is often distribution. Retailer chains are often reluctant to introduce new products, and many prefer to wait till a track record has been established before including them in their stock. Consumer acceptance of new products tend to be relatively slow because of consumer uncertainty about the usefulness of the new product with respect to existing ones (Levitt, 1965; Rowe, Mason, Dickel, Mann and Mockler, 1986; Klepper, 1997;

Lee and Veloso, 2008). Therefore, the newer the product, the greater the marketing effort required to create the demand for it. At this stage it is usually assumed that there are no competitors, and some authors even define the market structure at this stage as a virtual monopoly (Schewing, 1974).

The *growth* stage begins when demand for the new product starts increasing rapidly. The profit associated by the growth stage attracts other competitors to the product market. According to ILC theories the evolution of the demand across time drives competition (Vernon, 1966; Rowe, Mason, Dickel, Mann and Mockler, 1986) and the rate and direction of innovation (Rosenberg, 1972; Dosi, 1982): the more the product is diffused among consumers, the higher the competitive intensity among rival firms, that usually translates in greater resource allocation (Calantone, Garcia and Droge, 2003). During this stage product and brand differentiation begin as firms start to look for competitive advantage (Abernathy and Utterback, 1978).

As growth slows the industry may enter a *shake-out*, a point where industry growth is no longer rapid to support the increasing number of competitors (Utterback and Suarez, 1993). As a results some of the industry's weaker competitors may not survive. Slowing demand also increases pressures on incumbents to retain current customers, either rising the value offered or lowering prices (Abell and Hammond, 1979). Moreover the intense competition often encourages incumbents to redefine the strategic relationships along the supply chain, for instance through the outsourcing of non-core activities (Abernathy and Utterback, 1978).

The *maturity* stage occurs when distribution has reached its peak. Volume (reflecting the number of consumers and frequency of purchase) is stable. Replacement purchases become then the major factors driving subsequent sales. In the maturity stage two different situations can take place:

- the technology is mature and leaves a little rooms to new features or significant product improvements, both in functionalities and in technologies. In this case price competition is quite common since firms are not able to differentiate from competitors through product innovations. Abernathy and Utterback (1978) link industry evolution to the pace of product innovation and the pace of process innovation. They argue that in the initial phase of a new industry, when a product is still new to the market and the demand still low, companies experiment and try to differentiate strategically mainly via product innovation. Yet, the closer the industry is to a stage of maturity (or demand saturation) and the higher the product knowledge by consumers, the higher the need to differentiate along other strategic dimensions such as price, service or process innovation;
- fast growing demand causes the market to be very penetrated while the technology is still rapidly evolving. In this case the competition can develop in more dimensions because firms are able to differentiate by introducing product innovations, "pulling" the market towards continuously rejuvenated products. We could say that in this kind of maturity the market is "technology driven" and not "demand driven", since are firms that create new needs for consumers, by introducing new product technologies (Barry, 1994). The mobile phone industry is actually living this type of maturity. For example, the introduction of color display and camera phones at the beginning of the 2000s, despite the highly penetrated market, helped the demand of mobile phones to continue to grow, pulled by replacement purchases. In this environment the ability to introduce new product technologies before competitors is one of the more effective differentiation strategies.

Firms incapacity to cope with changes in consumer preferences, product technology, and other environmental forces may lead to the *decline* of the industry. The typical reason for an industry decline is the entry of new products, coupled with decreased interest in the specific product of the industry. Under these circumstances, one of the few options left for keeping the product alive is price reduction and other drastic means that depress the profit margin and lead industry members to consider the product withdrawal.

3. Research methodology

3.1. Data collection

This paper draws upon a range of several sources to discuss the evolution of the global mobile phone manufacturers' product strategy. Primary sources include:

- Eleven telephone semi-structured interviews with product and marketing managers of some of the mobile phone manufacturers that have covered worldwide relevant market positions over the last two decades.

Secondary sources include:

- the major mobile phone manufacturers' annual reports and newsletters from the beginning of the 1990s till 2009. Our data includes Nokia, Motorola, Samsung, LG, Sony, Ericsson, Sony-Ericsson, Siemens, BenQ, BenQ-Siemens, Alcatel, Panasonic, Nec, Philips and Sagem. The firms in our sample represent more than 90% of the global market;
- the FACTIVA database, that searches more than 9,000 sources, including the *Wall Street Journal* and the *Financial Times*, and has often been used by other researchers for searches on business-oriented media;
- books, newspapers, press releases and business publications.

3.2. Data analysis

Data analysis was partially planned and partly emerged. Throughout the analysis, we shifted back and forth between the row data and the patterns emerging from the data. The analysis took an interactive rather than linear path but for simplicity is presented here in distinct stages:

Stage 1. Because the purpose of this study was to examine the changing rationales for manufacturers' product strategy development over the ILC, a first analytical step was to define the industry in terms of players and products, and see how industry structure, technologies and competitive dynamics have change over time. This would have served to identify a sequence of "stages" over the industry evolution. We began by collecting data and information from books, newspapers and business publications.

Stage 2. The second stage of analysis was aimed at understating the main factors characterizing mobile phone manufacturers' product strategy over the last two decades, in terms of product design, innovation, manufacturing and distribution, including also pricing and branding policies. We collected data from manufacturers' annual reports and newsletters, newspapers and business publications to understand similarities and dissimilarities among manufacturers strategies over time. We then wrote detailed case studies (Yin, 2003) per each manufacturer, with the aim of keeping track of their main strategic moves over the last two decades. The case studies were 10 to 15 pages in length and included informant quotes as well as tables and timelines summarizing the key strategic behaviors of each firms.

Stage 3. The third stage of analysis was about the questionnaire development. The aim of the questionnaire was to triangulate secondary sources with in-depth interviews with industry practitioners. The questionnaire was structured in three parts: The first part related to the manufacturer's historical growth in the worldwide mobile phone market, with a particular focus on product strategy issues such as manufacturing, distribution and innovation processes, as well as cost and differentiation strategies; the second part focused on the manufacturer's relationships with other players operating in the mobile phone ecosystems, such as suppliers, distributors, authorities and competitors; finally, the third part dealt with the manufacturer's strengths and weaknesses in the modern marketplace, and the perceived threats and opportunities for future scenarios. The questionnaire was sent to the managers by email before the telephone interviews. In order to ensure its intelligibility, the first draft of the questionnaire was piloted in two interviews with managers. As a result of the pilot study, we simplified the wording of the questions and we added some graphs to make some of the questions more intuitive.

Stage 4. Once the questionnaire was set, in the fourth stage of analysis we developed a list of the mobile phone manufacturers that have covered worldwide relevant market positions over the last two decades and we contacted their marketing and product managers. We used personal contacts and public databases to identify suitable candidates. Out of the initial contacts, we received positive response from eleventh managers (around 50% of the initial list). From April 2008 to May 2009 we conducted telephone interviews. Executives from the companies that agreed to be interviewed include: Samsung, LG, Motorola, Sony-Ericsson and Nec. Four interviews were recorded with the permission of the interviewee and transcribed. Each interview lasted approximately 60-90 minutes.

Stage 5. In the final stage of analysis we used information gathered from interviews to integrate previous case studies. This allowed us to build a chronology of the rationales for product strategies formation from the 1980s till 2009, in each of the stages of the industry life cycle.

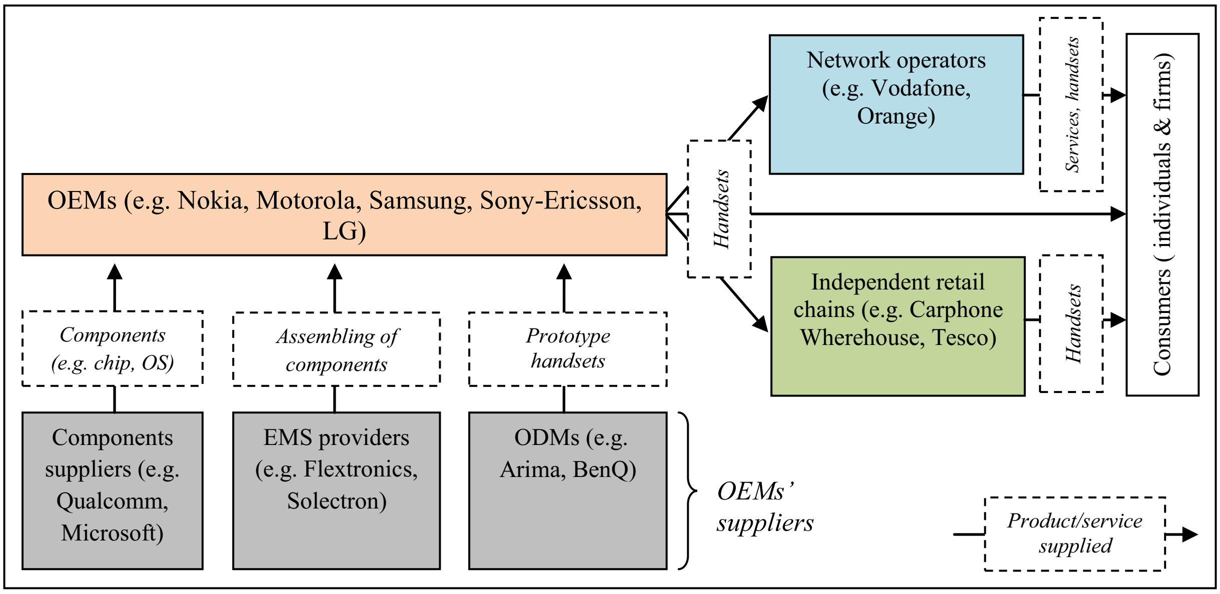
4. Industry definition

Nowadays the mobile phone industry is part of a complex ecosystem, which includes four main groups of players (figure 1): mobile network operators, original equipment manufacturers (OEMs), OEMs' suppliers, and mobile phone independent retailers. OEMs commonly refers to those firms that manufacture handsets and mark them under their brand name. Network operators aim to attract paying consumers to services on their networks. Network operators offer services by building networks on which they carry voice and data. For this purpose network operators purchase stocks of handsets by OEMs, and then sell them to consumers. Handsets are sold to consumers also by independent retailer chains, some of them commercializing only handsets, others selling handsets as part of a much wider assortment. Therefore OEMs nowadays behave more like wholesalers than a retailers, because consumers purchase handsets mainly from network operators retail channels (together with a contract to use the handset on their network) or from independent retail chains.

OEMs can outsource a number of activities to third parties. Some of them are suppliers of components (chip, software, operating systems, etc.), others assemble electronic components and devices on behalf of their OEMs (Electronic Manufacturing Service Providers – EMS providers), and others are independent contractors who developed prototype handsets and sold them to OEMs who in turn marketed them under their brand names (Original Design Manufacturers – ODMs).

However the mobile phone ecosystem has strongly changed over years. During the 1980s there were mainly two actors in the market: 1) OEMs, that presented a vertical-integrated supply chain with very few outsourced activities, and produced and commercialized handsets directly to consumers (only business users), and 2) network operators, working only as telecom services providers, attracting paying consumers to services on their networks.

Figure 1. The mobile phone ecosystem



Source: our elaboration

5. Manufacturers' product strategy evolution over the industry life cycle

5.1. The 1980s: the introductory stage

The credit for the first mobile phone is attributed to Martin Cooper who, when working for Motorola in 1973, made the first public call placed on a portable cellular phone in the US (Hamil and Lasen, 2005). However, it was not until 1979 that the first commercial program, developed in Tokyo by the Japanese mobile operator NTT DoCoMo, appeared (Gruber and Valletti, 2003). In any event, most of the pioneer initiatives took place in the United States at the beginning of the 1980s, which gave this country an initial advantage. The commercial origins can also be dated to the US in the early 1980s, when the first analogue systems appeared. In this process, the Federal Communication Commission (FCC) approved the AMPS (Advance Mobile Phone System) as a common standard. The introduction of such a common standard had two main objectives: to allow interstate roaming and handset compatibility (Fuentelsaz, Maìcas and Polo, 2008).

The map of global mobile phone standards was very country-specific in the early 1980s. While the United States adopted the AMPS, the UK introduced the TACS, derived from the

American version. North Europe countries developed the pan-Nordic NMT. Germany, France, Italy and Japan, instead, had their own indigenous system (Blackman, Cave and David, 1996). At that time, OEMs produced handsets working for only a certain number of systems since the required investment in several systems was considered too high, even by the biggest players. Today those handsets working with AMPS, TACS and NMT are commonly called “first generation mobile phones” (1G). Technically they all used an analog signal.

In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) launched a program for the standardization of the second mobile phone generation: the Groupe Speciale Mobile (GSM), later translated to Global System for Mobile Communication. The objective was to create a common bandwidth that would facilitate pan-European roaming, create mass markets that would result in cheaper calls and adopt the latest available technology.

Until the end of 1980s the mobile phone was an expensive piece of equipment mounted mainly on cars. OEMs were vertical integrated conglomerates that sold the product directly to consumers. Due to their extremely high prices, mobile phones were products only for the business market. Network operators played almost no rules in the mobile phone commercialization, gaining limited cash flow from mobile phone calls (Steinbock, 2001). The OEMs market was very concentrated: Motorola performed the worldwide leadership, mainly because its strong dominance in the United States market, at that time the biggest one. By 1982 the company saw the cellular car telephone market as a key opportunity. It had invested more than $ 100 million of engineering and manufacturing resources in pursuit of this new market. In 1983 the first analog portable mobile phone was placed into commercial operation. The other two big manufacturers were Ericsson from Sweden, that turned out its first handheld mobile phone in 1986, and Nokia from Finland, that launched its first handheld mobile phone in 1984. By acting as a “pioneer” in the mobile phone industry, Motorola was able to gain a substantial first mover advantage over rivals, across all the 1980s, both in terms of capabilities and market position.

5.2. First half of the 1990s: the first growth

The GSM was launched in Europe in 1991. Handsets working with GSM were commonly called “second generation mobile phones” (2G). The GSM, contrarily to the analog systems, uses digital signal. The major advantage of digital systems (second generation) over analog systems (first generation) is in voice quality and in the level of efficiency with which they use the frequency spectrum. Since frequency spectrum is a limited resource, frequency spectrum efficiency is important (Funk and Methe, 2001). Moreover the digital system enables the development of services, encryption of voice and data, additional capacity, reduction of the size of base stations and lower prices. The GSM was introduced in the United States in 1995, and it worked together with the AMPS (Paetsche, 1993; Garrard, 1998). The launch of the digital technology marked two distinct technological discontinuities: the sudden redundancy of first-generation analog devices, and the rise of second generation services and equipment. By understanding the analog-digital system discontinuity, and how the company could benefit from it, Nokia was encouraged to commit earlier than its rivals to the emerging pan-European digital GSM mobile communication standard, to focus on base station development in the GSM European R&D alliance, and to eagerly start building relationships with the newly franchised independent mobile network operators (Doz and Kosonen, 2008).

Meanwhile, the development of handsets surprised nearly everyone. The fixed carphone model was liberated from the car and became portable. Size and weight shrank, prices came down steadily and, despite mobile phones were still exclusive products mainly for the business market, the number of subscribers also among individuals grew faster than anyone could have anticipated. The commercialization of handsets to the consumer market was in great part favored by the increasing number of network operators' retail channels.

Moreover, the GSM system allowed OEMs to introduce additional product features that in the following years became "technical standards": Short Messaging Service (SMS), for example, was just an appetizer for things to come.

In 1992, Nokia and Ericsson followed a radical focus product strategy on the mobile phone industry, while Motorola was still competing in a wide variety of markets, extending from tiny chips for cars to US Army ground stations for airborne surveillance equipment (in 1993, cellular accounted for 40% of Motorola's sales).

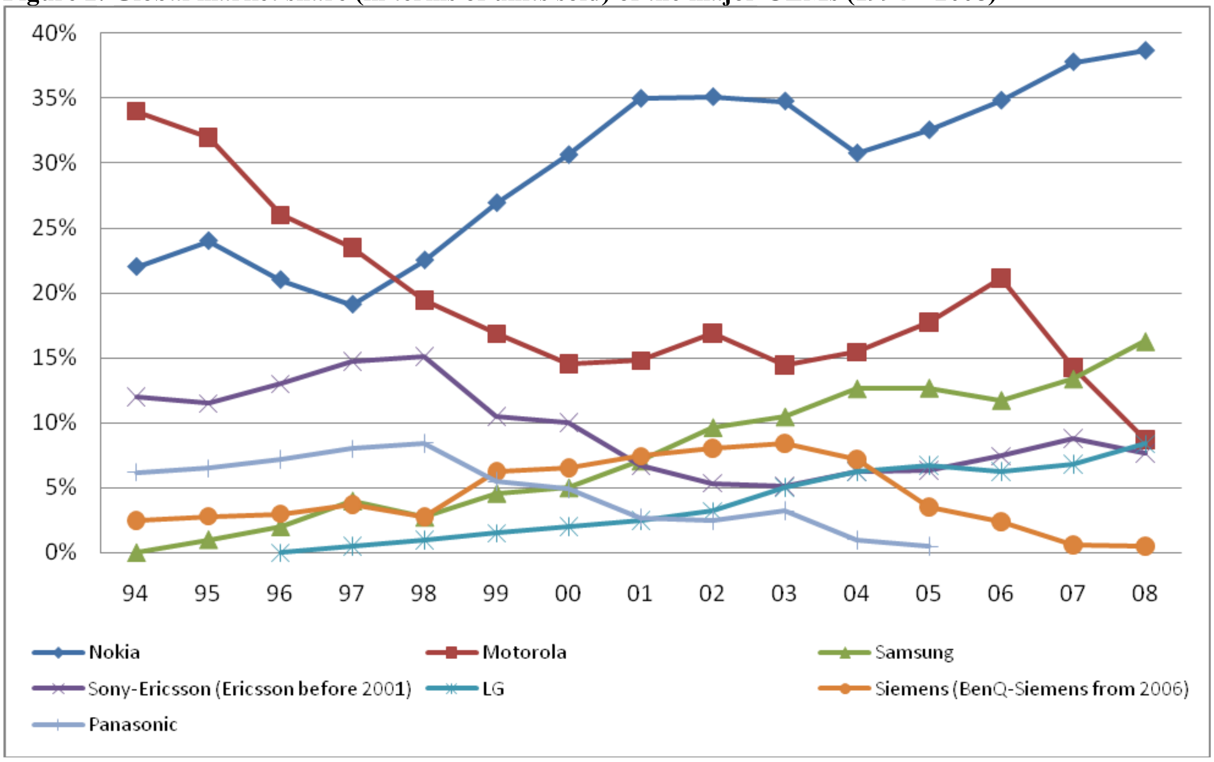
5.3. Second half of the 1990s: the second growth

5.3.1. The decline of analog devices and the leadership of Nokia in the digital

The mobile phone revolution started in the mid-1990s (Steinbock, 2003; Rice and Galvin, 2006). While up until then the construction of networks and handsets continued to grow at a steady pace, the market was still largely a domain for business users. In the second half of the 1990s size and weight of handsets strongly reduced. At the same time prices dropped and network coverage expanded, making the cellphone a mass-market product in most developed countries (Agar, 2004). Driven by the popularity of digital mobile phones, worldwide sales of mobile telephone terminals to consumers reached 160 million units, an increase of 50% over 1997. Digital mobile phone sales surpassed analog phones in 1998, as digital accounted for 84.6% of total mobile phone sales.

In 1997 the biggest OEM was Motorola of United States, with a global market share of 23.5%. Other players with relevant market positions were Nokia of Finland (19.1%), Ericsson of Sweden (14.8%), Panasonic of Japan (8.2%) and Alcatel of France (2.4%) (figure 2). Followers were Siemens of Germany, Samsung of South Korea, Philips of Netherland, Sony and Nec of Japan, and Sagem of France. Starting from the beginning of the 1990s Motorola began losing market share mainly because, despite the growing interest in digital technologies, it had focused on the production and development of analog devices for too long. The resulting excess capacity together with exit barriers from the production of analog devices strongly affected the firm's sales and profitability, making it slower and costly the transition to digital standards. Instead, contrarily to Motorola and many other OEMs, Nokia was able to catch quickly the transition to digital standards, having focused investments in 2G mobile phones from the beginning of the 1990s (Steinbock, 2003; Dittrich and Duysters, 2008). Because of its rapid response to changes in technologies and consumer preferences, the Finnish OEM became the World largest manufacturer of mobile phone, surpassing the industry giant Motorola, in 1998 (figure 2).

Figure 2. Global market share (in terms of units sold) of the major OEMs (1994 – 2008)



Source: Gartner Dataquest

5.3.2. Miniaturization and the quest for more features

A significant step in the evolution of mobile phones took place when they became truly pocket-size. The role of design was suddenly determinant in a model's success. Earlier, design had been governed by ways of fitting the phone comfortably inside the car. Starting from the second half of the 1990s, the phone became an independent item to be displayed, a reflection of the user personality. Handsets were progressively miniaturized till they could fit a pocket or a handbag.

As handsets became consumer goods, users began to ask for special features. The most revolutionary feature diffused among mobile phone models in the second half of the 1990s was the capabilities of sending text messaging. The SMS, a text-messaging feature of GSM digital cellular phones became a vibrant business and social phenomenon especially in Europe, were teens quickly made it their own (Le Bodic, 2005). In the mid-1990s most handsets were then equipped with proper keyboards, enabling the user to dial not only numbers but also letters and various characters. Some manufacturers offered also group messaging capabilities where messages are broadcast to several users simultaneously, creating a sort of mobile chat room. At the end of the 1990s, almost all new handsets models were capable of sending SMS.

In 1997 mobile phones were equipped with video games. The first game that was pre-installed onto a mobile phone was "Snake" on a selected Nokia model. Snake and its variants, installed on almost all Nokia models, became soon very popular all over the world. Given the success of mobile games especially among teenagers, most of OEMs tried to emulate the Nokia's success by establishing relationships with game designer.

Based on the internet technologies, in 1999 was introduced the first wireless application protocol (WAP). The WAP originated from several years of cooperation among OEMs (Nokia, Motorola and Ericsson), network operators, and local authorities. With the introduction of the WAP users could access with a micro browser to personal Web pages and configure the services they could get through the phone. These included specific information, lists of number for group messaging, personalized ring tones, and stylized postcards that could be sent to one's own phone or to a friend's (Ling, 2004).

As mobile phones were increasingly packed with new features, manufacturers began to work more closely with content producers, game designers and the entertainment industry. Using the handset as a general-purpose terminal, the rise of the SMS, mobile chatroom and mobile portals, WAP and WAP-based applications, games and so many other product innovations had worldwide pioneering significance. Most of these can be traced by Nokia (Table 1), and this is probably the reason that allowed the company to reinforce its worldwide leadership over time.

Table 1. Main product technologies introduced by OEMs in the second half of the 1990s

Product technology	**Firms introducing the technology***	**Year of introduction**
Voice dial	Philips	1997
Composer	Ericsson	1997
Infrared	Nokia	1997
Games	Nokia	1997
Downloadable ring	Nokia	1998
Email client	Nokia	1998
WAP	Nokia	1999

* The first firm adopting the new product technology in its portfolio.
Source: annual reports and newsletters of companies belonging to our sample.

The rush to introduce new features and applications forced OEMs to support increasing R&D expenditures. Most of the OEMs began to outsource their manufacturing to contract manufacturers in order to focus on more value added activities and benefit from economies of scale. These contract manufacturers, also known as Electronic Manufacturing Services (EMS) providers, assembled electronic components and devices on behalf of their OEMs. EMS providers originated mainly from the computer industry or from computer peripherals. Because the worldwide EMS providers market were very fragmented, OEMs were able to exert a strong bargaining power, that resulted in very low prices of outsourced components and assembling activities.

5.3.3. Segmentation as a basis for differentiation

As momentum in mobile cellular shifted closer to consumer market, segmentation accelerated accordingly. Increasing segmentation served to OEMs as a basis for differentiation. Equipment manufacturers were struggling to design handsets for all actual consumer segments, from mono-color elegant-business style to colorful interchangeable plastic covers for fashion-conscious teens, and easy-to-use models for twelve years old set. Because some of the most requested features by consumers, such as SMS, no longer distinguished mobile vendors, consumers purchased phones that suited their different lifestyles. Of course both features and design contributed to the rapid growth of mobile subscriber base, but the transition of the mobile phone from a business niche device to a global consumer product required a new approach to producing and marketing mobile phone. Everyone was a potential mobile phone consumer. As the market became increasingly segmented, the ability to master various product categories became crucially important (Ling, 2004).

Until the end of the 1980s, design was largely a neglected strategic tool. Yet, it began providing a potent way to differentiate and position a company's products and services. Some OEMs invested a lot of resources on to constantly improve the handset aesthetic. For example, Nokia in the 1990s hired young designers from art schools in order to keep in touch with trends (Haikio, 2002). The significance of design in the mobile cellular business has coincided with the transition from the business market to consumer market. Starting from the late 1990s, many celebrities, such as Paul Newman, Tom Hanks, Steven Spielberg, etc., provided the stage for a carefully orchestrated marketing campaign in which opinion leaders encouraged the use of a certain brand among their fans. For example, Nokia gave its 8860 phones as gifts to all the presenters at the Emmy Awards in 1998 (Steinbock, 2001). A professional tool thus became a mass-market product comparable with wristwatch. As manufacturers were increasingly competing at equal price and functionalities, design was seized as one of the main dimension of differentiation.

In turn, the need to use segmentation as a way of differentiating, pushed OEMs, especially the biggest ones, to strongly widen their market portfolio, in each of the served market segments. We find that the average number of new models introduced in the global market by OEMs passed from 3 in 1997 to 7 in 2000 (table 2).

Table 2. New mobile phone models introduced every year by OEMs in the global market

	97	98	99	00	01	02	03	04	05	06	07	08
TOTAL	32	47	45	76	74	89	184	239	323	266	270	273
Annual growth		46.9%	-4.3%	68.9%	-2.6%	20.3%	106.7%	29.9%	35.1%	-17.6%	1.5%	1.1%
Mean	2.9	4.3	4.1	6.9	6.2	8.1	15.3	19.9	26.9	24.2	24.5	30.3
Median	2.0	3.0	4.0	7.0	5.5	7.0	11.5	17.5	22.0	18.0	19.0	25.0
S.D.	2.3	2.7	2.2	3.4	4.0	4.8	10.7	9.5	17.5	21.6	24.5	22.8
No. of OEMs*	11	11	11	11	12	11	12	12	12	11	11	9

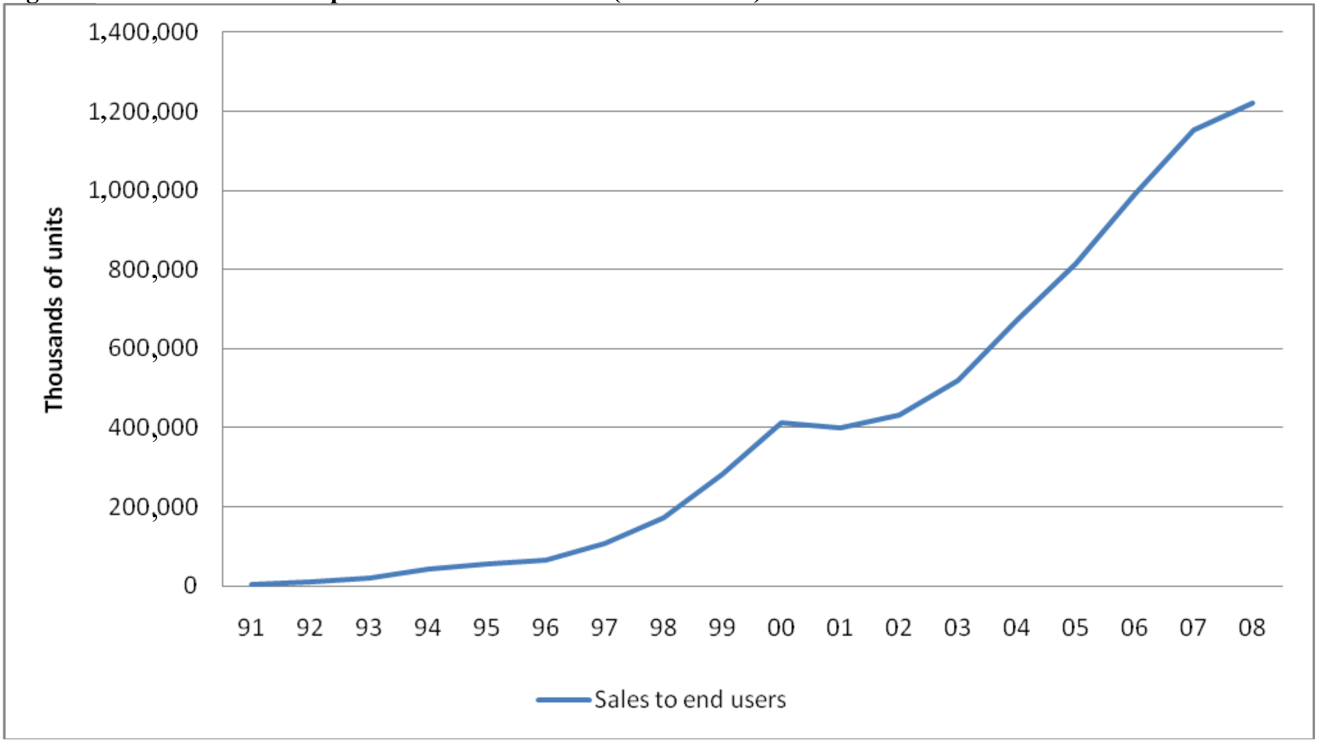
* Number of OEMs operative in the market, among those belonging to our sample.
Source: annual reports and newsletters of companies belonging to our sample.

5.4. First half of the 2000s: the shake-out

5.4.1. The economic downturn and the war of prices of entry-level phones

Worldwide mobile phone sales between 1996 and 2000 experienced a compound annual growth rate close to 60%, but in 2001, for the first time in its history, the mobile phone industry suffered a drop in unit sales (figure 3).

Figure 3. Worldwide mobile phone sales to end-users (1997 – 2008)



Source: Gartner Dataquest

Mobile phone sales were somewhat depressed by the US economic recession started in 2000 and exacerbated after 11 September 2001. The weakened consumers' purchasing power shifted the demand towards low price handsets. The most common strategy followed by OEMs in order to respond to the sales slowdown resulted in aggressive pricing of entry-level phones. Most of those manufacturers that were not able to be competitive in this segment faced losses in market share. For example, over the first half of the 2000s, the majority of the sales for Siemens were in low tier, low cost, low margin products, and this helped the company to record very strong growth. Siemens' products were ideally suited to emerging Eastern European markets, especially Russia. Its sales further strengthened as it took full advantage when some competitors were unable to meet that market demand. Similarly Nokia, the market leader, was able to maintain a strong leadership due to price cut especially in basic models. Motorola, instead, maintained the second position based on its strong performance in the North American and Chinese markets, but its decision not to launch a wide range of basic-low cost handsets in the Western Europe was the main cause of losses of market share in this area. Different the case of Samsung and LG, that continued to gain market share by investing mainly in mid-to-high end cellular phones (Hu and Hsu, 2008), with the aim of position their brands in the "luxury" segment (high-quality phones based on high-end technologies) (figure 2).

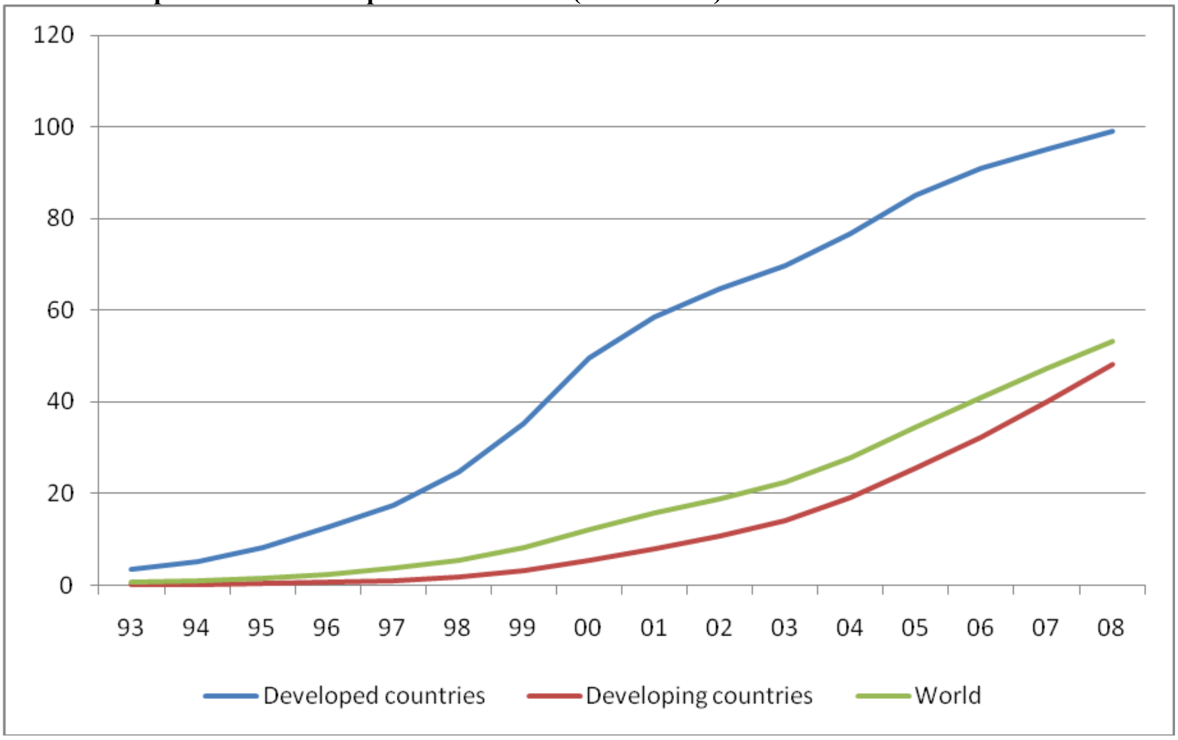
Despite the mobile phone market in 2005 was characterized by "device diversity" as OEMs launched a wide range of new handsets with features, such as gaming, music and video, the majority of worldwide sales remained in the low-tier, low-function segment. The shift to lower-end phones dramatically lowered barriers to market entry.

The economic downturn led to a renewed competition also among network operators that, in order to increase their subscriber bases, began offering low-priced prepaid packages. This clearly made even faster the handset commoditization in these years.

5.4.2. The quest for a replacement market and the rise of color display and camera phones

If from one side the competition was focused on aggressive pricing of entry-level handsets, on the other side the highly penetrated nature of the Western European and US market in the first half of the 2000s (figure 4) meant that future mobile terminals sales growth had to come from replacement purchases (Kumar and Zahn, 2002).

Figure 4. Mobile phone subscribers per 100 habitants (1994 – 2008)



Source: International Telecommunications Union.

Mainly three product technologies drove the replacement cycle across these years: multimedia messaging service (MMS), color displays and camera phones. The very function of the handset was clearly changing. Certainly, it served as a traditional phone, but the constant introduction of new features made it possible to use it as a multi-tasking device. Telecommunication network operators meanwhile, were increasingly focused on commercializing new applications and services, such as MMS, that served to augment their revenue from across a mature subscriber base while simultaneously acting as a catalyst for replacement sales.

The replacement market was in part favored also by the introduction of high speed data transfer technologies, that marked the shift to a new generation of handsets. In particular the introduction of the General Radio Packet Service (GPRS), in 2001, gave light to the so called 2.5 generation (2.5G) of mobile phones. GPRS is a radio technology for GSM networks that adds packet-switching protocols, shorter set-up time for ISP connections, and offer the possibility to charge by amount of data sent rather than connect time. Few years later, the introduction of the Enhanced Data rates for GSM Evolution (EDGE) acted as a bolt-on enhancement to 2G and 2.5G GPRS networks. The introduction of the EDGE is often described as 2.75G.

The high growth of the industry and the increasing presence of the mobile as a commodity encouraged in 2003 the development of a new technology, the Universal Mobile Telecommunications System (UMTS), that was expected to quickly substitute for GSM, to offer both a wider range and a higher quality of services, such as wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. However, and in spite of its promising possibilities, the development of UMTS was not as rapid as expected and, at the end of 2005, GSM was still the dominant technology in the mobile world (Fuentelsaz, Maìcas and Polo, 2008). Therefore mobile phones set with UMTS technologies, commonly called "third generation mobile phones" (3G), did not significantly contributed to the growth of a replacement market both in US and especially in Western European countries.

In 2005 the global market was clearly split in two mature markets. There was the replacement market in regions such as Western Europe and North America where network operators subsidized enhanced handsets, and consumers were willing to upgrade to devices with more features, especially camera phones with color display, and emerging markets such as Africa, parts of Eastern Europe and China, where new sales were fueling customer demand. In both markets the increasingly shorter product life cycle of mobile phones brought to strong product discounting. This made easier for consumers to pick up more advanced technology at a lower price, and in turn pushed pressure on manufacturers' margin and profitability.

Being the competition mainly focused on new product innovations, the speed of introduction of new product features was for OEMs one of the most important source of competitive advantage. Japan became an innovative centre where top OEMs first tested new technological features. This environment favoured innovation processes of Japanese OEMs, such as Panasonic, Sharp and Nec, that were able to anticipate the biggest competitors in the introduction of revolutionary features such as polyphonic ringtone, photo and video-camera (table 3). Notwithstanding, because of their weakened brand recognition outside their local "highly saturated" market, Japanese OEMs were not able to gain a first mover advantage over foreign competitors, and their product innovations became quickly copied and used as a source of product differentiation by the biggest rivals.

Table 3. Main product technologies introduced by OEMs in the first half of the 2000s

Product technology	Firms introducing the technology*	Year of introduction
Polyphonic ringtone	Panasonic	2000
SMS chat	Nokia	2000
MP3	Samsung and Siemens	2000
Bluetooth	Ericsson	2001
Color screen	Nokia and Ericsson **	2001
MMS	Motorola	2002
Photocam	Sharp	2001
Videocam	Nec	2003

* The first firm adopting the new product technology in its portfolio
** A couple of phone models capable of displaying four colors (red, white, green and blue) were introduced by Siemens in 1997. But the first phones capable of displaying a complete range of colors (more than 200 colors) were introduced in 2001 by Ericsson and Nokia.
Source: annual reports and newsletters of companies belonging to our sample.

5.4.3. The de-verticalization of OEMs supply chain

While during the late 1990s, beginning 2000s, many of the minor European players exited production either through sale or closure, new players from Asia ventured into the field. They were mainly low-cost manufacturers from China and Taiwan (Jin and Zedtwitz, 2008). The influx of this new competition pushed down the average selling price of mobile phones, hitting the margins of the established OEMs like Nokia, Motorola and Samsung. As capabilities required to be competitive for incumbents increased, we find that the vertical and horizontal disintegrations in the industry increased as well. Where OEMs were able to internalize all of the design, production and distribution activities in the 1980s and 1990s, the changing nature of products made this business model impossible over the 2000s. As also suggested by some authors (Abernathy and Utterback, 1978) vertical integration is the most likely business model in a period where competition is not intense. But the stronger the rivalry among players, the higher the need to focus on the core business and exploit the specialized competences of partners upstream (suppliers) and downstream (distributors) of the supply-chain.

At first, to benefit from economies of scale and withstand the price variations, OEMs outsourced more and more manufacturing and assembling activities to EMS providers. For example, Sony-Ericsson, an OEM born in 2001 from the *joint-venture* between Ericsson and Sony, outsourced most of its manufacturing to Flextronics International, a Singapore-based EMS provider. Nokia, that was traditionally vertical integrated, outsourced about 15% of its assembling and manufacturing activates to Flextronics, Solectron (US) and Elcoteq (Finalnd). Other OEMs such as Motorola, Alcatel and Siemens also began to outsource part of the production process (table 4). The advantages of outsourcing to EMS providers were that they left the OEM free to focus on its core strengths: product R&D, sales and marketing.

At the beginning of the 2000s the market of EMS providers experienced a strong growth with respect to the 1990s, mainly driven by a few players. The EMS providers industry had become capital intensive and more concentrated: the market share for the top six EMS providers climbed from 20% in the mid-1990s to 55% in 2001.

Table 4. Main EMS providers and their OEM clients over the 2000s

EMS provider (country)	OEM Client
Flextronics (Singapore)	Nokia, Sony-Ericsson, Siemens, Motorola
Solectron (US)	Nokia
Elcoteq (Finland)	Nokia, Sony-Ericsson

Source: annual reports and newsletters of companies belonging to our sample.

The rush of some OEMs to design new models with enhanced capabilities further pushed down the margins as R&D expenditures were rising. This gave birth to a new entity in the supply chain called the Original Design Manufacturers (ODMs). Unlike in the EMS model, where OEMs developed and retained the handset intellectual property rights, ODMs where independent contractors who developed prototype handsets and sold them to established OEMs who in turn marketed them under their brand names. The advantages of outsourcing to ODMs were that it allowed the OEM to reduce design and R&D expenses. However the growing importance of ODMs also became quickly a threat to established OEMs. The partnership with OEMs educated ODMs, turning some of them in real competitors. BenQ, a Taiwanese ODM, was the most prominent example that was selling handsets under its own brand (table 5).

Table 5. Main ODMs and their OEM clients over the 2000s

ODM (country)	OEM Client
Arima (Taiwan)	Sony-Ericsson, Nec
BenQ (Taiwan)	Motorola, Nokia
Compal (Taiwan)	Motorola, Panasonic, Alcatel
Dbtel (Taiwan)	Siemens
GVC (US)	Sony-Ericsson
HTC (Taiwan)	Orange, Siemens, Motorola
Microcell (Finland)	Sony-Ericsson
Quanta (Taiwan)	Panasonic, Siemens, Philips, Nec

Source: annual reports and newsletters of companies belonging to our sample.

The need to focus on the core business in order to reduce expenditures but at the same time keep on improving handsets capabilities, increasingly pushed OEMs to outsource also the production of handsets operating systems. By 2000 several OEMs established partnerships with operating system (OS) makers such as Microsoft, Symbian and Palm, whose advanced software enabled a rich user experience for new data services, including secure Web and email access, and multimedia capabilities (table 6). But the strong brand image of some OS makers, such as Microsoft, if from one side enhanced the value of handsets allowing OEMs to fix higher selling prices and in turn gain higher margins, on the other side was perceived by OEMs as a threat potentially eroding their branding power.

Table 6. Main OS makers and their OEM clients over the 2000s

OS makers (country)	OEM Client
Microsoft (US)	Sony-Ericsson, Samsung, LG, Motorola, HTC
Symbian (UK)*	Nokia, Sony-Ericsson, Samsung, LG
Palm (US)	Samsung

*Acquired by Nokia in 2008.

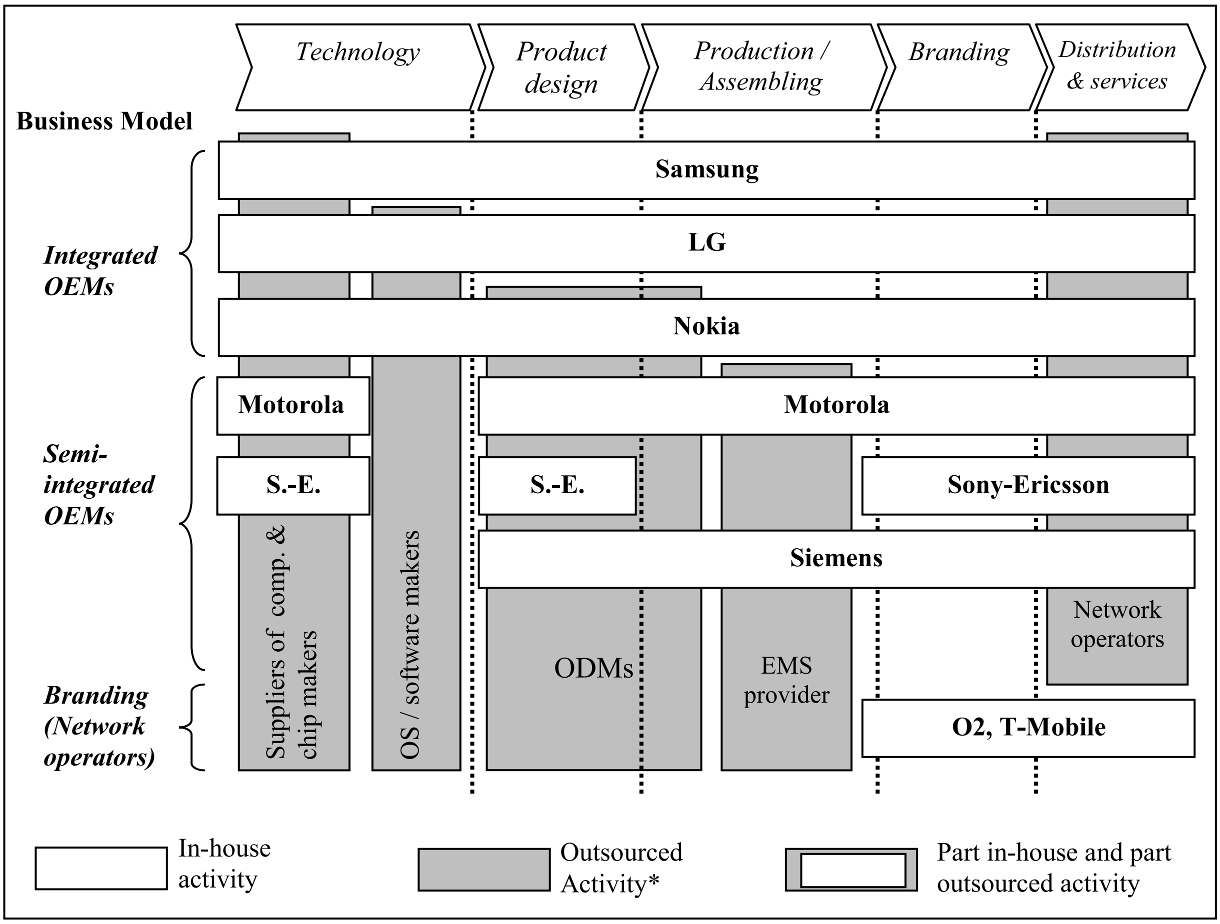
Source: annual reports and newsletters of companies belonging to our sample.

Moreover, while in the 1990s network operators left handsets design and configuration to OEMs, at the beginning of 2000s a growing number of network operators, such as T-Mobile, Orange and O2, began having their own branded handsets. They basically outsourced all the upstream supply chain activities, controlling the only design and branding ones.

Therefore, starting from the end of the 1990s, except for some of the South Korean OEMs, such as Samsung and LG, that did not have an outsourcing strategy (Hu and Hsu, 2008),[1] almost all the major handset manufacturers began to outsource part of their activities to external parties. The increasing outsourcing of production, assembling, and design activities gave birth to different business models (figure 5).

[1] Except for the manufacturing and assembling of a few very low-end products targeted to the China's market, and except for the manufacturing of advanced OS installed in certain high-end models.

Figure 5. OEMs business models in the 2000s: from vertical integrated to deconstructed supply chains



*We define an activity as "outsourced" if it is externalized to third parties even only for a small amount (e.g. the production of a single type of component).

Source: our elaboration from annual reports and newsletters of companies belonging to our sample. The sequence of macro-activities on which we have developed the analysis has been adapted from the "McKinsey business system" framework.

There is an interesting debate about the more efficient end best performing OEM business model. Authors in favor of vertical integrated business models (Hu and Hsu, 2008), such as those of Samsung and LG (companies that purchase most of their cellular phone components from their own business group), argue that this structure helps create internal resource interaction, allowing more innovative changes. On the contrary, authors in favor of semi-integrated business models (Rice and Galvin, 2006) as the one of Motorola and Sony-Ericsson, argue that it enables the OEM to be more flexible and, at the same time, acquire the knowledge of the partners.

The possibility of outsourcing the production, assembling and design of handsets to a wide number of specialized third parties (chip and OS makers, EMS providers, ODMs), allowed OEMs to widen their product range very quickly, continuing the positive trend started in the second half of the 1990s. In fact we find that the average number of new models introduced every year by OEMs passed from 6 in 2001 to 27 in 2005. However, it is also interesting to note that, while at the end of the 1990s all the OEMs were able to introduce in the market almost the same number of product models every year, differences in the size of OEMs' product portfolios strongly increased over time. As shown in table 2 the standard deviation of the number of new models introduced every year by OEMs increases very quickly from 2000.

The role of suppliers in OEMs product strategy was definitely changed with respect to the previous decade. From the beginning of the 2000s most of OEMs suppliers incorporated sophisticated value activities and engaged forward integration, whereas OEMs were left mainly with distribution and marketing activities. However, since most of the OEMs suppliers were unable to innovate in marketing and distribution, and since OEMs dominated these downstream activities, all parties benefited.

5.4.4. The rise of parallel markets

Although the brand image of biggest manufacturers was a strong barrier to entry in the market, the mobile phone was a product easy to imitate both in terms technologies and design. And in fact, while OEMs succeeded to protect the main design of their products with patents in Western European and the US markets, this was quite harder in the less regulated markets of many developing countries. For example, in 2004, a couple of microchip design companies from Taiwan, developed a platform that integrated many complex mobile phone software systems onto a single chip.[2] This gave birth to the mobile phone black market, making it easy

[2] In other words, this platform made it possible to configure the operating systems of the major OEMs with a single chip.

and cheap to build fake handsets and churn out new models at astounding speeds. The mobile phone black market toke place mainly in the Asia/Pacific region. In 2008, an estimated 150 million, or 20%, of the 750 million handsets produced in China were counterfeit. Of those, over 50 million were sold in China while the remainder were sent to foreign markets. As lamented by the major OEMs, the black market phones were dramatically lowering the prices and margins of brand name mobiles. Some manufacturers, like Nokia, said they were working with the Chinese government to crackdown on the counterfeiting companies as well as raise awareness about the potential dangers of the fake phones, some of which have had exploding batteries or expose consumers to abnormal amounts of radiation. However no serious steps were taken to limit the production and selling of fake phones. In China bandit phones were even advertised on late night television shows.

Together with the birth of the black market, in the first half of the 2000s a considerable bubble of unsold inventory depressed sales in key markets. The OEMs and network operators most exposed to the inventory overhang sought out the gray market in the Asia/Pacific region. In particular the Chinese market experienced what was arguably the most active period of gray market importing of mobile terminals in several years. The inventory glut caused a significant disruption of the normal dynamics of sell-in and sell-through. The oversupply situation resulted in numerous leading OEMs selling more handsets to end users than they actually shipped into distribution channels. The once endemic problem of global inventory mismanagement due to robust demand in the gray market did not disappeared during the second half of the 2000s. Countries such as Saudi Arabia, Singapore, Hong Kong and the Philippines became de facto distribution points for gray market terminals into the fastest growing markets in the Middle East and Asia (Gartner, 2009).

5.5. Second half of the 2000s: the maturity stage

5.5.1. Technological convergence

In the mid-2000s the number of worldwide mobile phone sales to end users was nearing 1 billion. The developed countries average per capita penetration was close to 100% (figure 3); leading countries like Italy, Taiwan, Hong Kong and Israel performed penetration rates at about 140%. Since the saturation was reached, demand was wholly for replacement. In this stage of industry maturity, in order to stimulate the demand towards replacement purchases, OEMs have added both to low and high-end handsets many “non typical” functionalities such as digital camera, MP3 player, internet connection, radio, voice recorder, etc. This phenomena has been commonly called “technological convergence” (Rosenberg, 1963; Borés, Saurina, and Torres, 2003), expressing the merge of several different technologies in a single device (Gill, 2008). Those features that till the mid-2000s served as an element of product differentiation, have become the dominant design in the product portfolio of most OEMs.

By offering functionalities that are not related to basic voice communication capabilities, OEMs are in effect entering markets that are populated by firms that make products for different uses, such as digital camera, MP3 players, voice recorder, etc. For instance, the latest mobile phones offer features that are comparable to medium quality digital camera and MP3 music player. But also the watch making companies around the world are affected by the convergence in mobile phones, due to the emergence of handsets as time keeping devices (Eastwood, 2006, 2007). The increasing number of applications allowing the mobile phone user to write, read, download and send documents are even blurring the line among handsets and portable computers, and it is for this reason that some PC makers are now diversifying in the mobile phone segment. Apple, with its iPhone, a device combining voice, MP3 player and PDA application, is one of the most prominent examples.

As argued by most of the product and marketing managers we interviewed, although a more pure-play device, such as the digital camera or the MP3 player, normally has more advanced features than a multi-tasking mobile phone, in the medium or long term consumers will probably forego these advantages of pure-play devices in favor of multi-tasking mobile phones.

5.5.2. The mobile phone as a fashion accessory

In the last five years mobile phones are increasingly being seen as fashion accessories rather than utilitarian devices. Together with the technological convergence, aesthetic design and co-branding agreements seem to be two emerging competitive strategies. We have found numerous partnerships between OEMs and fashion houses: Motorola with D&G and Aston Martin, LG with Prada and Roberto Cavalli, Samsung with Giorgio Armani, Nokia with Cath Kidstone and many others (table 7).

Table 7. OEMs' co-branding products with fashion houses

OEM	Fashion house	Co-branded model	Year of introduction
Nokia	Cath Kidstone	Cath Kidstone Nokia 6111 / 6230i	2006
Motorola	D&G	Motorola D&G RAZR V3i	2006
	Aston Martin	Motorola V600 Aston Martin	2006
LG	Roberto Cavalli	LG U880 Roberto Cavalli	2005
	Prada	KE850 Prada	2007
Samsung	Armani	P520 Armani	2007
	Adidas	F110 Adidas	2008
	Ted Baker	Samsung Ted Baker	2008
Siemens	Escada	Siemens SL55 / SL65 Escada	2005 / 2007
Alcatel	Mandarina Duck	Alcatel Mandarina Duck	2007

Source: annual reports and newsletters of companies belonging to our sample.

Given the style conscious target, these phones tend to emphasize design over functionalities. This competes against the interest of network operators, which prefer consumers to be using advanced phones allowing access to a broader range of network services (e.g. the WAP, the Internet). However, fashion brands will increasingly become important as phones become less distinct in terms of features. Most consumers now accept a camera or web access as a given for new mobiles. Within few years this would be the same for advanced features currently seen as revolutionary. This has seen brands going into the market directly: Levi's in 2007 launched of its own branded handset, for example.

5.5.3. The concentration of the OEMs market

Market share distribution among the biggest OEMs has evolved substantially in the past decades (figure 2). Concentration level initially reduced in the first half of the 1990s due to the decreasing market share of the leader Motorola, and increased again after 1999 with the increasing market share and gained leadership of Nokia (table 8). In 2008, five OEMs – Nokia, Samsung, Motorola, Sony Ericsson, and LG, controlled about 80% of the global mobile handset market.

Table 8. Cumulative worldwide market share of the biggest four OEMs (Cum.4)

	94	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**
Cum. 4 (%)	74.2	74	67.2	65.3	65.5	60.5	61.7	63.9	69.6	68	66	69.7	75.1	74.2	72.1

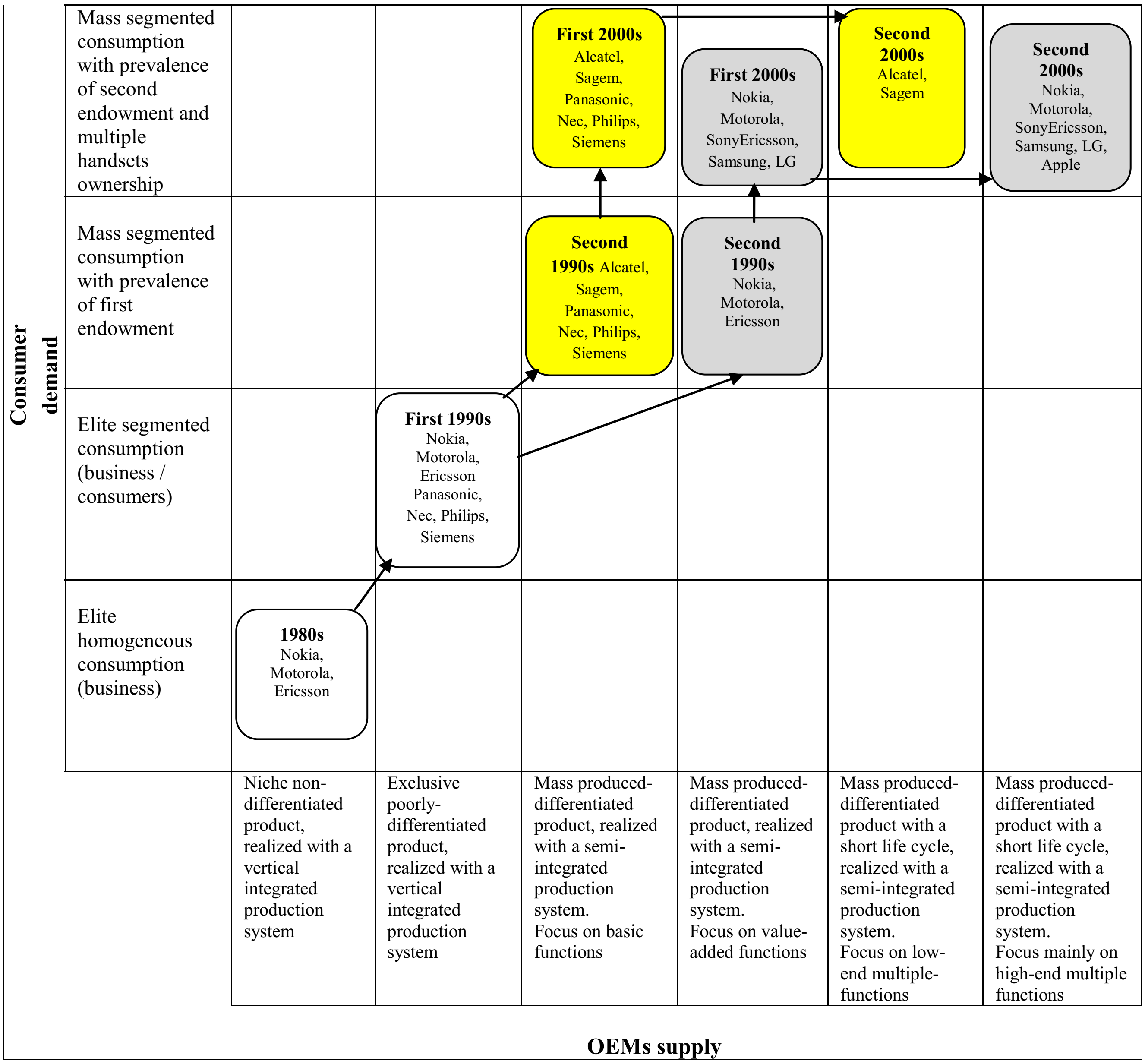
The high level of concentration has conferred to the "big five" a relevant competitive advantage with respect to the smaller rivals. In fact despite the increasing competition from low-cost Asian manufacturers, brand recognition still speaks louder in developed countries. Moreover, despite the increasing number of strategic relationships of OEMs with suppliers, the bargaining power OEMs are able to exert on backward and forward third parties is still substantially high. As far as OEMs suppliers are unable to innovate into marketing and distribution, OEMs will influence prices and quantity.

6. Discussion: a longitudinal overview

6.1. OEMs product strategy evolution over time

Earlier in this paper, an analysis of the main changes that have exercised influence on OEMs' product strategies from the 1980s till the end of the 2000s, has been undertaken. Based on primary and secondary sources we observed that the rational of mobile phone manufacturers' product strategy has radically changed over the industry evolution. Figure 6 shows the industry transformation cycle based on the evolution of consumer demand and the OEMs supply.

Figure 6. Consumer demand / OEMs supply matrix



Source: our elaboration

In the 1980s the market for mobile phone was still in an introduction phase, given the low product diffusion among consumers, the underdeveloped product technologies, the few number of players in the market and competitions mainly at national level (table 9). The mobile phone was an expensive product targeted only for the business market, manufactured and distributed by vertical integrated OEMs (table 10). In turn OEMs need for differentiation was very low, since the main problem for consumers was “product availability” (table 11).

The beginning of the 1990s marked two distinct technological discontinuities: the sudden redundancy of first-generation analog devices, and the rise of second generation services and equipment. Nokia’s management became more strongly aware of the implications of digitalization than did its competitors, and this served the Finnish company to start building a strong competitive advantage. Meanwhile the mobile phone reduced its size, became portable and was then introduced in the consumer market. However, because its price was still very high, the demand came mainly from business users. A number of conglomerates from developed countries (such as Panasonic, Nec, Philips and Siemens) sow the mobile phone industry as a key opportunity, and decided therefore to enter in the market. In this stage of “first growth” the main elements of product differentiation for OEMs were the handset size and weight, as synonymous of product “portability”, and a few number of revolutionary features, such as the ability of sending text message (table 11).

In the second half of the 1990s the mobile phone became a commodity, produced for the mass-market. The profit associated by the demand growth attracted many new competitors, especially from the Asian developing countries, such as China and Taiwan, with the main competitive advantage of low labor costs. As momentum in mobile cellular shifted closer to consumer market, segmentation accelerated accordingly. Increasing segmentation served to OEMs as a basis for differentiation. In this stage of “second growth” OEMs, in order to benefit from economies of scale and focus resources and investments on core activities, began to outsource the manufacturing and assembling of components to contract manufacturers (table 10). Over these years a number of revolutionary product technologies were introduced in the market. Among them the diffused popularity of SMS technology altered the traditional scope of the handset, offering and alternative way of wireless communication to the voice.

The first half of the 2000s marked a period of shake-out. The highly penetrated nature of the Western European and US market meant that an increasing number of consumers owned more than one handset. In turn, future mobile terminals sales growth had to come from replacement purchases. In order to benefit from economies of scale but at the same time keep on introducing new product innovations able to rejuvenate product design and capabilities, OEMs increased the number of strategic alliances with third parties, outsourcing even design and R&D activities. The new product innovations, such as color display, camera and MP3 player, were changing again the mobile phone traditional scope of providing pure voice capabilities and text messaging. Those OEMs there were not able to innovate or quickly adopt successful product technologies were forced to exit the market.

Over the second half of the 2000s, the increasingly fast obsolescence of mobile phones due to the continuous introduction by OEMs of new product technologies, has brought to strong product discounting. This has made easier for consumers to pick up more advanced technology at a lower price, and in turn pushed pressure on manufacturers' margin and profitability. In stage of maturity, brand recognition is the main source of competitive advantage for OEMs, as phones are less distinct in terms of features.

Table 9. The worldwide mobile phone industry: competitive landscape

Mobile phone industry variables	1980s	First half 1990s	Second half 1990s	First half 2000s	Second half 2000s
Level of OEMs concentration: Con. 4	About 70% (1985)	About 70% (1993)	65.5% (1998)	68.08% (2003)	72.05% (2008)
OEMs competitive landscape	• Worldwide leadership of Motorola (more than 50% of the market) • Followers: Ericsson and Nokia	• Dominance of Motorola, Ericsson and Nokia; • Minor positions performed by other OEMs from Weastern Europe (Philips and Siemens) and Japan (Nec and Panasonic).	• Increasing number of OEMs from developed countries (Western Europe, US and Japan) • Worldwide leadership of Nokia (in 1998)	• Exit of minor European OEMs • Rise of Asia low-cost OEMs	• Dominance of few OEMs from developed countries • Strong turnover of Asia low-cost manufacturers
Competition size	• Mainly national	• International	• Global	• Global	• Global

Source: our elaboration

Table 10. The worldwide mobile phone industry: OEMs supply chain relationships

Mobile phone industry variables	1980s	First half 1990s	Second half 1990s	First half 2000s	Second half 2000s
OEMs supply chain relationships with network operators	• OEMs sell products directly to consumers and network operators play no rule in the process; • OEMs produce handsets for a limited number of telecommunications standards;	OEMs sell products or 1) directly to consumers, or 2) through the first network operators' retail channels; • OEMs produce handsets for a growing number of telecommunications standards;	• OEMs sell products to consumers through the network operators' retail channels (network operators buy stocks of handsets from OEMs, and sell them to consumers);	• Network operators begin having their own branded handsets	• Growing number of network operators having their own branded handsets
OEMs' supply chain relationships with supplier (ODM, EMS providers, chip and OS makers, etc)	• OEMs outsource components and assembling to very few suppliers; • Suppliers as a "support" to the OEMs production process.	• OEMs outsource components and assembling to very few suppliers; • Suppliers as a "support" to the OEMs production process.	• Increasing number of OEMs outsourcing the manufacturing of components and applications to suppliers; • Suppliers as "cooperators" in the OEMs production process.	• Increasing number of OEMs outsourcing, assembling and design of handsets to ODMs and EMS providers (in particular from China and Taiwan); • Suppliers as "strategic partners" in the OEMs production process.	• OEMs outsourcing, assembling and design of handsets to ODMs and EMS providers (in particular from China and Taiwan); • Suppliers as "strategic partners" in the OEMs production process.
OEMs supply chain business model	Integrated	Integrated	Integrated and semi-integrated	Mainly semi-integrated	Mainly semi-integrated

Source: our elaboration.

Table 11. The worldwide mobile phone industry: OEMs product innovations

Mobile phone industry variables	1980s	First half 1990s	Second half 1990s	First half 2000s	Second half 2000s
Key offering for consumers	Availability	Portability	• Design in line with the consumer lifestyle	• Service / experience (multi-tasking)	• Service / experience (multi-tasking) • Status
Main product technologies introduced in the market	Analog system	• GSM digital systems • SMS (still in the infant stage)	• WAP • Games • Diffusion of SMS	• Color display, MMS, Camera, MP3 player • GPRS, EDGE and UMTS technologies	• Smartphone features (e.g. advanced OS, fast internet connection, touch screen)
Main elements of product differentiation	None: OEMs offer many different versions of mobile phones; most of them are mounted on cars	• Portability: smaller and lighter handsets • GSM digital system • SMS	• Games, WAP • Segmentation based on the product design / aesthetic • Wide product range	• Multi-tasking products • Wide product range	• Aesthetic, design, fashion; • OEMs brand image
Dominant design	none	Portable handsets	• Miniaturization	• Miniaturization • games, WAP	Multi-tasking: camera, color display, MP3, GRPS/EDGE, etc.)
Technical standard	Analog system	Discontinuities: analog & digital systems	• GSM digital system • SMS	• GSM digital system • SMS	• GSM digital system • SMS, MMS
Product scope	Voice capabilities	Mainly voice capabilities (SMS introduction and very slow diffusion)	Voice + text capabilities (SMS fast diffusion)	Mainly voice + text capabilities (camera, MP3 and internet mobile were emerging)	Voice + text capabilities + camera + MP3 + internet mobile

Source: our elaboration.

6.2. Dominant designs and Technical Standards over the Industry Life Cycle

Our analysis also suggests that the mobile phone industry have confronted to the typical characteristics of dominant designs and technical standards (Utterback and Suarez, 1993; Funk, 2003, 2006; Rice and Galvin, 2006). A dominant design is a product architecture that defines the look and functionalities for the product, and becomes accepted by the industry as a whole. Technical standards instead emerge when there are "network effects" – the need for users to connect in some way with one another.

At first, over the 1980s, OEMs and consumers experimented with products and manufacturing. Few OEMs were operative in the market and Motorola performed a strong leadership. Ericsson and Nokia were the two main followers and there were space for only few other much smaller manufacturers. Handsets were in the initial stage of the industry life cycle, and were able to offer only voice capabilities. At the beginning of the 1990s, with the introduction of the digital system, as new entrants joined rivalry with uniquely designed products, incumbents leaders (Motorola, Ericsson and Nokia) sought to perfect their original designs and exhaust competition by rapidly introducing new models as part of an extensive product portfolio. These handsets were much smaller and lighter, worked with the GSM technology and were able of sending SMS. In the late 1990s miniaturization of handsets became accepted by the industry as a whole, defining a dominant design in handsets aesthetic. At the same time GSM technologies and SMS triggered network effects among users and became technical standards. Both dominant designs and technical standards marked a period of shake-out at the beginning of the 2000s: because of the increasingly penetrated market, firms that were not able to make the transition towards portable digital handsets were unable to compete efficiently and in turn exited the market or lost market share (Funk and Methe, 2001). The sperimentation in terms of size and digital technology then diminished and competition consolidated for the next few years.

Starting from the beginning of the 2000s some OEMs set on some of their handsets a wide number of new features, such as camera, color display and MMS, in order to differentiate their offer and look for a replacement market. These revolutionary technologies were widely accepted by consumers and encouraged product standardization among OEMs in the second half of the 2000s. Camera phone with color display became then the new dominant design. MMS a new technical standard (table 11).

At the end of the 2000s the market has reached a point of "apparent" stability, with few large firms having slightly differentiated products and relatively stable sales and market shares. Each handset introduced by the biggest five OEMs can be fitted in a pocket, work with a GSM network, has a color display, is able to send MMS, take pictures, or access to WAP services. What nowadays differentiate a device from another is instead its brand (e.g. Nokia, Samsung, Motorola, etc.), enforced mainly by the OEM's ability to promote it. Of course product features count as well. But those features that appear "advanced" (e.g. advanced operating systems, touch-screen, GPS, fast internet connection) and are used by some OEMs as an element of product differentiation in high-end devices, will be soon accepted by consumers as a given, forcing firms towards a new wave of standardization.

Technical standards in the mobile phone industry exist to facilitate the interoperability of electronic network devices and have been promoted to reduce systemic risk from application incompatibilities. Moreover standards have provided positive network externalities for users and producers (Funk, 2003). Dominant designs, instead, have defined common look and functionalities for mobile phones, increasing the homogeneity of product aesthetic and functions among the various brands. In the last years dominant designs have forced OEMs to compete on other product dimensions such as cost efficiency, users segmentation, co-branding strategies and rapid response to changes in technology and consumer preferences.

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Market Evolution and Time to Adoption of New Technologies by Industry Incumbents. The Case of the UK Mobile Phone Industry

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Abstract

In this paper we shed more light on the relationship between product diffusion and the time that companies take to launch products that incorporate a new technology introduced by their competitors, which we call time to technology adoption. First, we hypothesize that there is a negative relationship between product diffusion in a market and a firm's time to technology adoption. Second, we hypothesize that the time to adoption of functionality-defining technologies is shorter than the time to adoption of substitute technologies. Third, we hypothesize that the time to adoption of technologies introduced by the market leader is shorter than the time to adoption of technologies introduced by other industry members, and the gap between the two diminishes as the market matures. We test our hypotheses in the context of the UK mobile phone industry. Data spans from 1997 to 2008 and covers adoption patterns of 22 technologies in 566 new mobile phones launched by 13 industry incumbents. Model estimations provide support for our hypotheses. We discuss our results and draw several implications to improve on existing theory and on managerial practices.

Keywords: time to technology adoption, product diffusion, mobile phone

INTRODUCTION

Today business environments are increasingly characterized by rapid technological change and unpredictability. In these environments, a company ability to understand when to incorporate in its product portfolio a new technology is likely to be a powerful source of competitive advantage and can even affect its long term survival (Hamel, 2000). It follows that understanding the dynamics underpinning a company's time to adoption of new technologies is crucial for senior managers and executives seeking to improve their product competitiveness. Not surprisingly the topic of time to technology adoption has enjoyed significant development in the business and management literature (Rosenberg, 1972; Ettlie and Vellenga, 1979; Robertson and Gatignon, 1986; Damanpour and Gopalakrishnan, 2001) and many studies have identified factors affecting the adoption of technologies within systems (Roger 2003; Zaltman, Ducan and Holbek, 1973; Tornatzky and Fleischer, 1990). Rogers (2003) counts more than 5,200 articles on the topic.

Yet, a number of issues need to be investigated more carefully if we are to get a better understanding of firms' time to adoption of new technologies. For instance, in the extant literature, several antecedents have been linked to a firm's responsiveness to new technologies yet very little research has been carried out to link technology adoption decision to the specific stage of an industry evolution. Most of the empirical studies on adoption timing of innovations assume that factors affecting the time to adoption are constant over time and are not influenced by the specific market dynamics at any point of time. In doing this, existing technology adoption literature overlooks, for instance, that as market evolves decision makers may take a different technology adoption timing decision. We argue that technology adoption literature should incorporate more explicitly market evolutionary dynamics if we are to improve on its predictive power. In this paper, we seek to tackle this gap by formally bringing market evolution into technology adoption literature. We seek to shed more light on the relationship between product diffusion and the time that companies take to launch products that incorporate a new technology introduced by their competitors, which we call time to technology adoption. Our key point is that there is a negative relationship between product diffusion in a market and a firm's time to technology adoption. We then further refine our argument by elaborating on time to technology adoption over the product diffusion cycle for different type of technologies – i.e. functionality-defining technologies and substitute technologies – and for technologies brought forward by different actors – i.e. market leader or other incumbent. We hypothesize that the time to adoption of functionality-defining technologies is shorter than the time to adoption of substitute technologies. We also hypothesize that the time to adoption of technologies introduced by the market leader is shorter than the time to adoption of technologies introduced by other industry members, and the gap between the two diminishes as the market matures. We test our hypotheses in the context of the UK mobile phone industry. Data spans from 1997 to 2008 and covers adoption patterns of 22 technologies in 566 new mobile phones launched by 13 industry incumbents. Model estimations provide support for our hypotheses. This paper's key contribution is twofold. First, it moves us a step closer to formally considering the market evolution-dependent nature of technology adoption decisions. We find that time to technology adoption decreases as product diffusion increases and we provide rationale for this occurrence. Second, we carry out one of the few "multiple innovations – multiple organizations" study and we show, theoretically and empirically, that the time to technology adoption for functionality defining technologies and for technologies brought forward by market leaders is slower than the time to technology adoption of substitute technology and technologies brought forward by non market leaders, respectively.

We organize the remainder of this article as follows: We begin with a literature review of the main factors affecting both diffusion and adoption timing of product technologies among incumbents. Subsequently, we derive our hypotheses on time to technology adoption by industry members over the industry life cycle. Third we describe our sample and variables. Fourth, we present the empirical results and key findings. Finally we conclude with a discussion of the findings, implications, and limitations of our study.

TECHNOLOGY ADOPTION LITERATURE

The existing diffusion literature has identified a wide number of factors influencing the adoption of a new technology by organizations. Some of these factors are linked to the *characteristics of the technology itself*. For instance, Rogers (2003) argues that four attributes of a technological innovation - relative advantage, compatibility, trialability, and observability - are positively associated with its rate of adoption, while another attribute, complexity, is negatively related to the rate of adoption. Other authors show that the relative advantage of the technology (Loch and Huberman, 1999), the technology's compatibility with existing products (Farrell and Saloner, 1985; Katz and Shapiro, 1986; Sahay and Riley, 2003) and complementary technological infrastructures (Katz and Shapiro, 1986; Shy, 2001) are likely to affect technology diffusion patterns.

Other factors affecting the diffusion of new technologies have been linked to the *characteristics of a firm's external environment* and *to a firm's position in the environment.* In one stream of research, technology diffusion – often measured as adoption rates - has been defined as a function of mass media communication (Fourt and Woodlock, 1960) and information diffusion (Bass, 1969; Mansfield, 1961). Information diffusion processes can take different forms (Geroski, 2000) including: broadcasting and information provision; epidemics and "word of mouth" processes; and information cascades. Institutional theorists have tackled the topic by arguing that it is the institutional pressure that makes organizations increasingly similar to one another – hence affecting the patterns of adoption of new technologies (DiMaggio and Powell, 1983). Building upon research findings in economics, sociology, and cognitive and behavioural theories, Abrahamson and Rosenkopf (1993) and Fiol and O-Connor (2003) have introduced the construct of "bandwagons" into technology diffusion theory. Bandwagon theories specify a positive feedback loop in which increases in the number of adopters create a stronger bandwagon, and a stronger bandwagon, in turn, causes further increases in the number of adopters (Abrahmson and Rosenkopf, 1997). Other authors find that the adoption of a new technology can be influenced by the level of competition in the firm's environment (Utterback, 1974; Kimberly and Evanisko, 1981; Utterback and Suarez, 1993) and by the position of a firm in a network (Shapiro and Varian 1998). Robertson and Gatignon (1986) develop a number of propositions on the role of the supplier industry in affecting speed of technology diffusion as well as the competitive environment among potential adopters. In particular the authors argue that both "supply-side factors", such as competitiveness among suppliers, technology standardization, vertical coordination between suppliers and consumers, R&D and marketing support, and "adopter-industry factors", such as competitiveness among adopters (firms), professionalization and cosmopolitanism of the adopter industry are all factors affecting the adoption timing of a technology among firms.

Further factors affecting the diffusion of innovation have been linked to *internal environmental characteristics*. For instance, Waarts, Everdingen and Hillegersberg (2002), suggest that it can be expected that the likelihood of adopting new information technology systems depend on the IT intensity or dependency of a company: the more a business depends on computerized information processes, the more likely the company is to be interested in a new kind of software in order to manage these resources effectively. Some scholars have linked the adoption of an innovation with a firm's previous experience in dealing with certain types of innovation or its internal new product development and R&D capabilities (Atuahene-Gima, 1993; Macher and Mowery, 2003). Other authors have provided evidence of positive and negative relationship between the adoption timing and the firm's amount of resources. The argument for a positive relationship suggests that firms with high level of resources emphasize formal roles and control systems and tend to become more rigid. Bureaucracy research (Blau, 1970) and organizational ecology studies (Hannan and Freeman, 1989) concur, indicating that the level of firm resources, often operationalized as firm's size, is related to higher organizational inertia, higher formalization and standardization, and structural rigidity. Christensen, Anthony and Roth (2004) suggest that, as they grow, organizations increasingly rely on processes that over time become embedded in hard-to-change organizational routines and values. These conditions prevent large, well-endowed firms from being early adopters of technology. The argument for a negative relationship suggests that resource-rich organizations are more likely to be early adopters of technology because of slack resources (Nohria and Gulati, 1996), formal innovation management practices (Van de Ven, 1986), or because their resources translate in higher absorptive capacity (Cohen and Levinthal, 1990).

MARKET EVOLUTION
AND THE TIME TO ADOPTION OF NEW TECHNOLOGIES

As shown above, in the extant literature, several antecedents have been linked to a firm's responsiveness to new technologies yet very little research has been carried out to link technology adoption decision to the specific stage of an industry and market evolution. Most of the existing studies on adoption timing of innovations assume that factors affecting the time to adoption are constant over time and are not influenced by the specific market dynamics at any point of time. In doing this, existing technology adoption literature overlooks, for instance, that as market evolves decision makers may take a different technology adoption timing decision. This is surprising given that market evolution is an important competitive force and that several researchers have studied its impact on competitive mechanisms effectiveness and firm's performance. For instance, Agarwal, Sarkar and Echambadi (2002) study 33 product innovations and find that an industry's growth pattern has a significant "conditioning effect" on the relationship between entry timing and firm survival. Suarez and Lanzolla (2007) show that market evolution has a strong impact on the effectiveness of several competitive mechanisms including resource pre-emption, switching cost setting and technological capability building. Bohlmann, Mitra and Golder (2002) suggest that first mover advantages are more sustainable in markets where horizontal (as opposed to quality-based) product differentiation, predominates – a situation more common in slow-growing markets (Utterback, 1994). Some research studies have shown that market evolutionary dynamics affect firms' product and process strategies (Utterback and Abernathy, 1975; Utterback and Suarez, 1993; Klepper, 1996, 1997; Dean, 1950; Levitt, 1965; Barry, 1994), resource allocation (Calantone, Garcia and Droge, 2003) and pricing policy (Abell and Hammond, 1979). We argue that technology adoption literature should incorporate more explicitly market evolutionary dynamics if we are to improve on its predictive power. Below, we seek to formally bring market evolution into technology adoption literature and we elaborate the interplay between market evolutionary stage and the antecedents of a firm's technology adoption timing decision. We define time to adoption of a new technology, or time to technology adoption, as the time that a company takes to incorporate in its products a new technology launched by a competitor. Market evolution in a given product category, is often measured in sales, household penetration, or number of new adopters. In what follows we refer to market evolution in terms of product diffusion and we use market evolution and product diffusion in an interchangeable way.

Market evolution and time to adoption of new technologies

Market evolution of consumer and industrial product innovations is generally characterized by an initial period of slow growth immediately after first product commercialization that is eventually followed by a sharp increase or "sales takeoff" (Mahajan, Muller and Bass, 1990; Rogers, 1995; Golder and Tellis, 1997; Klepper, 1997) and a later phase of market maturity and decline (e.g. Mahajan, Muller and Bass, 1990). Market evolution in a given product category is influenced by several market-related dynamics: e.g. technological and consumer uncertainty, changes in consumer tastes or preferences (Moore, 1999), emergence of new regulations, degree of market fragmentation, and consumer learning (Agarwal and Bayus, 2002). When product market penetration is low, during the early stage of market evolution, the uncertainty around product technology and consumer preferences tend to be higher (Levitt, 1965; Anderson and Zeithaml, 1984; Klepper, 1996; Hill and Jones, 1998; Lee and Veloso, 2008). Various authors suggest that the uncertainty about the industry evolution can affect the firm's propensity to adopt product innovations (Fidler and Johnson, 1984). High uncertainty about the industry evolution is often associated with higher resistance to adoption of innovations within firms (Fidler and Johnson, 1984) and is therefore likely to trigger longer times to technology adoption.

As a product becomes more diffused in an industry, consumer's knowledge about the product performance and technologies is higher and then it is easier for consumers to shift from a brand to another (O'Shaughnessy, 1989; Winer, 2007). The consumer behavior literature unfolds several mechanisms through which consumers may become more aware of product features and, ultimately, of their own preferences. These mechanisms include (Gregan-Paxton and Rodder John, 1997): exposures to external information sources, such as advertising and product experience, and processes of internal knowledge transfer from familiar to novel domains. Overall, experience with products enables consumers to understand better and faster the link between specific features and the benefits provided by those features (Hoeffler, 2003). As learning takes place, an assortment of determinant attributes and a growing number of objects are associated with the "evoked set" (Howard 1963). In this sense, the perceptual map of the individual grows in both complexity and clarity (Pessemier 1978). Product choice criteria literature for technology-based products (O'Shaughnessy, 1989; Gregan-paxton, Hoeffler and Zhao, 2005; Winer, 2007) argues that consumer choices for technology-based products tend to be "lexicographic" as opposed to "compensatory" (Hansen, Christensen and Lundsteen, 2007) and that in turn when consumers have enough information and knowledge on the product, a brand can be rejected just for the absence of the latest product technology. It follows that when customers know more about a product, because the product is more diffused, companies may have to be quicker in adopting a new technology launched by a competitor to avoid that their products fall out of the "evoked" set. Moreover, when market is more evolved and uncertainty about industry evolution is lower, usually there is smaller asymmetry of information among incumbents (Klepper, 1996). This may make it possible for firms to more easily predict further product diffusion and competitor behaviors (Lieberman and Asaba, 2006) hence easing their investment decisions. Faced with a choice, firms therefore often choose to match the behavior of rivals as soon as possible in an effort to ease the intensity of competition and keep competitive parity (Lieberman and Asaba, 2006). Combining the arguments above, we posit:

Hypothesis 1: All the other things being equal, firm time to technology adoption is inversely related to product diffusion in a market

Functionality-defining and substitute technologies

Above we have elaborated on time to technology adoption, without considering the type of new technology that has been introduced. Yet, in a given market, different technologies may emerge. We define functionality-defining technologies those which enable brand new functionalities in a product. We define substitute technology a technology which performs the same or similar function as an existing functionality-defining technology by different means (Porter, 1980). For instance, in the mobile telephone industry, infrared was a functionality-defining technology enabling mobile phone to mobile phone connectivity. Bluetooth was a substitute to the extant it enables to perform the same functionality using a different technology. In other words the substitute technology offers a new way of performing a function already performed by an existing product technology (Henderson and Richard, 1958).

Senior managers tend to be responsible for the decision to adopt a new technology because adoption requires the approval of significant capital expenditures (e.g. ERP, CRM) and sometimes even a strategy change that can only be endorsed by an organization's senior level. Their decisions to adopt a new technology tend to be influenced by adopter bandwagons and are typically based on rational efficiency (Westphal, Gulati, and Shortell 1997), the "symbolic value" of the new technology (DiMaggio and Powell, 1983; Meyer and Rowan, 1977), "managerial improvisation" (Orlikowski, 1996), call options (Miller and Folta, 2002), or simply "me too" behavior (Strang and Macy, 2001).

Compared to functionality-defining technology, substitute technologies may be riskier for firms that want to adopt them (Black, Carlile and Repenning, 2004; Rogers and Adhikayra, 1979) and organizational uncertainty in the choice of adopting new substitute technologies has been documented both in growing and mature industries (Mansfield, 1961; Rosenberg, 1972; Wilton and Pessemier, 1981; Rohlfs, 2003; Smith, 2005; Lin, Huang, Cheng and Lin, 2007). Regardless of the market evolutionary stage in which substitute technologies are introduced, for firms is more difficult to forecast if a substitute technology will be perceived by consumers has effectively better than the existing, functionality-defining, technology performing the same function. This makes the level of uncertainty associated to the new substitute technology greater than that associated to the existing functionality-defining, technology. To reduce this "uncertainty gap" between the two technologies performing the same function firms should educate potential customers in advance about the usefulness of the new substitute technology with respect to the technology currently in use. However transfer of knowledge to consumers about the advantage of the substitute over the existing technology is usually more difficult to produce when a technology is not yet introduced (Wilton and Pessemier, 1981; Kalish, 1985), especially for firms that position themselves in niche of the market. We posit:

> ***Hypothesis 2: Regardless of levels of product diffusion, firm time to adoption of substitute technologies is longer than firm time to adoption of functionality-defining technologies.***

Market leader and other incumbents

When an industry is in its infancy and products are not yet widely diffused, market leaders have been widely considered as strong influencer in a market. In this phase, as previously argued, uncertainty about industry and consumer evolution is high and firms have asymmetric information about competitive dynamics (Anderson and Paine, 1975). Managers have limited prior experience about the likely output of alternative strategic actions and are likely to be more open to external sources of information (Lieberman and Asaba, 2006). In this light, Bikhchandani, Hirshleifer and Welch (1998) argue that the actions of the leading firm are considered more strongly than others, because the former is perceived to have better information and leaders are perceived as the ones less likely to fail (Knickerbocker, 1973). In this light, managers may follow the leader to minimize risks (Knickerbocker 1973), particularly if they are risk adverse (Head, Mayer, and Ries 2002) or if they are small firms that need to obtain legitimacy within the industry (Fligstein, 1985). It follows from these arguments that companies will also be quicker in adopting new technologies launched by the market leader than technologies launched by other incumbents. When the product is more diffused in an industry and the initial uncertainty decreases, organizational competencies mature, and firms look for a specific position in the market (Klepper, 1996, 1997). In fact, resource partitioning theory (Carroll, 1985; Carroll, Dobrev and Swaminathan, 2002) posits that over the industry life cycle usually the market leader targets its product on mass market and leaves niches to other competitors (Prescott and Visscher, 1977; Bonanno, 1987). We argue that over the product diffusion life cycle, imitative dynamics shifts from the market leader to other niche players, which need to differentiate their strategy with respect to the one of the market leader, customizing the product for specific targets of consumers. This in turn implies that the gap between the time to adoption of product technologies introduced by the market leader and the time to adoption of product technologies introduced by the other incumbents diminishes the more the product is diffused in the market. We posit:

Hypothesis 3a: Regardless of levels of product diffusion, the time to adoption of product technologies introduced by the market leader is shorter than the time to adoption of product technologies introduced by other industry members.

Hypothesis 3b: As product diffusion increases, the time to adoption of product technologies introduced by the market leader and the time to adoption of product technologies introduced by other industry members tend to converge.

METHODS

Sample

We test our hypotheses in the context of the UK mobile phone industry, from 1997 to 2008 and we study adoption patterns of 22 technologies introduced by the 13 mobile handset players operating in the UK (Nokia, Motorola, Samsung, LG, Ericsson, Sony, Sony-Ericsson, Siemens, Philips, Panasonic, Sagem, NEC, Alcatel) (please refer to Table 1 for the list of technologies and innovators). Overall, 566 new mobile phones were introduced in this period (Table 2) and Nokia was the clear market leader across the whole period. Over the 1997-2008 time period, mobile phone market penetration in the UK passed from 12% (first quarter 1997) to 122% in first quarter 2008 (Figure 1).

Information about product technology adoption within the sampled firms were collected from monthly industry-specific magazines that report detailed product features summaries about new mobiles introduced in the UK market (*What Mobile*, *What CellPhone*, *Total Mobile*). These magazines are widely regarded as the industry standard. Information about handsets technologies and industry dynamics were also triangulated in several interviews with marketing and product managers of some of the main mobile phone manufacturers operating in the UK.[1] We excluded from our sample all smartphone devices, because these are products targeted to different consumers and implying different technologies.[2]

[1] Marketing and product managers from the companies that agreed to be interviewed include: Sony-Ericsson, LG, Samsung, Motorola and Nec.

[2] A smartphone is an electronic handheld device that integrates the functionality of a mobile phone, personal digital assistant (PDA) or other information appliance. Because there are no hard rules to distinguish smartphones from other mobiles, we collected several definitions of smartphone from different secondary sources with the aim of identifying demarcation criteria that would allow us to separate "standard" mobile phones from other handheld devices. According to most of the definitions we collected, a key feature of those products named as smartphones is their "advanced operating system", providing a graphic interface similar to the one of a desktop computer and allowing additional applications to be installed on the device. Examples of advanced operating systems for smartphone are Symbinan, BlackBerry OS, Mac OS, Microsoft Windows Mobile, Linux, Palm OS, which among the advanced operating systems, count for more than 95% of the market. Information on mobile phone operating systems were collected mainly from *Gartner Dataquest*. We therefore used the variable "advanced operating system" as a demarcating criteria to exclude smartphone from our sample.

Table 1. Mobile phone technologies introduced by manufacturers in the UK market from January-97 till July-08, and the mobile phone penetration among consumers the month each product technology was introduced

Product technology	Firms introducing the technology*	Month of introduction	The UK mobile phone penetration**
-	-	jan-97***	12.05%
Voice dial	Philips	jul-97	13.40%
Composer	Ericsson	ago-97	13.40%
Infrared	Nokia	oct-97	14.29%
Games	Nokia	jan-98	15.27%
downloadable ring	Nokia	feb-98	15.27%
Email client	Nokia	mar-98	15.27%
WAP	Nokia	feb-99	25.35%
EMS	Motorola	ago-99	33.10%
Polyphonic ringtone	Panasonic	jan-00	45.76%
Recordable ring	Panasonic	jan-00	45.76%
SMS chat	Nokia	nov-00	67.49%
MP3	Samsung	dec-00	67.49%
GPRS	Motorola	mar-01	72.14%
Bluetooth	Ericsson	ago-01	77.11%
USB	Motorola	sep-01	77.11%
Color screen	Ericsson	dec-01	77.11%
MMS	Motorola	may-02	80.71%
Photocam	Nokia	ago-02	82.59%
True tone / real tone	Siemens	feb-03	85.33%
Videocam	Nec	mar-03	85.33%
UMTS	Nec	mar-03	85.33%
EDGE	Nokia	feb-04	93.56%
-	-	Jul-08***	122.36%

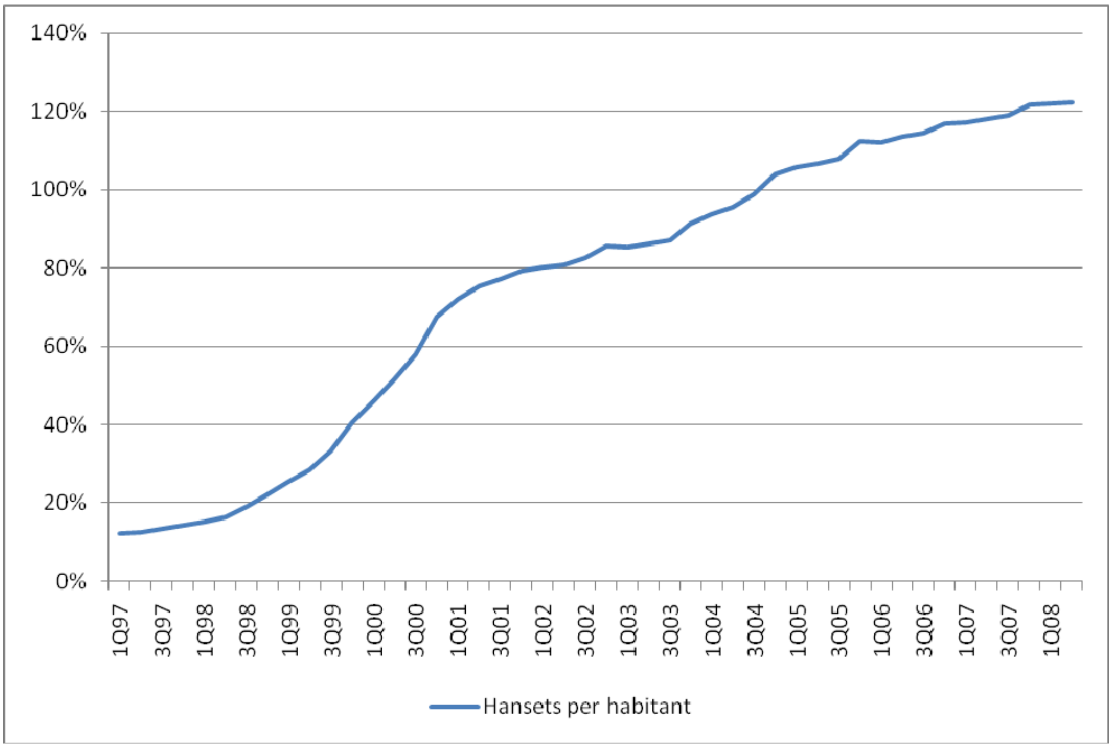
* First adopter: the first firm adopting the new product technology in its portfolio
** Handsets per habitant computed the month the technology was introduced in the UK market by the first adopter
***January-97 and July-08 represent respectively the beginning and the end of our time period

Table 2. Handset models introduced every year in the UK market

	97	98	99	00	01	02	03	04	05	06	07	1Q-2Q08
Market leader (Nokia)	3	6	4	5	4	11	10	13	12	10	5	14
TOTAL industry	28	37	32	50	43	41	60	64	66	61	46	41
Industry Mean	2.5	3.4	2.9	4.5	3.9	3.7	5.5	5.8	6.0	6.1	6.6	5.9
Industry Median	2.0	3.0	3.0	4.0	3.0	3.0	5.0	6.0	6.0	5.5	5.0	4.0
Industry S.D.	2.0	2.5	1.5	1.9	2.7	3.1	3.4	3.6	3.7	4.9	3.2	4.9
No. of players*	11	11	11	11	11	11	11	11	11	10	7	7

* Number of mobile phone manufacturers operative in the market.
Source: *What Mobile*, *What CellPhone*, *Total Mobile*.

Figure 1. Mobile phone penetration rate (handsets per habitant) in the UK market*



* 100% = 1 handset every habitant.

Measures

Dependent variable

Time to Technology Adoption (TTA). We compute this variable as the time elapsed (in months) from a new product technology introduction by the "first adopter" and a company's adoption in its products (Damanpour and Gopalakrishnan, 2001).[3] We define first adopter the first firm that adopts the new product technology in its portfolio. For instance, if the firm *i* adopts the product technology *k* 10 months after its introduction in the market (by the first adopter), the firm *i*'s time to adoption in terms of *k* will be equal to 10. For each product technology, the time to adoption is computed taking into account only product models introduced by those manufacturers that were operative in the market the month the technology was introduced by the first adopter. Otherwise we would get misleading results on the TTA

[3] A similar indicator has been used also in the marketing literature to express the adoption timing of a technology by consumers instead organizations (Prins and Verhoef, 2007).

for those manufacturers that adopted the technology later not because they were not fast in adopting the technology when it was introduced by the first adopter, but simply because they were not operative in the market. We compute the time to adoption of 22 new technologies introduced from January 1997 till July 2004 with the whole observation period spanning from 1997 to 2008.

Independent variables

Product Diffusion among Consumers (PDC). We measure the PDC as the number of handsets per habitant, also called mobile phone penetration rate, computed the month the technology is introduced in the market by the first adopter (Table 1). The market penetration has been widely adopted in the management and marketing literature as a measure of product diffusion among consumers and as an approximation of the industry maturity (Mahajan, Muller and Wind, 2000). Data on mobile phone penetration in the UK market were collected from the Ofcom, the UK official telecom regulatory body.

Substitute Technology. We measure this variable with a dummy, which takes value 1 for substitute technologies, 0 otherwise. We define substitute technologies as those technologies that offer a new way of performing a function already performed by an existing product technology, or "functionality-defining" technology (Henderson and Richard, 1958; Porter, 1980). Two or more mobile phone technologies may be closely substitutes but installed in the same product. For example infrared, USB and Bluetooth technologies both serve to transfer data among devices but all of them can be installed in a single mobile phone. The distinction among mobile phone "substitute" and "functionality-defining" technologies has been taken together with the product manager and the marketing manager of one of the major mobile phone manufacturers operating in the UK that were informed about the aim of the research, and agreed to be interviewed for the variable development. In particular, for the definition of the two groups of technologies we proceeds as follow: Together with the two managers we initially cluster product technologies in terms of their function from the user's point of view. In this way we identify a number of categories of technologies. For example, we consider Infrared, USB and Bluetooth under the category "connectivity": despite the three product technologies are based on different components and engineering, they perform the same function of allowing the user to transfer data from the handset to other devices. After have clustered product technologies according to their function we identify, within each category, the first product technology – "functionality-defining" – introduced to offer a certain function, and the other product technologies introduced later – "substitutes" – performing the same function of the "functionality-defining". Please refer to Table 3 which describes the sampled technologies and the related substitutes.

Technology Introduced by Market Leader (TIML). We measure this variable with a dummy, which takes value 1 for technology introduce by market leaders, 0 otherwise.

Time. We create a variable to control for the time evolution, from the introduction of the first product technology in July 1997, till the introduction of the last technology in February 2004. The variable takes value 1 for the introduction of the first product technology and increases of one unit every month.

Variables descriptive statistics are shown in Table 4.

Table 3. Technology categories description and evolution

Categories of mobile phone technologies	Functionality-Defining Technology	Substitute Technologies
Phone call: *Technology helping the user to make a phone call without entering a number manually or choosing it from the phone book, but just speaking the name the user want to call.*	Voice dial	-
Ring tone customization: *Technologies allowing the user to customize the handset ringtone.*	Composer	Downloadable ringtone, Recordable ringtone
Connectivity: *Technologies allowing the user to transfer data from the handset to other devices.*	Infrared	Bluetooth, USB
Games: *Games application installed on the handset.*	Games	-
Email client: *Technology allowing the user to check the email.*	Email client	-
WAP: *(Wireless Application Protocol) Technology designed for sending simplified Web pages to wireless devices.*	WAP	-
Message + pics/image/animation: *Telephone messaging systems that allows sending messages that include multimedia objects (images, audio, video, rich text) and not just text as in Short Message Service (SMS).*	EMS	MMS
Advanced Ring tone sound: *Technologies allowing the ringtone to consist in several notes or sounds at the time.*	Polyphonic ringtone	True tone / real tone
Instant messaging: *Technology that lets the user have a chat session similar to a chat on the Internet.*	SMS chat	-
Music: *Technology allowing the user listen to music with the handset.*	MP3	-
High speed data transfer: *Technologies allowing the user to use internet-based services and high network capacity.*	GPRS	UMTS, EDGE
Color display: *Technology allowing the handset to have more than 4 colors.*	Color screen	-
Photo: *Technology allowing the user to take pictures with the handset.*	Photocam	-
Video: *Technology allowing the user to record video with the handset.*	Videocam	-

Table 4. Descriptive statistics

	Variable	Obs.	Mean	S.d	Min	Max	1	2	3	4	5
1	**Time to Technology Adoption (TTA)**	187	25.29	17.32	2	90	1				
2	**Product Diffusion among Consumers (PDC)**	187	52	29.94	13.4	93.5	-0.402†	1			
3	**Technology Introduced by the Market Leader (TIML)**	187	0.34	0.37	0	1	0.027	-0.393†	1		
4	**Substitute Technology**	187	0.35	0.47	0	1	0.037	0.387†	-0.186†	1	
5	**Time**	187	35.89	24.71	1	80	-0.407†	0.982†	-0.329†	0.405†	1

Significance: †$p < 0.10$

RESULTS

We estimate our models by robust fixed effects regression, using STATA version 10.0. Fixed effects regression allows us to control for omitted variables in the panel data, assuming omitted variables vary across entities but do not change over time (Sock and Watson, 2007). In our case the fixed effects regression model has 13 firm dummy variables, absorbing the influence of all omitted variables that differ from one firm to the other, but that are constant over time. To test our hypotheses, we first regress the TTA on Product Diffusion, Technology Introduced by the Market Leader and Substitute Technology. Next, we compute the two-way interaction between Product Diffusion and Technology Introduced by the Market Leader, and the two-way interaction between Product Diffusion and Substitute Technology. We graph each interaction following procedures set forth by Aiken and West (1991).

Table 5. Model Estimation

Dependent variable: TTA	**Model 1**	**Model 2**
Product Diffusion among Consumers (PDC)	-0.325*** (-8.30)	-0.393*** (-6.75)
Technology Introduced by the Market Leader (TIML)	-5.100* (-2.16)	-14.251** (-2.87)
Substitute Technology	7.380*** (3.74)	13.135** (3.04)
PDC x TIML	-	0.194* (2.57)
PDC x Substitute Technology	-	-0.071 (-1.11)
Constant	41.399*** (14.11)	45.370*** (13.93)
Firms dummies (fixed effect)	*included*	*included*
Number of observations	187	187
R-sq	0.222	0.245

Significance: ***p < 0.001; ** p < 0.01; *p < 0.05; †p < 0.10; t-statistic in parenthesis.

Figure 2. Interaction effect of Product Diffusion among Consumers (PDC) with Substitute Technologies on Time to Technology Adoption

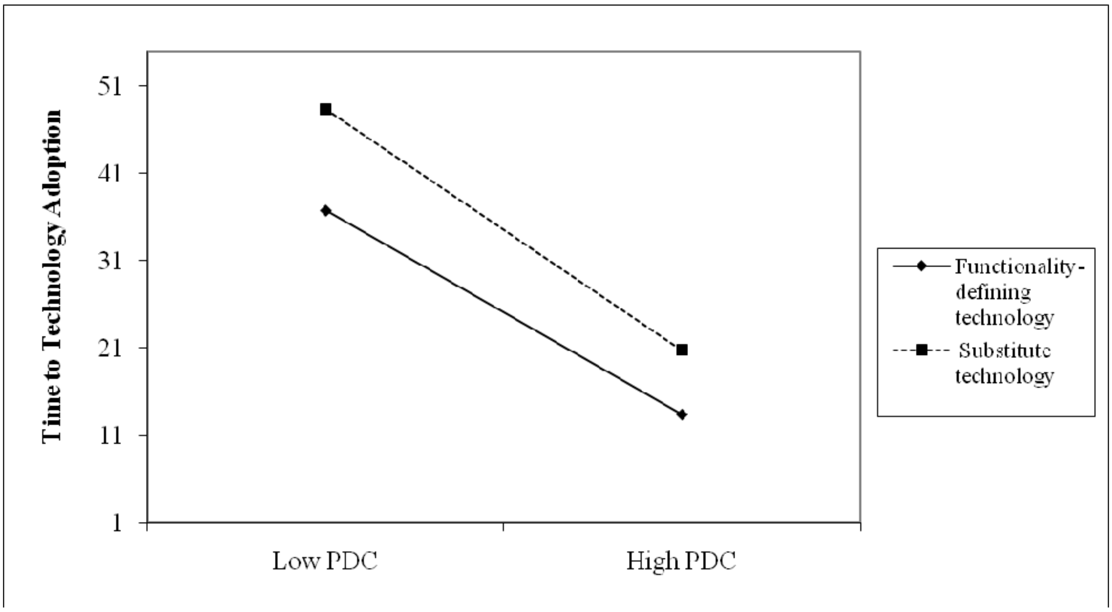
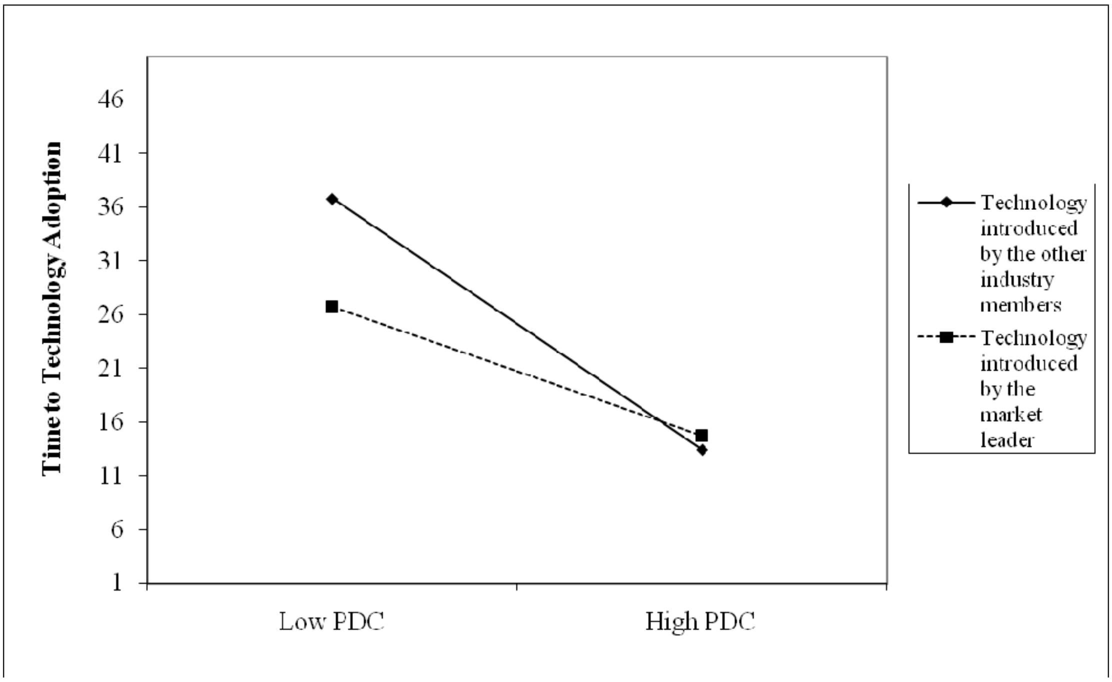


Figure 3. Interaction effect of Product Diffusion among Consumers (PDC) with Technology Introduced by the Market Leader on Time to Technology Adoption



As shown in Table 4, the variables Time and Product Diffusion among Consumers are highly correlated. That is because Product Diffusion among Consumers is always increasing over time. Therefore, in order to avoid multicollinearity we remove the variable Time from the regression model, and we use the variable Product Diffusion among Consumers as expression of both product diffusion and time evolution.

In Model 1 (Table 5) we include all the first-order effects of Product Diffusion, Technology Introduced by the Market Leader, and substitute technology. In Model 2 we include the two-way interactions. Hypothesis 1 posits that the higher the Product Diffusion, the shorter the TTA by industry competitors. As shown in Model 1, the relationship between Product Diffusion and TTA ($\beta = -.32$, $p < .001$) is significant and negative. Hypothesis 1 is therefore supported. Hypothesis 2 states that the time to adoption of substitute technologies is longer than the time to adoption of functionality-defining technologies, for any given level of Product Diffusion among Consumers. As shown in Model 1, the coefficient of the dummy substitute technology ($\beta = 7.38$, $p < .001$) is significant and positive, thus showing that the time to adoption of substitute technologies is longer than the time of adoption of "functionality-defining" technologies. We computed the interaction between Product Diffusion and Substitute Technologies in order to check if before or after a certain level of product diffusion rate, the time to adoption of "functionality-defining" technologies is longer than that of substitute technologies. As shown in Model 2 the interaction between Product Diffusion among Consumers and Substitute Technologies is not significant while the coefficient of substitute technologies is still positive and significant ($\beta = 13.13$, $p < .01$). The fact that the interaction term is not significant means that the slopes for the two groups of technologies are not significantly different (Lomax, 2007). Using the procedure outlined by Aiken and West (1991), we plotted the high and low levels of each variable (Figure 2) and we interpreted the findings following procedures set forth by Lomax (2007) and Jaccard and

Turrisi (2003). Figure 2 shows that the slopes of substitute and "functionality-defining" technologies are nearly parallel, meaning that, given the same level of Product Diffusion, the time to adoption of Substitute Technologies exceeds the time to technology adoption of functionality-defining technologies by roughly the same "amount". In other words, across the considered time period, there is a almost constant added time to adoption of Substitute Technologies over functionality-defining ones, regardless the level of the Product Diffusion. This result is consistent with the prediction of our Hypothesis 2.

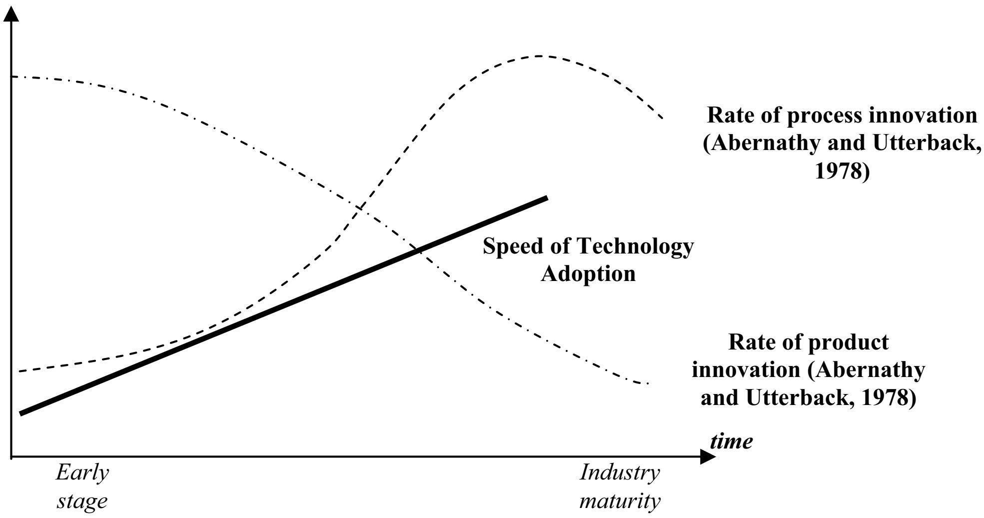
Hypothesis 3a posits that the time to adoption of product technologies introduced by the market leader is shorter than the time to adoption of product technologies introduced by other incumbents, and Hypothesis 3b stated that the gap between the two diminishes as the PDC increases. As shown in Model 2 of Table 5 the interaction between Product Diffusion among Consumers and Technology Introduced by the Market Leader ($\beta = .19$, $p < .05$) is significant and positive. To asses whether the form of the interaction is consistent with our hypothesis we plot the significant interaction according to standard procedures (Aiken and West, 1991). The graph of this interaction (Figure 3) shows that technologies introduced by the market leader are adopted much quicker when product diffusion is low, but the gap between the time to adoption of new product technologies brought forward by market leader and the time to adoption of new product technologies brought forward by the other incumbents decreases as Product Diffusion among Customers increases. Yet, Figure 3 also shows that for high values of product Diffusion, time to adoption of new product technologies brought forward by market leader becomes slightly longer than the time to adoption of new product technologies brought forward by the other incumbents. Hypotheses 3a and 3b are partially supported.

DISCUSSION

In this paper we have contributed to technology adoption strategy literature into two important ways. First, we have moved this literature a step closer to formally incorporating the market evolution-dependent nature of technology adoption decisions. We find that time to technology adoption decreases as product diffusion increases and we provide rationale for this occurrence. Second, we have carried out one of the few "multiple innovations – multiple organizations" study and we show, theoretically and empirically, that the time to adoption for functionality defining technologies and for technologies brought forward by market leader is shorter than the time to adoption of substitute technologies and technologies brought forward by non market leader, respectively. We also find that as product diffusion increases, the gap between the time to adoption of technology brought forward by market leader and the time to adoption of technology brought forward by other incumbents quickly diminishes and at a certain point the latter become shorter than the former.

Our findings allow us to complement the Abernathy and Utterback's (1978) model and spell out some potential misleading implications that may be derived from its application. Abernathy and Utterback's (1978) argue that, when a new product is introduced in a market and, arguably, consumer demand and preferences are not yet clear, firms tend to pay more attention to product innovation than to process innovation. Conversely, as a product becomes more diffused and consumer demands less uncertain, firms are predicted to concentrate their efforts on process innovation, as opposed to product innovation. Overall, Abernathy and Utterback's model (1978) suggests a decreasing rate of product innovation as the industry matures. Yet, companies may innovate their products and adopt a new technology not only for competitive differentiation – as implicitly assumed in the Abernathy Utterback' Model - but also to maintain "competitive parity" (Lieberman and Asaba, 2006) and avoid that customers switch to competitors' products (O'Shaughnessy, 1989; Winer, 2007). In this paper we have shown that actually the time to adoption, inversely proportional to speed of adoption, decreases (increases) the more the product is diffused. Figure 4 shows how the Abernathy-Utterback's model should be complemented to incorporate the results of our theory.

Figure 4. The paradox of product innovation



Managerial Implications

This study has several interesting competitive implications. Companies can use product market penetration as a proxy to understand competitive dynamics and develop projections on the imitative patterns within an industry. On the one hand, this is particularly important when companies want to protect their innovation from imitation. On the other hand, this is important to develop some hints on when to race to imitate competitors' innovations in order to maintain competitive parity. For example, our results suggests that "time-based" imitation processes tend to be particularly rapid the higher the product market penetration. This means that when the product is well diffused among consumers, the firm's innovation will be imitated quickly because the competitors' search for competitive parity. In this environment the innovator (the first adopter), in order not to erode its short-term first mover advantage and gain a return on its investment in the long run, may follow two strategies: 1) protect the product technology with patents, but this may be an effective strategy only in few technology-based industries, or 2) be able to continuously improve the product technology performance in order to be always one step forward the competitors. A second important point for managers to recognize is then the role of the market leader as catalyst of the other industry members in driving innovation strategies. Our results suggest that a source of competitive advantage for organizations is the ability to find a trade off between follow-the-leader and market-niche strategies, especially when the product is still poorly diffused among consumers. In other words, when the product is not yet largely diffused, our advice is to start building solid competitive position in market niches, but at the same time follow the leader for those innovations that entail higher uncertainty and risk. In fact being the leader in a market niche is a worthy goal, but being a follower also has its advantages (Lieberman and Montgomery, 1998). A strategic balance between the two alternatives might help the firm to react more efficiently to threats and opportunities produced by new product innovations.

Finally, it is important to note that if the firms' time to technology adoption changes over market evolution, there are serious implications for the firm's supply chain relationships. It is obvious that, in order to accelerate the adoption process the firm have to rely on the efficiency of its suppliers for the manufacturing and delivery of components, and on the efficiency of the R&D department for the "conformation" of the technology to the firm's product line (Stalk, 1988; Stalk and Hout, 1990). For example, at the beginning of the 2000s, the influx of new competition in the UK mobile phone industry pushed down the average selling price of mobile phones, hitting the margins of the established manufacturers. Capabilities required to be competitive for incumbents increased, since manufacturers were forced from one side to constantly introduce new advanced product technologies in order to differentiate their products, and from the other side to adopt successful technologies introduced by competitors in order to maintain competitive-parity. As a consequence of increasingly aggressive time-based imitation processes, vertical and horizontal disintegrations in the industry increased as well. Where manufacturers were able to internalize all of their design, production and technology development in the 1980s and 1990s, the changing nature of products made this business model impossible over the 2000s. As also suggested by some authors (Abernathy and Utterback, 1978) vertical integration is the most likely business model in the initial stage of the industry life cycle, where competition is not intense. But the stronger the rivalry among competitors, the higher the need to outsource activities, in order to focus on the core business and exploit the specialized competences of partners upstream (suppliers) and downstream (distributors) of the supply-chain.

Table 6 shows some data on the competitive performance of the companies involved in this analysis. A pattern seems to emerge: the companies that have achieved the highest market share over time are the ones that have had shorter average time to technology adoption.

Table 6. Number of introduced product technologies, TTA and performance of each firm

Firm	No. of functionality -defining technologies introduced by the firm	No. of substitute technologies introduced by the firm	Firm's average TTA in months – *ordered from the lower to the higher TTA* (S.d)	Average position of the firm in the order of technology adoption* (S.d)	UK Market share in 1998 (ranking)	UK Market share in 2007 (ranking)
Nokia	6	2	13.15 (12.46)	2.62 (1.80)	35.3% ***(1)***	31.5% ***(1)***
Sony-Ericsson	0	0	14.57 (8.75)	4.43 (1.40)	11.2% ** ***(not yet in)***	24.1% ***(2)***
Ericsson	2	1	16.00 (6.46)	2.67 (1.61)	10.8% ***(2)***	7.2% ** ***(joint v.)***
Motorola	2	2	19.00 (11.91)	3.91 (2.35)	9.2% ***(4)***	8.3% ***(4)***
Siemens	0	1	19.26 (11.45)	4.55 (2.16)	10.6% ***(3)***	0% ** ***(out)***
Sony	0	0	20.13 (11.68)	4.50 (2.20)	3.1% ***(6)***	2.3% ** ***(joint v.)***
LG	0	0	20.25 (7.85)	5.50 (1.73)	1% ** ***(not yet in)***	5% ***(5)***
Panasonic	1	1	27.18 (18.26)	6.21 (3.10)	2.9% ***(7)***	0% ** ***(out)***
Alcatel	0	0	27.32 (16.75)	7.05 (3.32)	1.4% ***(10)***	3% ***(6)***
Samsung	1	0	27.52 (14.72)	5.91 (2.41)	8% ***(5)***	22.9% ***(3)***
Philips	1	0	30.60 (18.42)	6.75 (2.79)	2.8% ***(8)***	0% ** ***(out)***
Sagem	0	0	33.85 (18.68)	7.10 (2.01)	1.1% ***(11)***	1.2% ***(7)***
Nec	1	1	39.50 (25.96)	7.33 (3.12)	2% ***(9)***	0% ** ***(out)***
TOT	*14*	*8*				
Mean			*23.72*	*5.27*		
Median			*20.25*	*5.50*	*3.1%*	*8.3%*

* e.g. 1 = on average the firm was the first adopter, 10 = on average the firm was the tenth adopter.

** Some firms entered the market after 1998, others exited before 2007. For these firms we report the market share of the year they entered in the UK market, and we indicate with 0% in case they stopped their operations before 2007. Here below some detail about these firms:

Ericsson and Sony stopped to introduce new models with their own brand in 2002. The same year they made a joint-venture and started introducing new models with the brand Sony-Ericsson;

Siemens stopped to introduce new models in the UK market in mid-2006;

LG started introducing products in the UK market from the end of 2003;

Panasonic stopped to introduce new models in the UK market at the beginning of 2006;

Philips stopped to introduce new models in the UK market in mid-2005;

Nec stopped to introduce new models in the UK market at the beginning of 2006.

Source: data on market share were collected from Mintel, firms' newsletters and interviews with managers.

Limitations and Suggestions for Future Research

Some limitations to the current study suggest opportunities for future research. First, although our paper follow a "multiple innovations – multiple organizations" approach (by testing the adoption timing in terms of several items introduced by multiple firms), we do not consider the evolution of product technologies over time (e.g. increasing number of colors of the display, increasing number of pixel of the camera), as also the different "competitive power" that each product technology may confer to the product (e.g. consumers might argue that the attribute photo-camera makes the handset much more attractive than the attribute voice dial). However also these might be factors slowing down or speeding up the time to technology adoption by organizations. Therefore future research might propose, for example, a number of indicators expressing the level of technological improvements (competitive power) of each product technology, and test if technological improvements (competitive power) and adoption timing are positively or negatively related. Second, this is a study based on one industry and one country. More studies cross-industry and cross-country should be done to ensure generalizability. Third we do not distinguish between those manufacturers that have in-house or exogenous R&D departments. Over years handset manufacturers have decomposed their supply-chain, initially by outsourcing assembling activities, later also chip manufacturing, and more recently even the design of the entire handset prototype. Different supply-chain business models can clearly entail a different impact on the firm's ability to introduce innovations or adopt innovations introduced by others. Future research could control for the existence of in-house or exogenous R&D departments, and explore the relationship between firms' supply-chain business models and TTA. Finally, other ways of clustering product technologies might bring to further interesting empirical evidence, supporting or contradicting our findings.

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Keeping Both Eyes on the Competition: Strategic Adjustment to Multiple Targets in The UK Mobile Phone Industry

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Abstract

Competition often leads firms to adjust their actions towards common industry benchmarks, or reference targets, in a process that Snow and Hambrick (1980) call "strategic adjustment". Research provides multiple explanations of the origins and dynamics of strategic adjustment, but studies have essentially examined the influence of only one or the other of the following two sources of industry targets: a) firms select targets based on the collective strategic decisions other firms in the industry; and b) firms select targets based on the strategic decisions of the industry leader. In this paper we explore how both these sources of target setting exercise influence on strategic adjustment. We suggest that evidence of influence by both these sources can be found by looking at the product portfolio strategies of firms that operate in industries where competitive positions depend on periodically launching models with multiple features and functionalities. We argue that firms will use the product decisions of both collective industry product decisions and the industry leader when deciding which features and functionalities to incorporate in their new models. We test this proposition using data on 627 mobile phone models launched in the UK by fourteen firms from 1997 to 2008.

Key words: multiple benchmarks, strategic adjustment, product decisions, mobile phones

INTRODUCTION

Benchmarking, the continuous measurement of products and practices against industry rivals, is a widely practiced management tool (Elnathan and Kim, 1995). Strategy research argues that whenever firms use the behavior of their rivals as a benchmark for strategy development, or align their strategy with that of their competitors, there is a corresponding tendency for products, business methods, and by extension market positions, to become increasingly similar. A number of theories have advanced explanations for this process. Institutional theory (DiMaggio and Powell, 1983; Haveman, 1993), and population ecology (Hannan and Freeman, 1977), argue that a search for legitimacy leads firms to emulate the strategies of competitors. Imitation theories (Bikhchandani, Hirshleifer and Welch, 1992, 1998) describe how firms emulate the strategies of competitors with stronger performance (or perceived to have better information) (Lieberman and Asaba, 2006) by imitating their practices. The literature on diffusion of innovation argues that technologies spread as increasing number of firms prove their worth, (Loch and Huberman, 1999; Beise, 2004), as they are widely adopted by the other industry members (Abrahamson and Rosenkopf, 1993), or once they acquire high visibility (O'Neill, Pouder and Buchholtz, 1998).

Common to all these theories is the assumption that firms dynamically adjust their behaviors to a predetermined target, a process that Snow and Hambrick (1980) have called "strategic adjustment". Research has provided multiple explanations for the origins and dynamics of strategic adjustment (Snow and Hambrick, 1980), but studies have essentially examined the influence of only one or the other of the following two external sources of industry targets: a) firms select targets based on the collective strategic decisions of the firms in the industry (Lev, 1969; Frecka and Lee, 1983; Fiegenbaum and Thomas, 1995; Greve, 1998); and b) firms select targets based on the strategic decisions of the industry leader (Haveman, 1993).

In this paper, by contrast, we explore how both sources of target setting influence strategic adjustment. We do this by analyzing the product portfolio strategies of firms that operate in industries where competitive position depends on the introduction into the market of new models with multiple 'product technologies': technologically innovative product features and functionalities (Gill, 2008). We argue that when selecting which product technologies should be included in their new designs, firms will benchmark against both collective industry and the market leader product decisions in their own decision-making. We further argue that firms will benchmark differently when adopting product technologies that represent incremental as opposed to radical innovations, with a preference for using collective industry product decisions when benchmarking incremental innovations, and the market leader when considering radical innovations.

The paper is structured as follows. First we provide a review of the theoretical and empirical literature on the issue of strategic adjustment of firms' behaviors towards common targets. Second we highlight the gap in the existing literature on strategic adjustment, and develop our hypotheses. Then we discuss our database of 627 mobile phone models launched in the UK by fourteen companies from 1997 to 2008. Next we describe the empirical model we use to test our hypotheses and we present our empirical findings. We show that firms adjust their strategic behavior towards two common targets: the collective product decisions of the industry members and the market leader's product decisions. We also show that firms use a single source, the market leader, as a benchmark when adopting radical product innovations, and mix two sources, the industry leader and collective industry behavior, when adopting incremental product innovations. Finally, we close the paper with the main conclusions and implications for research and practice.

LITERATURE REVIEW AND HYPOTHESES

Theories of Strategic Adjustment

Strategy scholars have defined the process of "strategic adjustment" as a dynamic orientation of firms' behavior towards common industry benchmarks, also called 'reference targets 'or 'reference points' (Lev, 1969; Snow and Hambrick, 1980; Huff, Huff and Thomas, 1992; Fiegenbaum and Thomas, 1995). The idea of adjustment of firm's behavior towards common industry benchmarks is intrinsic to many theories in management and strategy. Table 1 provides an overview of these theoretical perspectives. Several of these perspectives are worth highlighting. For example, Porter (1980) applies industrial organization paradigm to show how firms adjust their strategy to industry structure, and how, as a result of firm actions, industry structure evolves in such a way as to increasingly constrain firms towards similar strategies. Imitation theories (Bikhchndani, Hirshleifer and Welch, 1992, 1998) also agree that firms monitor the behavior of best performers in order to imitate their actions over time, thereby increasing the tendency towards adjustment (Elnathan and Kim, 1995; Lieberman and Asaba, 2006). Institutional theory (DiMaggio and Powell, 1983) likewise makes a similar prediction, arguing that environmental "isomorphism" makes organizations increasingly similar to each other: many organizational policies and practices are adopted because legitimate organizations serve as models for others that imitate them (Haveman, 1992).

Diffusion theories of innovation also indicate that convergence of strategies may arise as innovations spread through society as the early adopters select the technology first, and are then followed by the majority of their competitors, until a technology or innovation is widely adopted (Rogers, 1962). According to this perspective, firms orient their strategic behavior towards firms that adopt demonstrably better performing technology (Loch and Huberman, 1999; Beise, 2004), tend to adopt technologies that are widely in use in their industry (Abrahamson and Rosenkopf, 1993), or focus their adoption on technologies that have high visibility (O'Neill, Pouder and Buchholtz, 1998).

Other scholars, however, argue that the decision to adjust the strategic behavior towards an industry benchmark is not firm specific. For example, according to population ecology (Hannan and Freeman, 1977) firms obtain legitimacy (as a set of constitutive beliefs) because of a selection imposed by the environment. It is therefore the environment, and the need to properly respond to the environment, that determines the adjustment of the firm's action towards that of the other industry peers.

Table 1. Different perspectives on the "adjustment of firms' behavior towards industry benchmarks"

Theory	Selected references	Benchmarks (or reference targets)	Adjustment process
Industrial economics (strategic adaptation, strategic positioning)	Porter (1980); Schendel and Hofer (1979); Snow and Hambrick (1980); Quinn (1980); Kotler and Amstrong (1996).	The industry structure; competitors; needs and demands of the market	Managers scan the relevant environment for opportunities and threats, formulate strategic responses, and adjust strategy and processes accordingly.
Imitation (information-based; rivalry-based)	Lieberman, Asaba (2006); Bikhchandani, Hirshleifer and Welch (1992, 1998).	The market leader; the fashion leader; the best performer	Firms follow the strategic behavior of firms, 1) that are perceived as having superior information, 2) showing better performance.
Institutional theory	DiMaggio and Powell (1983); Haveman (1993)	Firms belonging to the same industry; the environment	Firms seek to achieve conformity through imitation (mimetic isomorphism). Organizations change over time to become more similar to other organizations in their environment.
Diffusion of innovation	Rogers (1962); Abrahamson and Rosenkopf (1993)	Firms that adopt a demonstrably successful technology	Innovations spread through society, as the early adopters select the technology first, followed by the majority, until a technology or innovation is common. The technology is adopted because its efficiency or for conformity with the other adopters.
Population ecology	Hannan and Freeman (1977)	Firms belonging to the same industry; the environment	Firms obtain legitimacy (as a set of constitutive beliefs) by following the behavior of similar firms, because of a selection imposed by the environment.

Industry rivals and the market leader as industry benchmarks

In strategy research, the concept of "strategic adjustment" towards 'reference points', 'targets', or 'benchmarks' was proposed by Snow and Hambrick (1980). Following Snow and Hambrick (1980) strategy scholars have identified various sources that firms use to define targets, with two in particular receiving the bulk of attention: 1) the collective behavior of the industry rivals, and 2) the market leader's behavior.

Industry rivals as reference target. Studies of the effect of performance on organization change (Cyert and March, 1963; Greve, 1996, 2003; Mezias, Chen and Murphy, 2002) often make the assumption that the benchmark, or "aspiration level", against which the firm orients its performance is determined by the performance of similar organizations, or more generally the performance of organizations operating in the same industry. This assumption is consistent with research that suggests that the decisions of industry rivals are good indicator of current market conditions. In part, this assumption is based on the fact that competitive interaction generates constraints that force firms to adopt similar practices and play by the same rules (Porter, 1980, Quinn, 1980).

Similarly Lev (1969) and Frecka and Lee (1983) show that there is a general tendency for firms of the same industry to adjust their performance to equilibrium positions, defined in terms of the collective behavior of the industry members. This adjustment process happens when departing from equilibrium may negatively affect the firms' competitiveness. Porter (1980) pursues the same point in the strategic group literature, showing evidence that the firm orients its strategic decisions towards those firms that occupy the same strategic niche (Garcia-Pont and Nohria, 2002), or strategic group (Kumar, Thomas and Fiegenbaum, 1990). DiMaggio and Powell (1983) go one step further and argue that in competitive contexts in which organizations confront high ambiguity, the need to establish legitimacy, as distinct from objective competitive requirements, will encourage decision makers to follow the example of other firms. This increases similarity of products and technologies, not to mention common organizational practices.

The forces that drive firms to use industry rivals to define benchmarks are therefore multiple, and in theory persuasive. However, translating this orientation into managerial action entails explicit measures or targets that are readily comprehensible. Research suggests that in practice the measure most commonly used to express the collective decisions of competitors is the industry mean. Studies therefore provide evidence that firms adjust their operating performances (Lev, 1969; Frecka and Lee, 1983; Lehner, 2000) and their revenue growth (Audia and Brion, 2007) towards the industry mean. But we also have studies showing that firms adjust their strategic behavior more narrowly to a target within the strategic group they belong to, identified therefore as the strategic group mean (Fiegenbaum and Thomas, 1995; Greve, 1998; Rhee, Kim and Han, 2006).

Market leader as reference target. Another view in the strategy literature argues that firms are strongly influenced by high performing rivals. Haveman (1993) shows that organizations follow successful organizations into new markets. Gimeno and Chen (1998) show that a firm is more likely to increase market similarity to market-similar firms if those firms have better performance than the firm. Burns and Wholey (1993) show that there is some evidence that the actions of organizations with high visibility, prestige and profitability influence other organizations. Watson (1993) argues that firms monitor practices of only certain type of competitors, usually the leading one, and use it as benchmark to implement better strategies and improve performances (Elnathan and Kim, 1995).

Researchers, however, provide different explanations as to why firms orient their actions towards the market leader. Knickerbocker (1973) argues that firms follow the leader behavior to minimize risks. Motta (1994) gives a game theoretic explanation for this follow-the-leader behavior; Head, Mayer, and Ries (2002) suggest that it can be sustained only when managers are risk averse. Fligstein (1985) argues that smaller firms may imitate the leader in an effort to elevate their status or legitimacy, despite a lack of resources to do so successfully. Bikhchandani, Hirshleifer and Welch (1998) likewise argue that the actions of the leading firm are weighted more strongly than those of the other industry members, because the former is perceived to have better information.

Influence of industry rivals and the market leader on adoption of product technologies

Most empirical studies of the strategic adjustment process to date have addressed the influence of a single dominant benchmark on the adjustment. But to what extent can firms follow multiple benchmarks? In this paper we argue that in technology-based industries where firms offer models with multiple product technologies, firms face the choice of which product technologies should be more or less widely adopted in their product portfolio (Rogers, 1962; Katz and Shapiro, 1994; Abrahamson and Rosenkopf, 1997; Gjerde, Slotnick and Sobel, 2002). The choice, to some extent, will be based on the product strategy of the firm, which is to say the portfolio of product offerings in its entirety. For reasons of design, production, and marketing economies of scope, the firm may have a preference for certain product technologies. But this has to be considered in light of the firm's competitiveness (Zaltman, Ducan and Holbek, 1973; Gjerde, Slotnick and Sobel, 2002). To maintain their competitiveness firms therefore monitor advances in product technology in relation to the adoption decisions of other firms in the industry (Abrahamson and Rosenkopf, 1993; O'Neill, Pouder and Buchholtz, 1998; Loch and Huberman, 1999). Benchmarking against the rest of the industry gives the firm useful reference points when it comes to deciding which product technologies to adopt, when, and to what extent the product technology will be used in the product range (Abrahamson and Rosenkopf, 1993; O'Neill, Pouder and Buchholtz, 1998; Loch and Huberman, 1999). As we argued earlier, firms can derive two reference points from the behavior of other firms in the industry for use in their product planning decisions. The first is based on the collective behaviors of industry rivals, and the second on market leader's behavior. Because these decisions are made at the product portfolio level, we argue that both will influence product decisions. We therefore have the following hypothesis:

Hypothesis 1: *When adopting a given product technology firms use the collective product decisions of the industry rivals as well as the product decision of the market leader as their benchmarks.*

Strategic adjustment in the adoption of radical and incremental product innovations

New product technologies can generate additional sales, but they also carry risks (Zaltman, Ducan and Holbek, 1973). These risks are proportionate to the degree of innovation. It is commonly accepted that the degree of product innovation will vary from the incremental to the radical (Dewar and Dutton, 1986). Incremental product innovations (IPIs) refine existing products or technologies and reinforce the performance of established product designs and technologies (Ettlie, 1983). Incremental product innovations are usually minor improvements or simple adjustments in current technology that are more readily accepted by consumers. By contrast, radical product innovations (RPIs) are major transformations of existing products or technologies that can render current product designs and technologies obsolete (Chandy and Tellis, 2000). Radical product innovations therefore often translate into fundamental design that significantly changes, and at times greatly expands, the way that consumers use the product (Ettlie 1983).

Radical innovations therefore confront greater technological uncertainty during development (Raz, Shenhar and Dvir, 2002; Sorescu, Chandy and Prabhu, 2003), and higher than normal consumer adoption uncertainty when the innovation is launched (Green, Gavin and Aiman-Smith, 1995; O'Connor and McDermott, 2004). This translates into widely disparate revenue scenarios: radical innovations can generate revenue streams that more than makes up for the costs of development and marketing, but at the opposite extreme consumer resistance to pricing or unfamiliar design features can severely depress revenues (Sorescu, Chandy and Prabhu, 2003).

Radical innovations are used to gain and maintain competitive advantage, but they carry technological and consumer risks (Sorescu, Chandy and Prabhu, 2003). Timing is therefore important: Moving early increases the probability of reaping the advantages that a radical innovation may confer, but also increases the corresponding technological and consumer risks. Moving later allows the firm to benefit from the experience of the rest of the industry and thus reduces these risks, but it also decreases the likelihood that the firm will capture the advantages of the innovation (Christensen, 1997; Chandy and Tellis, 1998; McDermott, O'Connor, 2002; Thieme, Song and Calantone, 2000). Faced with this dilemma firms often respond by using the behavior of other firms to model their decision making (Lieberman and Asaba, 2006).

Research suggests that firms will focus primarily on their rivals' behavior for two reasons. First, they are inclined to believe that their rivals may possess superior information on current and future market conditions (information-based motives), and second they focus on their rivals behavior because they must respond to potential threats to their competitive position (rivalry-based motives) (Lieberman and Asaba, 2006). Information-based motives are likely to dominate when uncertainty about market conditions is high, and managers have weak "prior probabilities" about the likely success of alternative paths. In this scenario larger firms usually take the lead and smaller firms follow because the latter assume that the former are better informed (Bikhchandani, Hirshleifer and Welch, 1998). Rivalry-based motives, instead, are likely to dominate when uncertainty is low and firms have similar information. In this scenario firms make the same moves as their rivals in an effort to maintain relative position or to neutralize threatening moves (Bernheim and Whinston, 1990; Chen, Smith and Grimm, 1992).

To what extent will information-based motives and rivalry-based motives exert influence on target selection when firms make incremental as opposed to radical technological decisions? The choice, we would argue, revolves around the salience of information-based or rivalry-based motives to the new product decision. In other words, although firms scan the actions of their rivals in general, their specific interpretation of these actions will be influenced by the relevance of these actions to their own product decisions, which, we would suggest, will be different when the decision involves incremental as opposed to radical innovations.

In the case of radical innovation firms are primarily interested in what their rivals' actions says about future market conditions. This points towards information-based interpretation of rivals' actions. The question, however, is whether firms will rely on the industry leader or the collective behavior of the industry, or a combination of both, when selecting targets for making radical product decisions. In the case of radical innovations we believe that firms will generally use the behavior of the industry leader to set targets for the following reasons.

First, the leader, by virtue of greater visibility due to a greater resource endowment (e.g. financial, marketing and distribution), is usually (perceived to be) more likely to affect the technological trajectory of the industry as well as the consumer attitudes toward the product innovation than all the other industry members (Dosi, 1982; Motta, 1994; O'Neill, Pouder and Buchholtz, 1998). When uncertainty is very high, looking at the adoption process of other rivals in the industry, different from the leader, can then be risky for the firm because the leader might follow different strategies and drive the market towards previously unexpected directions (Miller and Friesen, 1984). Second, thanks to its greater resource endowment the leader is usually (perceived to be) more able to get information on the environment and in turn formulate more precise estimations of feature industry dynamics (Bikhchandani, Hirshleifer and Welch, 1998; Lieberman and Asaba, 2006). Therefore, when uncertainty is high the strategy of the leader is the most likely to be in line with the current and future consumer demand. The above line of reasoning suggests that when technological adoption processes entail high uncertainty and complexity, as in the case of radical innovations, the industry leader is likely to exert the greatest influence on the rest of industry as a technological confirmation of the innovation potential (information-based motives). This gives us the following hypothesis:

Hypothesis 2a: *Firms use the product decisions of the market leader as their benchmark when deciding on the adoption of radical product innovations.*

A different calculation confronts firms when incremental product innovations are being considered. Although incremental product innovations often have lower potential revenues for industry adopters, they are also usually technologically easier to introduce, entail fewer resource uncertainties, and face less consumer resistance than radical product innovations (Chandy and Tellis, 2000). This usually implies that firms have lower asymmetry of information about the potential return of the innovation (Haundschild and Miner, 1997; Lieberman and Asaba, 2006). In other words, firms can more easily predict the future potential of the incremental innovation and legitimate their adoption strategy without using the behavior of other competitors as a source of information on current and future market conditions. This suggests that, when adopting incremental innovations, information-based motives of rivals' actions will not play a role in the selection of targets, but for the following reasons we argue that rivalry-based motives are more likely to be more salient.

Firms usually look to incremental innovations as a way to differentiate their products relative to other offerings in the market (Barney, 1991; Hannan, Ranger-Moore, and Banaszak-Holl, 1990; Porter, 1980, 1991). Research suggests, however, that incremental differentiation is more easily imitable (Moriguchi and Lane, 1999; Asaba and Lieberman, 1999). Firms therefore do not, as a rule, look to incremental differentiation as a strategy with which to gain strategic advantage (Lieberman and Asaba, 2006). Instead, firms see incremental innovation as part of the competitive 'status-quo' (Chen, Smith and Grimm, 1992), an important strategy for maintaining their competitive parity vis-à-vis rivals. When setting targets for incremental innovation firms will therefore be interested in reference points that capture the competitive status-quo. In the strategic adjustment literature this usually means taking mean value of the aggregate adoption decisions of the firms in the industry as reference target (Lev, 1969; Frecka and Lee, 1983; Greve, 1998). This gives us the following hypothesis:

Hypothesis 2b: *Firms use the collective product decisions of industry rivals as their benchmark when deciding on the adoption of incremental product innovations.*

SAMPLE AND VARIABLES

The UK mobile phone industry

Our research site is the mobile phone industry. Over the last decade mobile phones have expanded their product technologies beyond the original purpose of providing pure telephone or voice capabilities to include an ever-growing number of product technologies (e.g.

Infrared, Bluetooth, MMS, MP3 player, camera, etc). The strategy of firms in this industry consists of regular introduction of handsets models with multiple product technologies. This allows us to test the adjustment process in terms of the distribution of product technologies across the firms' product portfolios. In the case of the UK mobile phone industry, moreover, we had the added advantage that the market leader position (that is one of the two reference targets we use), during the period 1997-2008 has been consistently occupied by Nokia.

During the past decade, the UK mobile phone industry has been very concentrated. The first 5 manufacturers keep on generating about 70-80% of the industry revenue. A similar picture emerges in other European countries.[1] New players nevertheless continue to come into the market. And some of the biggest manufacturers has been forced to merge or shut down operations, leaving space for new entrants.

Innovation has been the dominant theme of the mobile phone industry since its inception. Competition is mainly based on the continuous introduction of new product technologies. These serve to stimulate the demand towards replacement purchases given the highly penetrated nature of the market.

Sample

The data were collected from the monthly magazines *What Mobile*, *What Cellphone* and *Total Mobile* (special interest magazines for mobile telephony in the UK) over the January 1997 - June 2008 period. The magazines publish data on mobile phones that are sold in the UK. We initially collected data on technologies (features and functionalities) of 627 mobile phones, sold in the UK from January 1997 to June 2008 by the largest 14 mobile phone manufacturers in terms of market share, irrespective of whether these companies were operating across all the considered period, shut down their operations before the end the June

[1] Data on manufacturers' market share were collected from "*Gartner Dataquest: 1997 – 2008*" and from "*Mintel International Group Limited* (2007)".

2008 or entered the market after January 1997.

We then excluded from our sample all smartphone devices because during this period these products targeted a distinctly different group of consumers.[2] By removing all smartphones from our dataset, 570 "standard" mobile phones remained in our sample, launched in the UK market by 14 manufacturers (table 2). Our final sample captures more than 90% of the handsets launched in the UK mobile phone market during the period 1997-2008.

Table 2. Number of mobile phones, standard mobile phones and smartphones* per manufacturer (*January 1997- June 2008*)

Manufacturers	*mobile phones*	*standard mobile phones***	*smartphones*
Nokia	127	93	34
Motorola	94	84	10
Samsung	80	77	3
Sony-Ericsson	59	53	6
Siemens	52	51	1
Sagem	47	45	2
Alcatel	32	32	0
LG	30	30	0
Ericsson	29	29	0
Panasonic	27	26	1
Philips	19	19	0
Nec	15	15	0
Sony	11	11	0
BenQ-Siemens	5	5	0
TOT	**627**	**570**	**57**

*We define "smartphones" those handsets with an advanced operating system. Operating systems we consider as "advanced" are: Symbinan, BlackBerry OS, Mac OS, Microsoft Windows Mobile, Linux, Palm OS.
**We test our hypotheses using only data on "standard" mobile phones.

[2] A smartphone is an electronic handheld device that integrates the functionality of a mobile phone, personal digital assistant (PDA) or other information appliance. Because there are no hard rules to distinguish smartphones from other mobiles, we collected several definitions of smartphone from different secondary sources with the aim of identifying demarcation criteria that would allow us to separate "standard" mobile phones from other handheld devices. According to most of the definitions we collected, a key feature of those products named as smartphones is their "advanced operating system", providing a graphic interface similar to the one of a desktop computer and allowing additional applications to be installed on the device. Examples of advanced operating systems for smartphone are Symbinan, BlackBerry OS, Mac OS, Microsoft Windows Mobile, Linux, Palm OS, which among the advanced operating systems, count for more than 95% of the market. Information on mobile phone operating systems were collected mainly from *Gartner Dataquest*. We therefore used the variable "advanced operating system" as a demarcating criteria to exclude smartphone from our sample.

Mobile phones technologies

The sample includes only mobile phone technologies for which were available detailed data and reviews over the period 1997-2008, and that were present on the market (e.g. commercialized) at least for half of the 46 quarters of this period (in other words, we excluded "short-life" technologies). Our sample captures more than 60% of the product technologies mentioned on the selected magazines. The product technologies we collected are listed and described in table 3.

Table 3. Description of the mobile phone technologies

Technology name	Technology description
Voice dial	Technology that stores the user's speech samples and links them to the user's contacts. It enables the user to make a call by dialing the number with the voice.
Ringtone composer	Technology that allows the user to create its own music tones through a "melody composer" software.
Bluetooth	Technology that facilitates communication between wireless devices such as mobile phones, PDAs (personal digital assistants) and handheld computers, and wireless enabled laptop or desktop computers and peripherals. A single Bluetooth-enabled wireless device is capable of making phone calls, synchronizing data with desktop computers, sending and receiving faxes, and printing documents.
Infrared	Technology that allows the user to exchange data with notebooks, printers, PDAs or other phones wirelessly via invisible infrared light. The connection works only in close distance and direct visibility.
Universal Serial Bus (USB)	Technology in the form of a plug-in connection that is used to connect some phones to PCs via cable. Most of the phones require proprietary USB cables to connect to a PC.
Multimedia Messaging Service (MMS)	It is a standard for telephone messaging systems that allows to send messages that include multimedia objects (images, audio, video, rich text) and not just text as in the Short Message Service (SMS).
Email client	An application that enables the user to send, receive and organize e-mails on its handset. It is called a *client* because e-mail systems are based on a client-server architecture.
Color screen	Screens with more than two colors
Photo-camera	Technology that allows the user to take pictures with the handsets
Voice recorder – voice memo	A technology that allows the user to record short messages to be played back later.
MP3 player	Technology that allows the user to listen to MP3 files with its handsets.
Radio	Technology that allows the user to listen to the radio with its handsets.
Bar (form factor)	The most basic handset style. The entire handset is one solid monolith, with no moving parts asides from the buttons and possible antenna.
Clamshell (form factor)	The type of phone consists of two halves connected by a hinge. The phone folds close when not in use.
Slide-up (form factor)	Type of phone similar to the clamshell but the two halves slide open instead of using a hinge.

Source: *What Mobile*, *What Cellphone* and *Total Mobile*.

Separate accessories for handsets were excluded, unless they were sold together with the handset, bundled in the same package.[3]

Mobile phone incremental and radical innovations

We clustered mobile phone technologies into 'incremental' and 'radical' product innovations. The distinction between incremental and radical mobile phone innovations was made in collaboration with product managers of five mobile phone manufacturers operating in the UK. The five managers were interviewed over the phone using a questionnaire divided into two parts. In the first part we listed a number of definitions of incremental and radical product innovations from the management literature, together with a number of practical examples from other industries. This allowed managers to frame and put in context the incremental/radical classification. In the second part we listed the product technologies we selected from magazines, and we asked the managers to indicate, per each product technology if, in the specific context of the UK market, it:

- *fundamentally altered the way consumers use their mobile phone,* ("market dimension");
- *rendered obsolete, or drastically reduced the competitiveness of those mobile phones that do not incorporate it* ("technology dimension").

The above classification corresponds closely to the technology and market dimensions that Chandy and Tellis (1998) and Sorescu, Chandy and Prabhu (2003) use to define radical product innovations. Those mobile phone technologies satisfying both of the two parameters for at least 50% of the interviewee (at least 3 over 5 interviewee) were named as radical product innovations, and the others as incremental product innovations. In particular, among

[3] E.g. if the handset can take pictures only through a digital camera that has to be purchased separately, this handset is not considered able to take pictures; on the other hand, if the separate digital camera is included in the handset package (namely, buying the handset you automatically get the digital camera device too), then the cell phone is assumed to provide the camera functionality

the sampled product technologies, those that got the requisites to be named as radical product innovations in the UK market are: MP3 player, radio, camera, color screen, MMS and Bluetooth.

Measuring Degree of Adoption of a product technology

In this study we examine the adjustment of firms' strategy towards multiple industry benchmarks during a period of rapid technological change. The measure we use to test our hypotheses is an indicator expressing the relative importance of a certain technology in the firm's product range. Per each of the fifteen product technologies, we initially assign to each product value 1 if the product has that technology and 0 otherwise, irrespective of whether the technology has improved or reduced its capabilities over time.[4] Then we define the firm's "degree of adoption (DOA) of a product technology" as the percentage of the firm's products with a certain technology, belonging to the firm's product range in a given period of time. In other words, the DOA of a product technology k at time t is the ratio between the number of the firm's products with the technology k at time t and the overall number of firm's products at time t. The DOA assumes values between 0 and 1. The closer the DOA of a certain product technology is to 1 (100%), the greater is the firm's percentage of models of mobile phone with the particular technology. The DOA expresses how important the technology is for the firm's product choice. (More detailed definition of the firm's product range and of the evolution of the firm's DOA of a product technology over time is provided later in the paper).

THE MODEL

The adjustment model

The model we use to test our hypotheses is a partial adjustment model (PAM) initially

[4] E.g. if the handset can take pictures, than the variable "photo-camera" for that handset will take value 1, irrespective of the number of camera pixel.

presented by Lev (1969) to study the periodic adjustment of firms' performance to the industry mean. The model has the following form:

(1) $$y_{i,k,t} - y_{i,k,t-1} = \beta(x_{j,k,t-1} - y_{i,k,t-1})$$

where:

- $y_{i,k,,t}$ represents the percentage of products with the technology *k* belonging to the firm *i*'s product range at time *t*. We name this percentage the firm *i*'s "degree of adoption" (DOA) of the product technology *k*;
- $x_{j,k,t-1}$ represents the DOA of the product technology *k* performed by the benchmark (or reference target) *j* at time *t – 1*. Since the target value that firms follow in choosing a certain DOA of a product technology is not observable, proxies are used. In particular we develop two models which respectively assume that the *industry mean* (the average DOA of a given technology *k* among all firms at time *t – 1*) – as a proxy of the collective behavior of industry rivals – and, as suggested (but never empirically implemented) by some authors (Fiegenbaum and Thomas, 1995; Fiegenbaun, Hart and Schendel, 1996), the firm with the highest market share, namely the *market leader* (the DOA of a given product technology *k* by the market leader at time *t – 1*) – as a proxy of the best performing firm – are regarded as targets for the firms' DOA of a product technology.
- The coefficient β represents the firm's speed of adjustment toward the reference target. The model assumes that when the firm observes a deviation between the reference target's DOA of a product technology and its current DOA of the same technology ($x_{j,k,t-1} – y_{i,k,t-1}$), it will adjust the DOA of that technology in the next period ($y_{i,k,t} – y_{i,k,t\ -1}$) by the factor β. When the estimated β falls between 0 and 1, it is an

indication that the firm adjusts the DOA of the technology towards the reference target. The closer β is to 1, the faster the periodic adjustment of the firm's DOA to the reference target. If β is either greater than 1 or less than 0 the firm will tend to move from its current target.

Improving the adjustment model

In estimating the coefficient of (1) we want to allow for the possibility that firms are adjusting the DOA of the product technology to a benchmark that is different from the industry mean or the market leader. For this reason we augment the reference target with a constant term z. In this way we specify that the target towards which firms are adjusting is equal to the chosen target value, as before, but now in addition there is an extra constant z which is shared by all industries (Konings and Vandenbussche, 2004). It captures the notion that firms might be systematically adjusting the DOA of a product technology to something higher ($z > 0$) or lower ($z < 0$) than the industry target.

Substituting $x_{j,k-1}$ with $x_{j,k-1} + z$ in (1), and modifying the resulting equation by the natural logarithmic transformation[5], gives equation (2):

$$(2) \qquad \ln y_{i,k,t} - \ln y_{i,k,t-1} = \beta z + \beta(\ln x_{j,k,t-1} - \ln y_{i,k,t-1}) + \varepsilon_{i,t}$$

where βz is a constant term and $\varepsilon_{i,t}$ is an error term assumed to meet the least-squares model requirement (Lev, 1969). When the constant term is not significant, the PAM holds, leading to the conclusion that the original model (i.e., without the constant) fits the data well. On the

[5] The model equation is modified by the natural logarithmic transformation because it more sensibly specifies relative rather than absolute changes in strategy decisions in relation to industry reference points (Fiegenbaum and Thomas, 1995). For example, the absolute deviation between a firm's strategic value of 0.20, and its reference point, say, 0.10, would be treated as equivalent to the deviation between a strategic value of 0.90 and a reference point of 0.80. But the former deviation should be regarded as far more serious than the latter. Therefore, taking the logarithmic transformation of both deviations, the former and the latter case would result as follow: ln (0.20/0.10) = 0.693 ; ln (0.90/0.80) = 0,117.

other hand, a statistical significant constant term βz would mean that firms are not orienting their action towards the chosen target $x_{j,k}$. As suggested by Konings and Vandenbussche (2004), in this latter case we can infer the value of z. If the value of βz is significant, the "implied value of z" can be found by dividing the constant term βz by the estimated adjustment coefficient β, and it expresses the distance between the chosen industry target and the targets towards which firms effectively orienting their action.

Let us set the constant term βz = α, and add 1 to each variable in order to avoid the logarithm of a null value.[6] Then the equation we will estimate using Panel Data techniques with data from our sample is:

$$(3) \qquad \ln(1+y_{i,k,t}) - \ln(1+y_{i,k,t-1}) = \alpha + \beta[\ln(1+x_{j,k,t-1}) - \ln(1+y_{i,k,t-1})] + \varepsilon_{i,t}$$

where $y_{i,k,,t}$ is the DOA of the product technology k for the ith firm in the tth period, k = 1,...,15, i = 1,...14. The time t varies depending on the type of technology.[7]

We will estimate (3) per each of the chosen 15 technologies, using both the industry mean and the market leader as reference targets. At the end we will estimate 30 panel data: 15 PAMs per each of the two reference targets. In each panel we control for the firm identity with robust fixed effect estimation.

The adjustment towards the target is computed separately for the DOA of each product technology. That is because we assume that firms do not obtain specific advantages or disadvantages in adopting product technologies jointly or separately, from the point of view of the handset production. In other words product technologies are assumed to be independent

[6] If in a certain period of time t the manufacturer does not have any product with the technology k, the DOA of the technology k at the t will be 0.
[7] Since the DOA adoption of each technology is computed on a time period that starts when the technology was first introduced in the market, the number of observations per each adjustment model varies depending on when the technology was introduced in the mobile phone market.

from the point of view of the manufacturer production strategy.[8]

The product range, the product life cycle, and the DOA of a product technology over time

Since the DOA of each technology is computed on the base of the firm's product range, we have to define what we mean for "product range" and explain how it changes over time. Here the firm's "product range" is defined as the number of different versions of product (in the case of a mobile phone manufacturer: the "number of different models of mobile phones") that the firm commercializes in a certain period of time. A product starts to be commercialized when it is introduced in the market by the firm. We therefore use the handset first review date as a proxy of the month in which the handset was introduced in the market. However manufacturers do not stop selling the product after the month of the product introduction. In fact, after having sold stocks of the product to mobile phone retailers, manufacturers usually keep on storing the product in their warehouses for several months, ready to supply again the product to mobile phone retailers in case of request. This means that the same product stays in the manufacturer's product range for several months. From the information we gathered after conducting a number of telephone interviews with marketing and product managers of some of the main mobile phone manufactures operating in the UK,[9] we concluded that the period of time from the introduction of the product by the manufacturer and the moment in which the manufacturer no longer supply the product to retailers is normally one year, for all the products launched in the UK during the 1997-2008 period. Since we are interested in the manufacturers' strategy, we define the "mobile phone life cycle" as the period of time starting with the introduction of the product by the manufacturer

[8] This argument was also supported by the information we gathered after have conducting a number of in depth interviews with product managers of some of the main mobile phone manufactures operating in the UK.
[9] Marketing and product managers from the companies that agreed to be interviewed include: Sony-Ericsson, LG UK, Samsung UK, Nec UK.

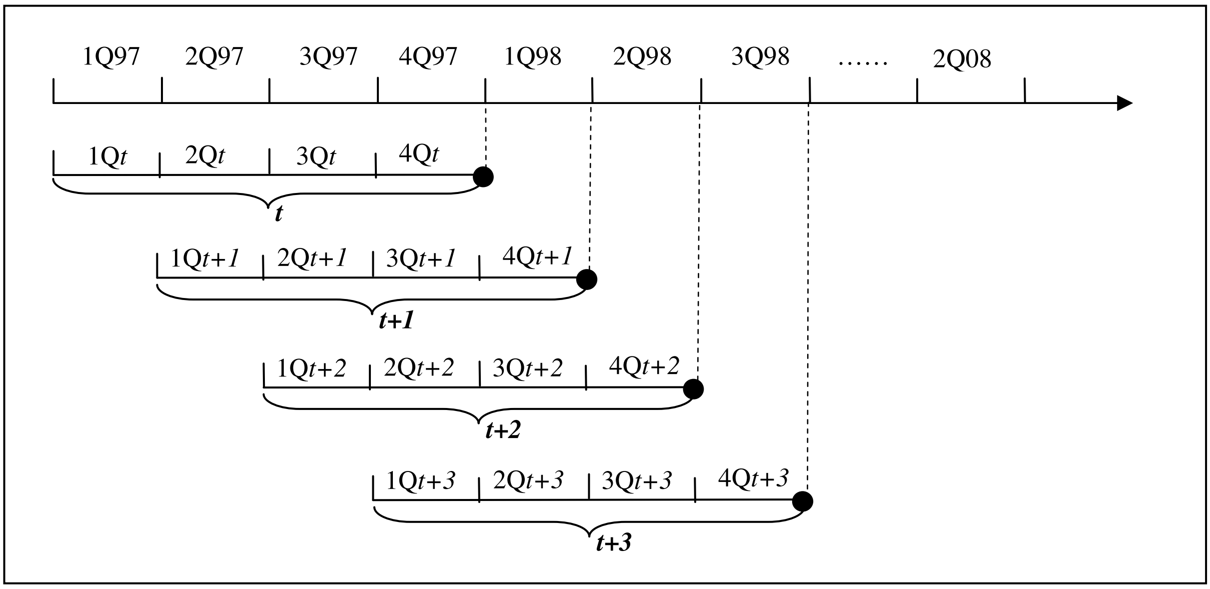
and ending with the moment in which the manufacturer no longer supply the product to retailers, irrespective of whether retailers, after this period, keep on selling the product to final consumers.[10] Therefore we estimate that each product stays in the firm's product range for one year. After one year, if from one side the firm's product range is reduced because of the withdrawal of products that are more than one year old, on the other side it will be increased by the new products launched in the following period.

If we assume that the life cycle of every handset is equal to four quarters and that all products introduced in a certain quarter are launched exactly in the first month of the quarter, then the evolution of the firm's product range can be described with a moving sum of time periods t, where each t is equal to four quarters (t = 4 quarters), with t that goes from t to $t+T$. The new items coming into the sum at $t+1$ are the new products launched by the firm in the first quarter after the period t, while products launched in the first quarter of the period t will be dropped out. Each observation describing the evolution of the firm's product range over time is ideally computed at the end of the last quarter of each time period t, such that it takes into account all the products introduced during the four quarters before the end of t.

Graph 1 illustrates the evolution of the firm's product range across time periods, assuming the firm starts introducing products in the first quarter of 1997 (1Q97).

[10] Independent mobile phone retailers and telecommunication companies dealers usually buy stocks of products by handsets manufactures and keep on selling them while stocks last.

Graph 1. Evolution of the firm's product range across time periods



Notes:
1Q*t* = first quarter of the time period *t*;
The dots in bold represent the points where each observation is ideally computed. The first observation, computed at the end of the last quarter of the time period *t*, takes into account all the firm's products introduced during *t*. The same happens for the following observations at the end of the time period *t+1*, *t+2*,…, *t+T*.

In this way the firm's product range will be computed always on a time period *t* of four quarters, as well as the firm's DOA of a technology ($y_{i,k,,t}$). Specifically, the evolution of the firm's DOA of a product technology over the *T* time periods is described by a moving average from *t* to *t+T*.

A manufacturer is considered "operational" in a given period of time if it has at least one product in its product range. This is also the minimum condition to compute the DOA of a product technology. For example, during the year 1997 Panasonic[11] launched new products in the UK market only over the first quarter of the year (1Q97). Since we compute each firm's product range on a period of time of four quarters, and we gathered data on product technologies from January 1997, Panasonic's first observation will be computed at the end of the 4Q97 (four quarter after the beginning of the 1Q97). Even if Panasonic did not introduced any new products in the second, third and fourth quarter of the 1997, the firm's product range computed at the end of the 4Q97 takes into account all the products introduced by the

[11] Panasonic is a Japanese corporation operative also in the mobile phone industry as handsets producer.

manufacturer in the previous four quarters (1Q97-4Q97), and therefore also those products introduced in the 1Q97. Therefore in the time period 1Q97-4Q97 Panasonic is considered to operate in the market. During the 1Q98 the firm launched new products in the UK market. At the end of the 1Q98 Panasonic's product range is computed taking into account all products introduced by the company during the 2Q97-1Q98 time period.

RESULTS

Table 4 provides the descriptive statistics of the manufacturers' DOA of each product technology ($y_{i,k,,t}$). As can be observed, the DOA of each product technology has a minimum value of 0 and a maximum value of 1. This means that there is at least one case per each technology in which a manufacturer, in a certain period of time, has adopted, in its product range, 0% and 100% of products with the technology. Table 5 provides the descriptive statistics of the industry average DOA of each product technology ($x_{j,k,,t}$).

Table 4. Descriptive statistics of the manufacturers' DOA of each product technology ($y_{i,k,,t}$)

Variable ($y_{i,k}$)	**Technology life cycle***	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Voice dial	1Q97-2Q08	432	0.441	0.386	0	1
Ringtone composer	1Q97-2Q08	432	0.365	0.409	0	1
Bluetooth	1Q01-2Q08	294	0.335	0.371	0	1
Infrared	3Q97-2Q08	432	0.296	0.326	0	1
USB	1Q01-2Q08	294	0.375	0.387	0	1
MMS	2Q02-2Q08	273	0.627	0.433	0	1
Email	3Q97-2Q08	432	0.359	0.397	0	1
Color screen	2Q97-2Q08	432	0.476	0.468	0	1
Photo-camera	1Q02-2Q08	253	0.585	0.396	0	1
Voice recorder	1Q97-2Q08	432	0.497	0.377	0	1
MP3	2Q00-2Q08	327	0.294	0.372	0	1
Radio	4Q99-2Q08	348	0.092	0.214	0	1
Bar	1Q97-2Q08	432	0.613	0.352	0	1
Clamshell	1Q97-2Q08	432	0.212	0.293	0	1
Slide-up	1Q97-2Q08	432	0.071	0.147	0	1

*The first and the last quarter in which the technology was adopted by at least one manufacturer

Table 5. Descriptive statistics of the industry average DOA of each product technology ($x_{j,k,,t}$)

Variable ($x_{j,k}$)	**Technology life cycle***	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Voice dial	1Q97-2Q08	43	0.443	0.202	0.066	0.770
Ringtone composer	1Q97-2Q08	43	0.359	0.210	0.033	0.718
Bluetooth	1Q01-2Q08	28	0.384	0.277	0.028	0.856
Infrared	3Q97-2Q08	43	0.289	0.171	0.033	0.612
USB	1Q01-2Q08	28	0.420	0.301	0.014	0.883
MMS	2Q02-2Q08	25	0.705	0.327	0.014	1
Email	3Q97-2Q08	42	0.381	0.248	0.02	0.775
Color screen	2Q97-2Q08	43	0.492	0.447	0	1
Photo-camera	1Q02-2Q08	24	0.638	0.289	0.009	0.905
Voice recorder	1Q97-2Q08	43	0.507	0.256	0.05	0.847
MP3	2Q00-2Q08	31	0.335	0.309	0.009	0.877
Radio	4Q99-2Q08	33	0.108	0.105	0	0.442
Bar	1Q97-2Q08	43	0.607	0.150	0.233	0.809
Clamshell	1Q97-2Q08	43	0.216	0.164	0	0.579
Slide-up	1Q97-2Q08	43	0.076	0.074	0	0.292

*The first and the last quarter in which the technology was adopted by at least one manufacturer

Table 6 shows robust fixed effect estimation of the PAM equation, computed per each of the fifteen product technologies, using respectively the industry mean and the market leader as reference targets. We name “model 1” and “model 2” the PAM equations, assuming an adjustment respectively towards the industry mean and the market leader. In table 6 technologies are grouped in categories (phone call, connectivity, messaging, display, further features, form factor) derived from segmentations provided by the magazines mentioned before.

Table 6. Coefficients of the estimated Partial Adjustment Models (using robust fixed effect estimation - panel data techniques)

Model: $\ln(1+y_{i,k,t}) - \ln(1+y_{i,k,t-1}) = \alpha + \beta[\ln(1+x_{j,k,t-1}) - \ln(1+y_{i,k,t-1})] + \varepsilon_{i,t}$ where in model 1 and in model 2 the parameter $x_{j,k}$ is equal respectively to the industry mean and the market leader (Nokia).

Technology category	Technology	*Model 1*					*Model 2*				
		Adjustment towards the industry mean					**Adjustment towards the market leader (Nokia)**				
		beta (*β*)	**constant term (*α*)**	***Number of observations***	***Implied value of z = α / β***	***R-squared***	**beta (*β*)**	**constant term (*α*)**	***Number of observations***	***Implied value of z = α / β***	***R-squared***
Phone call	**Voice dial**	**0.205*** (4.96)**	-0.000 (-0.00)	414	0	0.140	**0.070*** (3.22)**	-0.005 (-0.70)	372	0	0.124
	Ringtone composer	**0.064** (3.03)**	0.000 (0.10)	414	0	0.122	**0.077*** (4.74)**	0.002 (0.40)	372	0	0.160
Connectivity	**Bluetooth**	0.153*** (3.76)	0.014* (2.37)	277	0.092	0.137	**0.088** (2.94)**	0.009 (1.29)	249	0	0.134
	Infrared	**0.126*** (4.61)**	-0.000 (-0.10)	414	0	0.151	0.122*** (4.19)	-0.037** (-2.97)	372	-0.303	0.160
	USB	0.101** (2.63)	0.014* (2.54)	278	0.139	0.134	**0.110** (2.99)**	0.006 (1.22)	249	0	0.155
Messaging	**MMS**	0.236** (2.71)	0.017*** (3.77)	258	0.072	0.176	**0.189*** (4.03)**	-0.001 (-0.23)	230	0	0.244
	Email	**0.0817** (3.46)**	0.010 (1.53)	414	0	0.118	**0.041* (2.29)**	0.007 (0.97)	372	0	0.019
Display	**Color screen**	0.215*** (3.72)	0.010** (284)	414	0.047	0.173	0.195*** (3.53)	0.011** (2.88)	372	0.056	0.179
Further features	**Photo-camera**	0.297*** (3.79)	0.016* (2.58)	238	0.054	0.166	**0.287*** (3.56)**	0.003 (0.44)	213	0	0.177
	Voice recorder	**0.144*** (4.71)**	0.006 (1.13)	414	0	0.162	0.098*** (3.76)	0.011* (2.03)	372	0.112	0.143
	MP3 player	0.266*** (3.82)	0.010† (1.82)	311	0.038	0.162	**0.201*** (3.74)**	0.008 (1.29)	279	0	0.16
	Radio	0.115† (2.22)	0.005† (1.66)	331	0.043	0.015	**0.021† (1.82)**	0.000 (0.07)	297	0	0.102
Form factor	**bar**	**0.215*** (4.85)**	-0.010 (-0.89)	414	0	0.153	**0.131*** (4.36)**	-0.009 (-0.76)	372	0	0.138
	clamshell	**0.115** (3.49)**	0.000 (0.14)	414	0	0.136	**0.053** (2.65)**	0.005 (0.84)	372	0	0.118
	slide-up	**0.236*** (3.83)**	0.000 (0.22)	414	0	0.157	**0.056* (2.41)**	-0.004 (-0.93)	372	0	0.111

Notes: (see next page)
Significance: ***$p < 0.001$; ** $p < 0.01$; *$p < 0.05$; †$p < 0.10$; t-statistic in parenthesis.

The "implied value of z" = α / β. When z = 0 this implies that the partial adjustment model holds. When z > 0 firms are adjusting their product strategy to something higher than the target , when z < 0 firms are adjusting their product strategy to something lower than the target.

Variables with values of β in bold are those for which firms perform a significant adjustment towards one of the two targets, respectively the industry mean in Model 1 and the market leader in Model 2.

Our model focuses on the partial adjustment coefficient β. It was stated that $0 < \beta < 1$ and the constant term (α) statistically insignificant are indications that firms periodically adjust the DOA of a technology to a target within the industry. We found a statistically insignificant constant term and β between 0 and 1 for the DOA of 8 over 15 (53.3%) and 12 over 15 (80%) product technologies, using respectively the industry mean and the market leader as reference targets (table 7).

Table 7. Summary of results: adjustment of the DOA of a product technology across the period 1Q97 – 2Q08.

Phenomenon	Finding
Number of technologies for which firms perform a significant adjustment* towards the ***industry mean***.	8 over 15 (53.3%)
Number of technologies for which firms perform a significant adjustment* towards the ***market leader***.	12 over 15 (80%)

* conditions for a significant adjustment: β significant, $0 < \beta < 1$, and α not significant.

The coefficient of determination, R^2, is not large for any of the DOA tested. This indicates the existence of additional explanatory variables which are not included in equation (3). But the objective of this study is to examine the periodic adjustment hypothesis and not to develop a prediction model (Lev, 1969). Therefore, we can concentrate on the β coefficients, and the modest R^2 need not be of great concern. From these initial results we can say that in both models, for more than a half of the selected product technologies, firms adjust the DOA respectively towards the industry mean and the market leader. Only in one case ("color screen") firms converge neither towards the industry mean nor towards the market leader.

Hypothesis 1 stated that when adopting a given product technology firms use the collective product decisions of the industry rivals as well as the product decision of the market leader as their benchmarks. In order to test the validity of hypothesis 1, we confront our findings with the ones of Fiegenbaum and Thomas (1995), that adopt a similar model to analyze the strategies adjustment within strategic groups. The authors consider the adjustment towards a target as significant if for at least 50% of the chosen strategies the adjustment coefficient (β) is between 0 and 1 and the constant term is not significant. As summarized in table 7, since the adjustment process for the majority of mobile phone technologies is significant, respectively towards the industry mean (53.3%) and the market leader (80%), our results confirm Hypothesis 1.

Hypotheses 2a and 2b explore the influence of multiple benchmarks in the incumbents' adoption of incremental and radical innovations. Specifically, Hypothesis 2a stated that when adopting a given radical product innovation firms use the product decision of the market leader as their benchmark. In order to test Hypothesis 2a we compute the percentage of radical product innovations for which firms perform a significant strategic adjustment respectively towards "only the market leader", "only the industry mean", "both targets", and "none of them" (table 8), and we use the 50% of innovations as threshold value to measure the significant influence of the benchmark on the adjustment process. As shown in table 8, among the six radical product innovations, for the majority of them the adjustment process takes place only towards the market leader (5 over 6 cases; 83.3%), while for none of them the adjustment process takes place only towards the industry mean and towards both targets. Therefore this findings offer support for Hypothesis 2a.

Hypothesis 2b stated that in the process of adopting an incremental product innovation firms are influenced by the collective behavior of industry rivals. As we did for Hypothesis 2a, in order to test Hypothesis 2b we compute the percentage of incremental product innovations for which firms perform a significant strategic adjustment respectively towards "only the market leader", "only the industry mean", "both targets", and "none of them" (table 8), and we use the 50% as threshold value. As shown in table 8, in the majority of the nine incremental product innovations the adjustment process takes place towards both targets (6 over 9 cases; 66.6%). On the other hand, for 1 in 9 cases (11.1%) the adjustment is significant only towards the market leader, whereas for 2 in 9 cases (22.2%) the adjustment is significant only towards the industry mean. Based on these results we must conclude that hypothesis 2b cannot be supported. On the other hand, the results suggest that both sources, collective rivals' behavior and industry leader behavior, exercise influence. Methodologically, however, it is difficult to separate their influence, or determine which has a stronger impact on target setting in the case of incremental innovations.

Table 8. Adjustment towards the industry mean and the market leader depending on the type of product innovations*

Variable ($x_{j,k}$)	RPI	Adjustment only towards the ML	Adjustment only towards the IM	Adjustment towards both ML and IM	Adjustment towards neither ML nor IM	% of RPIs with adjustment only towards the ML	% of RPIs with adjustment only towards the IM	% of RPIs with adjustment towards both ML and IM	% of RPIs with adjustment towards neither ML nor IM	% of IPIs with adjustment only towards the ML	% of IPIs with adjustment only towards the IM	% of IPIs with adjustment towards both ML and IM	% of IPIs with adjustment towards neither ML nor IM
Voice dial				Yes									
Ringtone com.				Yes									
Bluetooth	Yes	Yes											
Infrared			Yes										
USB		Yes											
MMS	Yes	Yes											
Email				Yes									
Color screen	Yes				Yes	5 over 6 (83.3%)	0 over 6 (0%)	0 over 6 (0%)	1 over 6 (16.6%)	1 over 9 (11.1%)	2 over 9 (22.2%)	6 over 9 (66.6%)	0 over 9 (0%)
Photo-camera	Yes	Yes											
Voice recorder			Yes										
MP3	Yes	Yes											
Radio	Yes	Yes											
Bar				Yes									
Clamshell				Yes									
Slide-up				Yes									

* IM = industry mean; ML = market leader; RPI = radical product innovation; IPI = incremental product innovation.

DISCUSSION

The results of the current study suggest that strategic adjustment is the product of separate processes and multiple factors external to the organization. First, we show that both the collective product decisions of industry rivals and the market leader's product decision act as benchmarks for the firm in the process of product technology adoption. Second, we show that in the process of technology adoption, the benchmarks firms select vary, depending on whether the product technology represents a radical or incremental product innovation. In particular we provide evidence that when adopting radical product innovations firms use the market leader as their benchmark, while when adopting incremental product innovations, differently from our prediction, the collective behavior of industry rivals is not the dominant or even the sole source for setting reference targets: There is also the additional influence of industry leader behavior.

In the opening discussion we argued that incremental innovations are more likely to elicit rivalry-based concerns, which in turn should motivate firms to use collective rivals' behavior to define reference targets. The influence of the industry leader can be explained by additional risk calculation that influences target setting in the case of incremental innovations. An incremental innovation is technologically easier to introduce, faces less consumer resistance, but it also has lower revenue potential because it competes with proven close substitutes (Chandy and Tellis, 2000). The decision to adopt incremental innovations is therefore likely to hinge on the balance between upfront costs and downstream revenues. All other things being equal, the risk of higher than expected upfront costs will discourage the adoption of an incremental innovation if the revenue upside is constrained. To benchmark this risk firms will often include the incremental innovation decisions of the industry leader as an additional source of target setting for the following reason. For the industry leader, as for any firm, the market potential of an innovation is evaluated relative to its own total sales. But in the case of a market leader, however the potential market has to be larger than for other firms for the adoption to be worthwhile. Thus, using the industry leader's incremental innovation decisions as an additional source of target setting provides further information to risk estimation.

Turning our attention to wider implications of our findings, we argue that this study makes several important contributions to the strategy literature. First, we provide a theoretical rationale and find empirical support for our claim that when taking their product decisions firms are influenced by multiple benchmarks within the industry. In particular we explore the influence of two external reference targets: the collective product decisions of the industry rivals as well as the product decisions of the market leader. In passing we should note that these two benchmarks are very different in nature. Arguably, industry mean is a 'non-specific' reference target (by comparison to the market leader which derives from a specific information source). Industry mean does not, therefore, exist in and of itself, but is the result of the aggregate of all industry members' behaviors. The use of the industry mean as benchmark therefore raises the interesting question in industry dynamics research: how do firms 'experience' industry competition?

To our knowledge no studies have explored so far the process of adjustment towards two benchmarks, so different in nature. Therefore our findings extend prior conceptual and empirical work on strategic adjustment (Snow and Hambrick, 1980; Frecka and Lee, 1983; Fiegenbaum and Thomas, 1995; Greve, 1998) by empirically identifying a "multi-directional" influence on the adjustment process, exercised by benchmarks very different in nature.

Second, we provide a theoretical rationale and in part find empirical support for our claim that the benchmark exercising influence on the firms' technology adoption process varies depending on the type of product technology. In particular we show that when adopting radical innovations, normally characterized by higher technological complexity and large but highly uncertain revenues, firms use only the market leader as a benchmark, while when adopting incremental innovations, normally characterized by lower complexity and smaller but more certain revenues, firms use both the market leader and the collective behavior of industry peers as benchmarks. This latter finding does not support our hypothesis of adjustment towards the collective behavior of industry rivals when adopting incremental innovations, but does point to a process of target setting that combines different sources.

Managerial Implications

Based on our empirical results, we believe that there are a number of managerial implications to the use of PAM in strategic planning. In particular, if the manager by using the PAM is able to identify more than one potential reference target within the industry, he or she can investigate which targets the industry members are choosing and which are avoiding in the process of modifying their strategy over time. This information can be useful if firms' strategy tends to be oriented mainly towards one target instead of others. Under these circumstances, managers may explore the factors behind the process, and may consider the option of behaving differently from the other industry members. For example, if a mobile phone manufacturer intends to differentiate itself from its industry members in the adoption of a certain technology, it can monitor the targets firms are using, and use another reference target as a benchmark.

Moreover, the adjustment process towards certain targets can be used as a tool to identify groups of strategies (in our study we have a "strategy" – or product decision – for the adoption of each product technology). Specifically, in case of multiple reference targets within the industry, strategies could be grouped according to the set of targets assumed as reference, thus clustering potential different strategic attitudes. And in turn further considerations could be made on the technological/strategic similarities among strategies belonging to the same group. For example, in our study we find that depending on the type of product technology, radical vs. incremental, product decisions are driven by different benchmarks; but further interesting results could emerge by clustering product technologies according with other criteria.

Limitations and Suggestions for Future Research

Several limitations to the current study suggest opportunities for future research. The first limitation is intrinsic to the indicator we use to describe the evolution of firms' behavior over time, namely the DOA of a product technology. As specified before, this indicator does not take into account the increasing, decreasing or stationary capabilities of each technology across time. We only analyze the percentage of products with a certain technology belonging to the firm's product range, in a specific period of time, irrespective of whether the technology has evolved or not with respect to the previous periods. For example, the number of colors of mobile phones' displays has strongly increased from the four colors in 1999 to the 16 million colors in 2007; as also the resolution of the photo-camera or the number of minutes that can be taped with the voice recorder. In other words what we define as the "DOA of a product technology" takes into account only how many (i.e. the percentage of) products with a certain technology the firm has adopted, and not how developed this technology is at a certain moment in time. Therefore, further studies could analyze if firms change their benchmarks depending on the stage of development of the technology itself: firms might initially orient adoption processes towards a target once the technology is introduced, and change the target once the technology has improved its capabilities.

Second, although we believe that our hypotheses are general enough to be applied to other industries, this should be done with caution. We have conducted our analysis in a rapidly evolving industry with a continuous number of technologies that are adopted and then dropped. Considering the rapid change rate of products in the mobile phone industry, we have analyzed the strategic adjustment process across a relative wide period of time. Further studies could analyze the adjustment of firms' behavior in specific stages of the industry life cycle. In fact, if the partial adjustment of the DOA of a technology is significant across a wide period of time (in our case 1997-2008), different results might emerge by splitting the time period in more stages (e.g. industry growth, maturity and decline).

Moreover we hope that future research will explore the issue of multiple reference targets in industries with different characteristics, potentially allowing the researcher to identify other reference targets. For example it would be extremely interesting to investigate if the adjustment towards a reference target is influenced by other factors peculiar to the reference target, such as location, brand image and product price. It might be the case that the behavior of a country based manufacturer is a reference target for the other industry members, or that firms orient their action towards those firms selling products at the cheapest price. Following this logic, alternative reference targets may also be identified and tested.

Conclusion

This study contributes to research on the role of benchmarking in the firms' technology adoption process. It suggests that certain product strategy choices spread through the organization field and tend to be oriented towards different external reference targets within the industry over time. The study further suggests that product differentiation decisions are often made in relation to different industry reference targets, depending on the innovativeness of the product technology. The potential empirical extensions of our study will, hopefully, contribute to a better understanding of the rule of multiple benchmarks and facilitate managerial decision-making on the (degree of) adoption of new product technologies.

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