Successive Changes in Leadership in the Worldwide Mobile Phone Industry: The Role of Windows of Opportunity and Firms' Competitive Action

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Abstract
We take a historical perspective to gain insight into the determinants of changes in industrial leadership in the global mobile phone industry. The theoretical foundation of our analysis is (a) the catch-up cycle model proposed by Lee and Malerba (2015) that relies on an extended concept of 'windows of opportunity', i.e. changes in the technological, regulatory and consumer demand environment offering to latecomers the opportunity to surpass leading rivals, and (b) the concept of 'action aggressiveness' proposed by the competitive dynamics literature, a firm-level construct that refers to the extent to which a firm forcefully takes a large number and a large variety of actions to outperform its competitors in the marketplace. We show that the potential for leadership changes is greater for firms that are able to undertake 'aggressive' competitive actions at the time when 'significant' windows of opportunity are open. In particular, we analyze the determinants of two leadership changes: (1) in the second half of the 1990s, when the US giant Motorola lost its number one position, dethroned by its Finnish competitor Nokia; (2) in the first half of the 2010s, when Samsung of South Korea caught-up with Nokia. Two windows of opportunity played a significant role in the first leadership change: the analog–digital system technological discontinuity, and the asymmetric regulatory changes in Europe and the US. As for the second leadership change, a significant role was played by the regular phones–smartphones technological discontinuity.

"In the analog era, it was difficult for a latecomer to catch up […] But in the digital era, if you are two months late, you're dead. So speed and intelligence are what matter, and the winners haven't yet been determined."

(Interview with Samsung's CEO and Vice Chairman Yun Jong Yong, *Businessweek*, June 2003)

1. Introduction

In the first half of the 1930s, the Austrian economist Joseph Schumpeter (1934) developed the concept of 'creative destruction' to explain the competitive interaction undertaken by the market leader and challengers to safeguard or strengthen their competitive position. Schumpeter's argument suggested that the performance and visibility obtained by the market leader will motivate challengers to undertake new competitive actions in an attempt to catch up with the leader (Abernathy and Clark, 1985). Competitive actions may involve variables such as advertising, product innovation, new product introduction, price changes and product quality improvements, which may be relevant to the competition (Smith, Ferrier and Grimm, 2001). Since reaping the advantages associated with market share leadership (e.g., economies of scale, market power, reputation) is a key organizational objective for firms in many industries (Ferrier, Smith and Grimm, 1999), a central issue in industry evolution studies is to understand how firms sustain their leadership, dethrone leaders, or close the market share gap between themselves and leaders. Such issues have been addressed in three main stream of literature since the seminal work of Schumpeter.

First, the technological change literature (Tushman and Anderson, 1986) has described technological discontinuities as the main factors determining leadership changes. Radical technological changes are likely to destroy the value of the knowledge and competences accumulated by firms through the life cycle of the old technology, and often weaken the competitive position of those incumbents that continue to rely heavily on the old technology (Bergek, Berggren, Magnusson and Hobday, 2013; Christensen, 1997) and fail to sense and act on shifts in consumer preferences (Henderson, 2006). On the one hand, firms winning in the old technology may fall into 'competency traps' (March, 1991; Nelson and Winter, 1982): difficulties of changing organizational routines and the reluctance to adopt disruptive technologies nullifying profits from the existing products (Christensen, 1997). On the other hand, disruptive technologies are more likely to be created or exploited by new or emerging firms (Christensen, 1997) and, thus, chances arise for the followers to catch up with the leading firms.

Second, the literature about catching up by latecomer countries (Freeman, 1995; Malerba and Nelson, 2012; Nelson, 1993) argues that the occurrence of catching up is related to the intensity and

number of 'windows of opportunity' (Guennif and Ramani, 2012; Lee and Lim, 2001; Lee, Lim and Song, 2005; Mu and Lee, 2005). The windows of opportunity argument itself was initially proposed by Perez and Soete (1988) and was based on the idea that "the time of paradigm shift in technological trajectory often serves as a window of opportunity for latecomers since the disadvantages of the latecomers would not be large during such moments of time since everybody is a beginner" (Park and Lee, 2006: 721). Expanding on Perez and Soete's (1988) work on new techno-economic paradigms, various studies have progressively extended the concept of the window of opportunity to include changes occurring in market demand (Porter, 1990; Mathews, 2005) and changes and asymmetries in governmental regulations and interventions as well (Guennif and Ramani, 2012; Lee and Lim, 2001; Mu and Lee, 2005). In particular, Lee and Malerba (2015), by elaborating on the building blocks of sectoral innovation systems (Malerba 2004), describe windows of opportunity as a multi-dimensional construct based on: (1) the regimes of knowledge and technologies, (2) demand conditions, and (3) the surrounding institutions. The 'significance' of windows of opportunity, i.e. the extent to which they represent a radical change in the environment offering a performance advantage to firms that adapt to these changes earlier and better than rivals, determines the likelihood that the potential for a catching-up event will be created, especially when the 'overconfident' leader is 'trapped' by its inertial behaviors, and the challenger is able to 'respond' to the changing environment and learn from it (Lee and Malerba, 2015). The authors identify four consecutive stages in the industry catch-up cycle: 1) the 'entry' stage, in which the challenger attempts to enter an industry; 2) the 'gradual catch-up' stage, in which the challenger narrows the market share gap with the market leader thanks to cost advantages, investments, learning and the gradual accumulation of capabilities; 3) the 'forging ahead' stage, where the challenger leapfrogs the market leader by exploiting the windows of opportunity; 4) the 'falling behind' stage, occurring when the new market leader is progressively dethroned by a new emerging challenger.

Finally, based on the Austrian school's assumption that firm advantages are always transient, the competitive dynamics literature (Chen, Lin and Michel, 2010; D'Aveni, 1994; Ferrier et al., 1999; Smith et al., 2001) suggests that firms able to act creatively (e.g., by introducing new products or new marketing campaigns) are likely to improve their profits, competitive advantage, and industry position. In particular, the findings of these studies show that firm profitability and market share, as well as the rate of industry leader dethronement, are positively related to *action aggressiveness*. Aggressive firms, relative to conservative firms, are regarded as those that demonstrate greater 'intensity' and greater 'complexity' of strategic activity (Ferrier, 2001; Ferrier and Lee, 2002). Competitive dynamics theorists have defined 'strategic intensity' as the firm's capability to "carry

out a large number of competitive actions in rapid succession" (Ferrier and Lee, 2002: 164), and 'strategic complexity' as the "extent to which a sequence of actions is composed of actions of many different types" (Ferrier and Lee, 2002: 164).[1]

Although authors from these three streams of literature have offered various arguments and empirical evidence on the determinants of leadership changes, some important issues remain unexplored. First, there is no empirical evidence in the catching-up of latecomer country literature on how the three windows of opportunity (in technology, regulation and demand) contribute jointly to determine leadership changes in a specific industry. Second, although a few empirical studies in the technological change literature have combined technological discontinuities and firms' strategic posture in explaining firms' competitive advantage (Doz and Kosonen, 2008; Giachetti, 2013; Jenkins, 2010), there have so far been no studies specifically centered on how firms can adapt their competitive action to better exploit the opportunities offered by changes not only in the technological environment, but also of the demand and regulatory system. Third, although scholars in the competitive dynamics literature have shown that firm action aggressiveness is an important firm-level driver of changes in industrial leadership (Ferrier et al., 1999; Smith et al., 2001), there is a lack of studies looking at its interplay with *macro(industry)-level* factors, like windows of opportunity.

In this paper we draw on and contribute to these three streams of literature. More specifically, within the second (catch-up) stream we borrow two elements from the framework outlined by Lee and Malerba (2015): both the multi-dimensional perspective on windows of opportunity and the model of stages in the catch-up cycle. At a broad level we show that, in order to better understand the causes of changes in industrial leadership, both *macro-level* factors related to the external environment (i.e. windows of opportunity), and *micro-level* factors related to firms' competitive behavior, should be taken into consideration and analyzed in combination. In particular, we contribute to the existing literature by showing that in the forging ahead phase the potential for leadership change is greater for firms that, at the time when the windows of opportunity emerge, are able to outperform competitors undertaking aggressively those competitive actions (e.g., introduction of new product models and related technologies) which contingently result to be the most appropriate to gain market shares in the changing environment.

[1] The Lee and Malerba (2015) framework for exploring the process of leadership change in industries includes a component about firms' strategies in responding to windows of opportunity. This overlaps in part with the aspect of the competitive dynamics framework that focuses on the complex of firm-level competitive actions contributing to 'action aggressiveness'. However, that component of the Lee-Malerba framework is embedded in a set of variables concerned with wider characteristics of sectoral systems of innovation. In this paper we focus more specifically on the role of firms' strategies, as discussed in this paragraph, in influencing changes in industry leadership.

Our empirical evidence is grounded on a historical analysis of leadership changes in the global mobile phone industry, from the beginning of the 1980s, when the first handset was introduced to the market, to 2012. Over this period, the industry was characterized by important changes in technologies, government regulations and demand conditions. Some of these changes served as windows of opportunity for latecomer mobile phone vendors, leading to two leadership change episodes: 1) the US-based Motorola was caught up by the Finnish Nokia in the second half of the 1990s, and 2) Nokia was surpassed by the South Korean Samsung in the first half of the 2010s.

The remainder of this paper is structured as follows. In section two, we describe the methods used to investigate the determinants of leadership change in these two episodes. In section three, we describe the results of our historical analysis. Finally, in section four we conclude with a discussion of our findings.

2. Methods

2.1. Research design

We explore the effect of windows of opportunity and firms' competitive action on leadership changes by relying on the history of the global mobile phone industry as the setting for the analysis. In particular, our analysis is in the spirit of 'appreciative theorizing' (Nelson and Winter, 1982), which aims to provide causal explanation of observed patterns, mainly by means of storytelling (Jenkins, 2010). We take a historical perspective to gain insight into the long-term dynamics of changes in industrial leadership and the occurrence of windows of opportunity. This is a historical account of an industry in which outcomes can be measured and compared over time. We look for repeated patterns of changes in leadership that can only be observed at historical timescales (Fine, 1998). A historical perspective allows us to explore emergent principles and to examine the highly contextual relationships between changes in the environment ('windows of opportunity' in the specific case of our analysis), firm competitive actions and their performance (Jenkins, 2010).

The analysis is constructed in two periods, covering the history of the mobile phone industry from its inception in early 1980s until 2012. Each period is delineated by a change in industrial leadership: 1) in 1998 the US giant Motorola was dethroned by the Finnish competitor Nokia; 2) in 2012 Samsung of South Korea surpassed Nokia (Figure 1). The two changes in leadership were observed not only at the global level, but also in several countries (Table 1). Figure 1 and Table 1 show that global market share leaders (Figure 1) were also those which had the capabilities to attain leadership positions in the largest number of countries, irrespective of their differences in size and barriers to entry (Table 1).

Figure 1 and Table 1 about here

2.2. Data

The comparative historical research design posed demanding requirements for data that were not readily available in a suitable form in existing sources – broadly, two types of firm-related information spanning a period of about twenty years. The first type was information about the broad evolution of the mobile phone industry in terms of market and technology trends, as well as changes and differences in the regulatory environments of firms. The second, a much larger requirement, consisted of detailed information more directly related to the characteristics of firms themselves (their products, markets and technologies). Moreover, an important feature of this second category was that the relevant firms in the mobile phone industry cut across a wide variety of different kinds of player: mobile phone manufacturers (e.g., Nokia, Motorola, Samsung); mobile network operators or 'carriers' (e.g., T-Mobile, Vodafone, AT&T); independent mobile phone retailers (e.g. Carphone Warehouse); and manufacturers' suppliers including both (a) suppliers of components such as microchips, software and operating systems (e.g., Google, Microsoft, Qualcomm) and (b) assemblers of electronic components and devices (e.g., Flextronics, Solectron). All these players were able to operate as 'mobile phone vendors' – i.e. firms that marketed handsets under their brand name, regardless of the value chain activities in which they were involved before the product commercialization to end users.

To meet these requirements our study drew on data from a wide range of sources, consolidated in three main databases.

1) The FACTIVA database – a commercially compiled source that searches thousands of newspaper articles, including business oriented media such as *Businessweek*, *Financial Times* and *The Wall Street Journal*. Alongside extensive details about firms and their environments, several of these documents report interviews with managers of handset vendors and industry experts; This information was used to reconstruct the historical evolution of the industry, and in particular the main changes in the technological, regulatory and consumer demand environment.
2) A database constructed by the authors, consisting of information about more than 5,000 handset models and related technologies introduced by 82 mobile phone vendors from 1992 to 2012. The sources of this information consisted mainly of special interest web pages for mobile telephony, such as http://www.gsmarena.com and

http://www.mobile.softpedia.com.[2] These data allowed us to understand a) when product technologies were first introduced in the mobile phone industry and the time it took for competitors to adopt these technologies, b) the extent to which mobile phone vendors relied on certain technologies instead of others when launching new product models, and c) product line extension decisions and a wide range of other firm-level factors important for examining vendors' actions and response, and thereby their strategic intensity and complexity (Ferrier, 2001).

3) Another database, also constructed by the authors, included information about the market shares of larger mobile phone vendors and operating system (OS) manufacturers. The underlying data (primarily about units sold and market shares per mobile phone vendor and operating system manufacturer) were acquired from *Gartner Dataquest* and *Euromonitor International*. These data enabled us to identify the changes in industrial leadership over our study period (e.g. Figure 1 and Table 1), and to understand other aspects of the industry's evolutionary dynamics.

3. Windows of opportunity and leadership change episodes in the worldwide mobile phone industry

This section describes windows of opportunity that emerged in the global mobile phone industry and the responses to these windows by market leaders and challengers. Although we observed various changes over the time period in the technology, regulatory and demand environment, not all these changes contributed in a similar way to opening up a new opportunity for challengers to catch-up with leaders and forging ahead. Therefore, we distinguish between 'significant' and 'marginal' windows.

3.1. Nokia catches up with Motorola

This sub-section deals with the windows of opportunity and firms' strategic responses related to the first change in industrial leadership when Nokia caught up with Motorola. We observed two significant windows that coevolved and worked together: 1) the analog-digital system technological discontinuity, and 2) the asymmetric regulatory changes in Europe and the US. Changes in demand, and in particular the mobile phone commoditization in developed countries, served only as a marginal window as they did not concur to generate the catching-up event but had a tangible influence in strengthening or weakening the firms' responses. In this sub-section we discuss also

[2] Information about some handset models introduced during 1992–1997 also came from other online catalogues like IMEI (http://www.imei.info/phonedatabase/) and a special interest magazine for mobile telephony, *What Cellphone*.

how the US market leader Motorola fell into a 'competency trap', unable to exploit the significant windows of opportunity with the appropriate competitive actions, and how the challenger Nokia relied on strategic intensity and complexity to exploit the windows of opportunity and surpass the US rival.

3.1.1. The analog–digital system technological discontinuity: The first significant window of opportunity

The appearance of a new technology, radically changing the product usability and technical performance, and requiring new investments and manufacturing capabilities to incumbents, represents a window of opportunity for challengers, since both market leader and challengers line up at the same starting line with the new technology. The analog-digital system technological discontinuity in the mobile phone industry is a case in point.

The earliest phones worked on cellular networks based on analog standards, meaning that radio signals used by networks to connect the radio towers (which listen to the handsets) were analog. [3] Analog standards, such as Advanced Mobile Phone System (AMPS) in the US, Total Access Communication System (TACS) in the UK, Nordic Mobile Telephone (NMT) in Scandinavia, Nippon Telegraph and Telephone (NTT) in Japan, were often incompatible among countries (Funk and Methe, 2001). Since most mobile phone vendors had the resource endowments to produce handsets compatible with only a limited number of standards, this slowed down the diffusion of analog handsets, commonly called 'first-generation mobile phones' (1G) (Gandal, Salant and Waverman, 2003). Analog devices were very large in size and weight, mainly mounted on automobiles and particularly expensive (about $5,000 each). In 1983, the US giant Motorola launched in the market the DynaTAC 8000X, the first mobile phone small enough to be easily carried. Drawing on its early investments in cellular technology, Motorola held a strong leadership over the 1980s and the early 1990s, controlling nearly half of the global mobile phone market (Steinbock, 2003), and with a strong dominance in the US market, which at that time was by far the largest one. The main challengers were 1) Ericsson from Sweden and Nokia from Finland, that competed mainly in Europe until the late 1980s, and that were advantaged by the early success of the NMT phone system in Scandinavia, 2) the Japanese vendors Matsushita (Panasonic), Mitsubishi and Toshiba, that were able to gain relevant market positions with AMPS-based phones in the US market (Funk, 2002) (Table 2).

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[3] Standard systems for analog signal cellular phone service used separate cellular channels for each conversation. They therefore required considerable bandwidth for a large number of users.

Table 2 about here

Since mobile phones working with the analog standards were characterized by poor technical performance mainly caused by the relatively small capacity within a given frequency band that absorbed lots of noise, the increasing number of subscribers occurring in the late 1980s was making the adoption of these standards particularly critical (Funk and Methe, 2001). To overcome the limits of analog technologies, the European regulators chose to impose a common standard based on the digital technology (as opposed to the analog one), aimed at fostering the diffusion of the 'second generation' (2G) cellular telecom networks: the Groupe Speciale Mobile (GSM), later translated to the Global System for Mobile Communication.[4] The new digital standard was expected:

1) to have a pan-European nature in order to allow roaming throughout the whole continent (Haug, 2002; Steinbock, 2003);
2) to take advantage of the numerous services related to digital technologies that were being developed at that time (e.g., SMS, games);
3) to facilitate the use of highly integrated circuits in the manufacturing of mobile devices, and then reduce the size and weight of handsets so as to make them more 'portable' (Steinbock, 2002);
4) to diffuse rapidly so as to allow handset manufacturers to exploit economies of scale, lower prices, and thus foster the 'mobile phone commoditization' (i.e., the diffusion of the mobile phone usage to the mass market).

The GSM was launched in Europe in 1991, while it was introduced in the United States in 1995, where it worked together with the analog AMPS.

The introduction of the digital technology at the beginning of the 1990s led to a relevant discontinuity, both at the supply- and demand-level. As for the former, in fact, the transition to the digital standard required a specific set of new competencies for mobile phone vendors. First, to favor the 'digitalization', i.e. the diffusion of the new digital standards, largest vendors had to develop competences to supply also the telecommunication infrastructures needed to make the handsets working with the new standard (Funk and Methe, 2001). Second, since new technologies installed in digital mobile phones were often introduced to improve the handset software performance (Palmberg and Martikainen, 2005), handset vendors were forced both to increase their in-house software development capabilities and build strategic relationships with software component suppliers (Sadowski, Dittrich and Duysters, 2003). As digital mobile phones diffused

[4] GSM is a digital mobile telephony system based on a technology that divides each cellular channel, or 'frequency', into various time slots in order to increase the amount of data that can be carried.

among consumers, the rapid adoption of the latest digital product technologies was necessary to maintain competitive parity with rivals (Giachetti and Lanzolla, 2015). Finally, it was important to start building relationships with the newly franchised independent mobile network operators that were pushing handset vendors to lengthen their line of digital devices to increase revenues from related digital mobile phone services (e.g., SMS, downloadable ringtones). At the demand-level, with respect to analog devices, digital handsets offered superior technical performance to the user (e.g., better voice quality) (Fuentelsaz et al., 2008) and an extended set of functionalities (e.g., games, SMS, Internet and email functions) that made the new generation of mobile phones relatively new to the user. This resulted in a sudden redundancy of 1G analog devices and the rise of 2G services and infrastructures. Digital mobile phones experienced a rapid diffusion after their introduction in the early 1990s, and in 1998 the market for digital handsets was already larger than the one for analog – digital accounted for 84.6% of total handset units sold (*Gartner Dataquest*).

3.1.2. Asymmetric regulatory changes in Europe and the US: The second significant window of opportunity

The mobile phone industry ecosystem was radically influenced not only by the analog-digital technological discontinuity, but also by marked differences in the policies implemented by the regulatory authorities in the world, mainly in Europe and in the US (Fuentelsaz, Maìcas and Polo, 2008).

For the analog technology, the US authority, with the implementation in 1983 of the AMPS as a single analog standard, favored the agreements between different regional network operators. In such a way, the US authority extended the roaming possibilities (Fuentelsaz et al., 2008) and the positive network externalities (Shapiro and Varian, 1998). In contrast, the European scenario was dominated by many state-owned telecommunications services, which resulted in local monopolistic situations with the effect of favoring the birth of several non-compatible analog standards, limiting the handset vendors' chance to rely on economies of scale and reduce prices. This also slowed the penetration rates of cellular phones and services due to the high calling fees set by network operators (Blackman, Cave and David, 1996; Funk and Mehte, 2001). These asymmetric effects on competition rules were reflected in significant differences in the diffusion rates of cellular phones throughout the world. In 1993, the US, with less than 5% of the world population, accounted for 48% of the world subscribers, while Europe accounted for 25% and Asia/Pacific (including Japan) 15% (The World Bank, 2013). From 1983 to the early-1990s the US giant Motorola profited from these asymmetries in demand among countries, largely affected by differences in regulatory

activities that inevitably offered a favorable competitive condition to US-based mobile phone vendors.

For the digital technology, the behavior of regulatory authorities changed markedly. The US Federal Communication Commission chose to let the market determine the standards (Gandal, Salant and Waverman, 2003). In the mid-1990s, the main, not compatible, opponent standards were the TDMA (Time Division Multiple Access) standard, provided by Ericsson, and the IS95-CDMA (Code Division Multiple Access) standard, which was implemented by Qualcomm (Lee and Lim, 2001). Furthermore, the implementation of digital standards in the US experienced a long coexistence with the analog standards, since analog phones were still profitable. In contrast, in Europe, the regulators chose to impose the GSM standard, a unified system for digital technology defined in its technical specification through tight collaboration between governments and industry. The European regulatory strategy was that of rapid replacement of the analog standards with the GSM system. The decision to eliminate the market in defining the digital standard and "the adoption of a common standard in the EU can be considered a great success, contrary to the strategy followed in the US" (Fuentelsaz et al., 2008: 448). At the end of 2005, the world market penetration of GSM was much higher than that of the alternative standards: GSM represented nearly the three-fourths of the total users.[5] Moreover, the regulatory asymmetries between the US and Europe resulted in substantial gaps in the digital phone penetration, with the highest diffusion rates in Europe.

3.1.3. Towards the mobile phone commoditization in developed countries: The marginal window of opportunity

The mobile phone revolution started at the beginning of the 1990s, determining a radical change not only in the product architecture, but also in the profile of mobile phone users (Steinbock, 2003). While up until then the handset market was still largely a domain for business users, with the introduction of digital technologies, the size and weight of handsets was further greatly reduced, the prices dropped and the network coverage expanded, making the cellular phone a mass-market product in most developed countries. In turn, the profits associated with this growth stage of the mobile phone industry attracted other competitors to the product market. Since firms had to cope with an increasingly heterogeneous demand, market segmentation served mobile vendors as a basis for differentiation. They were struggling to design handsets for all the actual consumer segments, from a mono-colour elegant business style to colourful interchangeable plastic covers for fashion-

[5] Information collected from Nokia archival data.

conscious teens and easy-to-use models for the 12-year-old set. Therefore, the transition of the mobile phone from a business niche device to a global consumer product required a new marketing approach: everyone was a potential mobile phone consumer.[6] As the mobile phone market became increasingly segmented, the ability to master various product categories became crucially important (Häikiö, 2001).

Although we believe changes in the demand conditions during the 1990s were not highly relevant for the generation of a catching-up event, they however represented an additional window of opportunity for those mobile phone vendors that were able to understand earlier than rivals the progressive transition of handsets from niche to mass-market products.

3.1.4. Motorola's competency traps during the digital revolution

After an initial period of strong industrial leadership, Motorola fell in a competency trap when the analog–digital system technological discontinuity became relevant (Crockett and Elstrom, 1998; Giachetti, 2013; Häikiö, 2001).

Although the digital standards were quickly diffusing in many countries, Motorola persisted to invest heavily in analog mobile phone technologies, believing that customers would accept the technological trajectories imposed by its leadership and that its main market, the US, would have experienced a slower penetration of digital phones (Funk, 1998). In 1995, Motorola top management came up with a program called 'Signature' to promote the company's new analog phone, the StarTAC, priced more than $1,000, and offered only to those network operators who bought at least three-fourths of their phones from Motorola and only if they agreed to promote the phone in stand-alone displays. The largest network operators, like AT&T, refused to participate in the program since were already in the process of switching to the digital system, convinced about its superiority. When in the mid-1990s network operators started offering to users digital phones, while Nokia and Ericsson's product line was almost entirely focused on digital devices, Motorola was still very concentrated on handsets compatible with analog standards. US network operators began to buy handsets from Nokia, the main challenger, that was able to progressively penetrate the US market, at that time characterized by a subscriber base much larger than any other country. Over the first half of the 1990s Motorola lost half of its global market share (Figure 1). Due to the "high growth of GSM subscribers and the lower market shares of Motorola in GSM-based phones (23%) than AMPS- (70% in the US) and TAC-based (40%) phones" (Funk, 1998: 425), also in the second half of the 1990s, when digital phones sales started to grow rapidly, Motorola's market share

[6] Driven by the popularity of digital mobile phones, at the end of the 1990s the average mobile telephone penetration rate in developed countries surpassed 40% (The World Bank, 2013).

continued to drop. This loss of market share occurred mainly in the US, where the decision to support Qualcomm's IS95-CDMA over GSM delayed Motorola's penetration in the digital market segment (a segment whose boom was mainly driven by the success of the GSM). Motorola was rapidly losing shares also in Europe, where most of network operators had already adopted GSM and were reluctant to ally with a company which was still heavily investing in the opponent CDMA standard (Funk and Mehte, 2001).

3.1.5. Nokia's successful strategic responses in tackling the digital revolution

While Motorola missed various opportunities of the digital revolution at the beginning of the 1990s, Nokia was able to undertake a set of competitive actions to better exploit the advantages offered by the three previously mentioned windows of opportunity and progressively catch-up with the US rival.

First, as for the analog-digital system technological discontinuity, the Finnish vendor during the 1990s took an aggressive competitive posture mainly in three ways. It focused much earlier than its rivals on the development of digital services and equipment, so that it became the leading supplier for GSM cellular infrastructure (through Nokia Telecommunications) in Europe (Steinbock, 2001). Moreover, it acted as first mover in the introduction of most of the revolutionary innovations based on the digital standard, like SMS and games (Table 3), thus making its handset models more competitive with respect to those of rivals. Finally, it rapidly lengthened its product line with respect to its competitors, in order to give customers of digital handsets a larger variety of product choices (Figure 2), thus covering all the principal segments (e.g., phones for the consumer market and phones with advanced features for the business market), all the major standards, and capturing the product diffusion advantage rapidly when the mass market was forming (Steinbock, 2002). With this complex repertoire of competitive actions, Nokia was able to effectively manage the technological and demand uncertainty derived by the rapid changes in the environment and to strengthen its relationships with the largest network operators.

Table 3 and Figure 2 about here

Second, Nokia took advantage of some favorable conditions related to the asymmetry in regulatory changes between Europe and the US. In fact, the European regulatory strategy of replacing rapidly the analog standard with the GSM digital system, amplified the effectiveness of Nokia aggressive investments in the digital standard, and encouraged Europe-based vendors, and Nokia in particular, to adapt their capabilities rapidly to fit the emerging technology. Moreover, Nokia gained a specific positioning advantage with respect to the other European competitors. On

the one hand, in the 1990s, the evolution of the Finnish innovation system was important in favoring the growth of new technological competencies in the digital field. In 1999 the R&D expenditure in Finland relative to GDP was 3.2% (starting from 1.8% in 1989), while it was only 1.9% in EU (OECD). On the other hand, Nordic countries, due to the high costs of connecting their sparsely populated areas with fixed wire, were one of the first regions in the world to install wireless phone services and to pose strong incentives for establishing cellular services. In Finland, in particular, by 1995, the penetration rates (mobile phone subscribers per 100 habitants) had risen above 20%, the highest share in the world at that time (The World Bank, 2013).

Third, Nokia's management team understood earlier than rivals that only with greater usability and excellent design mobile phones could become mass consumer products rather than mere network terminals (Doz and Kosonen, 2008). From the mid-1990s Nokia's handsets were characterized by user interface friendliness, smaller and lower weights in order to facilitate portability, and innovative design thanks to the numerous collaborations with leading designers (Häikiö, 2001).

From the end of the 1990s and throughout most of the 2000s, Nokia was able to establish a solid market share leadership not only at the global level (Figure 1), but also in most geographic markets (Table 1).

3.2. Samsung catches up with Nokia

In this sub-section we examine the windows of opportunity and firms' strategic responses related to the second change in industrial leadership: Samsung catches-up with Nokia. We observed a single significant window: the regular phone-smartphones technological discontinuity. We believe asymmetric regulatory changes (i.e., asymmetric regulation in support of Korean mobile phone vendors) acted mainly as a favoring condition that initially supported Samsung in the gradual catch-up stage, while changes in the demand conditions (i.e., rapid diffusion of handsets in developing countries) had a tangible but less relevant influence in the forging ahead stage. In this sub-section we discuss also how the market leader Nokia fell into a 'competency trap', unable to exploit the significant window of opportunity with the appropriate competitive actions, and how the Korean challenger Samsung relied on strategic intensity and complexity to exploit the window of opportunity and surpass the Finnish rival.

3.2.1. The regular phones–smartphones technological discontinuity: The most significant window of opportunity

Since the mobile phone markets in the first half of the 2000s reached impressive penetration rates in most developed countries, mobile phone vendors were forced to rapidly upgrade handsets with new technical features in order to stimulate the demand for replacement purchases. The 'unexpected' upsurge of product innovations in this stage of industry maturity fostered the diffusion of 'smartphones' (Giachetti and Marchi, 2010). In fact, since the end of the 1990s, handsets have been commonly distinguished in two categories: (a) regular phones, or 'feature phones', offering mainly basic phone and multimedia functionalities, relatively cheap and targeted at the low- and mid-end market, and (b) 'smartphones', namely handsets equipped with advanced operating systems offering PC-like capabilities (e.g., download and read documents, install applications), more expensive than regular phones and targeted at the high-end market. We decided to use the 'advanced operating system' as the demarcation criterion to distinguish between 'smartphones' and 'regular mobile phones'.[7]

The diffusion of smartphones marked a strong discontinuity in the industry (Funk, 2008), both at the supply- and demand-level. At the supply-level, the technological discontinuity resides mainly in the introduction of more sophisticated operating systems (OSs) for smartphones with respect to those OSs commonly mounted on regular phones. The advanced OSs mounted on smartphone devices were increasingly sourced externally from specialized providers and were aimed to provide standardized interfaces between hardware and software components. Despite that, vendors had to develop absorptive capabilities and architectural competences, especially related to software integration, that became the key differentiation element to obtain competitive advantage (Suarez and Kirtley, 2012). At the demand-level, the discontinuity referred mainly to the user experience, that radically changed with the introduction of smartphone-related technologies, both from the handset hardware and software side. Since the mid-2000s the price/performance ratio of an increasing number of smartphone models became clearly better than that of regular phones, and this stimulated a strong replacement rate in the market (Figure 3).

Figure 3 about here

Nokia had held a leadership in the market for smartphones since its Symbian OS was first commercialized in 2000. As mobile phones showed the first signs of technological convergence in

[7] We took this decision regarding operating systems, after performing an extensive content analysis of various special interest magazines for mobile telephony. The operating systems we consider as 'advanced' in the time period analyzed are mainly the following: Android OS, Bada, BlackBerry OS, Linux, Mac OS, Microsoft Windows Mobile, Palm OS, and Symbian.

the mid-1990s,[8] with an increasing importance of software as technologies for product differentiation, Nokia and other vendors founded Symbian Ltd. in 1998, a joint venture between Nokia, Psion, Ericsson and Motorola, to share a common platform (and thus facilitate applications and data transfer compatibility between handsets) and contrast a potential escalation of Microsoft Windows' operating system for mobile phones, introduced in 2000. While Symbian OS had a rapid diffusion, Microsoft Windows Mobile was never able to gain momentum in the market. By 2008, Symbian was still the market leader in advanced OSs for mobile phones, with more than 60% market share (Figure 4). Nokia was by far the largest licensee, controlling the production of about 70% of all Symbian phones.

With the boom of 'convergent' multi-tasking devices in the mid-2000s, many other technology firms like PC manufacturers and software providers started to sell high-end smartphones. Apple entered the fast-growing market for smartphones with the launch of its iPhone in 2007. The iPhone was run on Apple's own mobile OS called iOS, not licensed to other vendors. The entry of iOS changed the face of the smartphone market (West and Mace, 2010). First, unlike the older mobile OSs, like Symbian, iOS was custom built to support the multi-touch display.[9] In this Apple took advantage of its unique strengths in user interface, styling and branding, on which consumers were putting particular attention. By contrast, Nokia's new multi-touch devices, similar to the iPhone in terms of design but equipped with Symbian, did not sell as expected. One reason was the bad performance of Symbian when responding to the user's commands sent by the phone multi-touch interface (Suarez and Kirtley, 2012). Second, Apple also increased the competitiveness of the iPhone by leveraging its installed base of iTunes, the largest music retailer in the US, used by consumers to purchase also applications for handsets, popularly known as 'apps'. Mobile 'apps' were initially offered for information retrieval and agenda functionalities. However, the entry of Apple in the mobile phone industry marked a relevant change at a demand-level, since it fostered the rapid diffusion of apps into other popular categories, such as social networks, mobile games, location-based services, banking and ticket purchases. Apps became another key differentiation element to survive in the mobile phone competitive landscape since its rapid diffusion radically changed the mobile phone user's experience.

In 2008, the introduction of Google's Android OS, an operating system based on open standards, shocked up again the smartphone market (Kenney and Pon, 2011). First, Android, as

[8] 'Technological convergence' refers to the tendency of handsets to be equipped with technologies originating in other product category (e.g., camera, MP3 player, radio).
[9] In computing, multi-touch refers to a touch sensing display's ability to recognize the presence of two or more points of contact with its surface. Apple iPhone was the first handset equipped with this technology.

Apple's iOS, had a vast collection of apps, most of them free to consumers. Second, mobile phone vendors could adopt Android for free, since Google did not required any license fees to pay as in the case of other wireless operating platforms like Symbian and Windows Mobile. Google decided to provide Android for free as all Android-based phones came embedded with Google Search, and this led to greater usage of Google's search services and applications like Gmail, enhancing the propensity for users to click on Google's paid ads and increasing its ad revenue. In this way, mobile phone vendors adopting Android could reduce operating costs related to the production of their smartphones (and at the same time rely on a highly performing OS), and in turn increase the price competitiveness of their product portfolio. The first Android handset, also known as 'T-Mobile G1', was introduced by T-Mobile and co-branded with Google in September 2008. Globally, in 2011 Android became the highest selling smartphone operating system, mainly driven (as we will explain later) by the success of Samsung's Android-based smartphones, followed by the rapidly declining Nokia's Symbian with half the market share of Android (Figure 4).

Figure 4 about here

Google offered a 'platform' on which other players within the ecosystem (e.g., manufacturers, network operators and applications developers) could build and enhance their revenue by exploiting the larger installed base of consumers attracted by the broader supply of applications. For example, at the beginning of 2011, with regard to the US market, the Apple App store contained more than 333,000 apps (nearly 35% free), the Android marketplace counted for more than 200,000 apps (nearly 65% free), while Windows Marketplace for Mobile stored less than 12,000 apps (nearly 20% free).[10] The much lower apps availability was one of the main causes of Microsoft OS market share rapid decline (Figure 4).

Our analysis highlights that the launch of the Apple's iPhone and Google's Android OS caused a technological discontinuity in the mobile phone industry, giving birth to a new generation of smartphone devices, and offering catching-up opportunities for challengers with respect to the leader Nokia (as we will also discuss later in more detail). Interestingly, while the analog-digital technological discontinuity at the beginning of the 1990s was an exogenous window of opportunity for all mobile phone vendors, the window of opportunity related to the diffusion of the new generation of smartphone devices (and the resulting decline of regular phones) was favored by the launch of radical innovations (i.e., iPhone and Android) endogenously introduced and exploited by Apple and Google (both competing as handset vendors), but exogenously adopted by all the other

[10] Information on the number and type of applications were collected mainly from http://www.distimo.com.

vendors. This suggests that, although we defined windows of opportunity as *macro-level* determinants of leadership change episodes, they are not necessarily exogenous for all rivals because they can be endogenously created by some rivals themselves.

3.2.2. Towards the mobile phone commoditization in developing countries: The marginal window of opportunity

Since mobile phone vendors did not hold the same market share in all geographic markets in which they competed, the asymmetries in the characteristics of the demand (e.g., size, growth rate) severally shaped the competition in the global market and affected the catching-up trajectories significantly.

In the late 2000s, when the smartphone revolution was mounting, the global mobile phone market was clearly split into (1) developed countries, where the demand was mainly for replacement and the role of network operators in subsidized enhanced handsets was crucial, and (2) emerging markets, where new sales were fueling the customer demand and progressive commoditization of the mobile phones was occurring (The World Bank, 2013). Overall, in 10 years the world map of mobile phone demand was revolutionized: for example, in the 2000-2009 period, the average growth rate of the number of subscriptions in the four largest European developed countries in terms of nominal GDP (i.e., France, Germany, Italy and UK) was more than seven times slower than in BRIC economies (Brazil, Russia, India, and China) (The World Bank, 2013). In 2002, China had already overtaken the US as the number one mobile market in the world, with a customer base of roughly 200 million users. In 10 years, the Chinese mobile phone market grew further at an exponential rate and reached over 700 million subscribers in 2009, and over 1.1 billion in 2012 (Vialle et al., 2012). Yet, since in 2011 the number of mobile phone subscribers per 100 inhabitants in China was still around 20% lower than in the US and less than half than in Finland, there was still enormous potential for future handset demand, smartphones in particular (Xia, 2011). In such a changing environment, firms with strong market positions in the largest fast-growing markets, such as China, can have greater advantages in terms of sales and economies of scale with respect of vendors mainly positioned in the mature markets.

3.2.3. Nokia's competency traps during the smartphone revolution

During the smartphone revolution exploded in the second half of the 2000s, Nokia ignored the possibility to incorporate Android OS in some of its new handset models. Over the 2000s almost all smartphones introduced by the Finnish vendor were equipped with Symbian OS (Table 4). The firm's decision to buy out the minority partners of Symbian for more than €250 million, and to

continue to invest in Symbian OS was a clear sign the company was reluctant to cannibalize profits from the existing operating system, which was apparently successful until the mid-2000s but showed increasingly disappointing results after the apps hype and the diffusion of handsets with multi-touch display (Suarez and Kirtley, 2012). In fact, Symbian on the one hand was not optimized for touchscreen displays, on the other hand it offered to users a portfolio of apps not comparable to the one of Android (Kenney and Pon, 2011). This resulted in an impressive market share loss of Nokia (and then Symbian)'s phones in by now the only profitable market: the smartphone one (Figure 4). Even the decision of Nokia, in 2011, to progressively switch to Microsoft Windows Mobile (Table 4) and attract more third-party applications developers, did not help the firm to revamp its weakened brand image and competitive position, and the hegemony of Android and iOS was not challenged.[11] It is also interesting to note that, in the second half of the 2000s, before sales and profits began to decline in 2011, Nokia's R&D budget for handsets was a third higher than Samsung, almost double BlackBerry-maker Research In Motion and more than twice Motorola, as a confirmation the Finnish vendor was investing a lot, but at a certain point its innovation strategy was no more adequate to exploit the opportunities offered by the changing environment (Ewing, 2009; Srivastava and ben-Aaron, 2011), increasingly influenced by Apple and Google's ecosystems.

Table 4 about here

3.2.4. Samsung's successful strategic responses in tackling the smartphone revolution

The key success factors that helped Samsung to exploit the advantages offered by the previously mentioned windows of opportunity and catch up with Nokia can be explained as follows.

First of all, it is worth to notice that Samsung took advantage of some favorable initial conditions occurring in the Korean economic and institutional environment which, since the early 1990s, significantly supported Samsung in its gradual catch-up stage. In the 2G markets, similarly to the decision taken by the European authorities to impose the GSM standard, the Korean Government chose to impose a unique mandatory digital standard in the local market: the CDMA. Through an R&D consortium established in conjunction with local mobile phone vendors and the US firm Qualcomm (Lee and Lim, 2001), the Korean Ministry of Information and Communication subsidized more than half of the CDMA project's total costs of US$12.45 million (Jho, 2007). This

[11] On February 2011, Nokia and Microsoft announced a roadmap for a broad strategic partnership, aimed at fostering the diffusion of a new ecosystem. Under this agreement, Nokia would largely use Microsoft Windows Mobile on its high-end phone models (and then would progressively stop producing Symbian-based smartphones), and both companies would work together on joint marketing initiatives.

policy decision of the Korean government worked as an entry barrier to foreign handset vendors, which were limited in selling telecom equipment to the Korean market, and this gave the Korean firms a first-mover advantage in the new technology (Lee and Lim, 2001). By the end of 1997, one year after the introduction of CDMA, Samsung had achieved a 57% market share in the Korean CDMA cellular market. In 1999, while Nokia was becoming the undisputed leader in the GSM segment, Samsung reached the worldwide leadership in the CDMA market with more than 50% of share (Yoo, Lyytinen and Yang, 2005), at that time corresponding approximately to 15% of the world mobile subscribers. Moreover, the consolidated capabilities in the development of CDMA phones boosted the Korean vendor's competitive position in the CDMA2000 (3G) market, that from the end of the 2000s was rapidly diffusing in China and other key developing countries, where Samsung was progressively strengthening its leadership. CDMA2000 showed greater compatibility with the 2G CDMA. This solution allowed Korean manufacturers to leverage their knowledge specialization advantage in CDMA as they did not want to put at risk their established positions in those export markets with the highest demand potential, where CDMA was still the dominant standard (Jho, 2007) or the standard used by large market segments (more than 53 million Chinese subscribers used CDMA handsets in 2012).

Second, Samsung arrived at the door of the regular phones–smartphones technological discontinuity with a consolidated brand image, greater than that of other Korean competitors, such as LG and Pantech. In fact, since the late 1990s, the Korean vendor has established itself as a high-end player and ultra-cool brand by focusing on stylish, feature-packed products. On the one hand, Samsung's massive investments in marketing strategies dated back to the late 1990s. At the beginning of the 2000s Samsung's sales and marketing expense per unit sold in the mobile phone business ($17) was already greater than expenses of Nokia ($9) and Motorola ($14) (Korea Information Strategy Development Institute – KISDI). On the other hand, Samsung's strategy has been always driven by huge investments in R&D. At early 2000s Samsung' R&D expense per unit sold in the mobile phone business ($16) was twice than that of Nokia (KISDI). In the mid-2000s Samsung added nearly 4,000 R&D engineers to prepare for the industry's shift to data-centric third-generation technologies (Ihlwan, 2007). By taking advantage of its cumulated experience in the production of stylish and technologically sophisticated devices, Samsung was the first mobile phone vendor to consider the immediate and massive adoption of the Android OS into its smartphones, and to use Symbian only for a limited number of models (Giachetti, 2013; Grobart, 2013). Samsung's Android-based smartphones, and in particular its line of high-end Galaxy phones, became a true competitor to Nokia Symbian-based phones and Apple's iPhone. In particular, we observed that from the end of the 2000s Samsung product line was much longer than the one of

direct competitors, such as Nokia, LG, Sony-Ericsson and Motorola, thanks to the numerous smartphones it introduced every year (Tables 4 and 5). At the whole product portfolio level, the number of new models introduced by Samsung on a yearly basis surpassed the number of phones introduced by competitors like Nokia and Motorola from 2005. Through an aggressive product portfolio strategy the Korean vendor introduced 166 new smartphones in the period 2010–2012 (Table 5), of which 86% incorporating an Android OS (Table 6), against the 94 smartphone models of the second most active firm (i.e., Motorola), and more than three times the number of new models launched by the leader Nokia (49). In 2012 the number of Android-based smartphones introduced by Samsung was nearly double those introduced by Motorola and LG, and three-times those introduced by Sony-Ericsson (Table 6). Despite the impressive number of new smartphone devices within its product line, Samsung was able to attenuate the risk of 'self-cannibalization' by launching Android-based phones with similar technical features but with different size. The set of full-touchscreen Galaxy high-end phones is a case in point. The rapid introduction of a wide range of similar devices in various sizes to see which is mostly appreciated by customers is one of those tremendously costly product line strategies most handset vendors avoid. But Samsung's highly vertical integrated structure offering the firm a great ability to rapidly produce displays, memories, processors, and other handset components, gave it a strategic flexibility and production efficiency most of competitors did not have (Grobart, 2013). In fact, when the environment is characterized by hypercompetition, and thus the 'speed of competitive response' is crucial for the firm survival (McGrath and Kim, 2014), vertical integration can accelerate the development of systemic innovations by facilitating information flows, the coordination of investment plans (Teece, 1996), and time-to-market reduction (Jacobides and Billinger, 2006). Driven by the launch of many Android-based successful products (e.g., Galaxy series) and by an upgraded identity as premium brand, Samsung rapidly pushed up its market share (Figure 1).[12] While the rapid and massive adoption of Android-based smartphones was undoubtedly a key factor fostering Samsung's first-mover differentiation advantage, the success of Samsung's products prompted many followers, the fast-growing Chinese vendors included, to adopt the Android OS, boosting the diffusion of this operating system in the global smartphone market.

[12] A counterexample to the successful product line extension strategy of Samsung is the focus strategy of Apple with its iPhone. In fact, the US firm, from the introduction of the iPhone in 2007, has relied almost only on a single product model per year (i.e., the iPhone, plus some variants in terms of color and RAM capacity, and some tablet devices with phone capabilities). The narrow product line strategy of Apple is successful because the firm positioning is only in the high-end market, and having few models within the line makes buying an Apple new product model 'simple', especially for brand loyal customers that want the process of choosing a high-tech expensive product to be not complicated by a plethora of choices. This focus strategy is coherent with all the other devices in the Apple's portfolio (i.e., tables, MP3 players, PC). Apple's action in the mobile phone industry is thus focused on a single device (e.g., heavy investments in advertising, broad iPhone launches in several countries, wide variety of iPhone complementary products).

Third, as for the window of opportunity related to the commoditization of mobile phones in the emerging economies, Samsung benefitted from its consolidated leadership in the largest market for handsets, i.e. the Chinese one. In China, over the 2000s, Samsung's market share constantly increased at an impressive speed: the Korean vendor became the leader in 2012 with a market share of more than 20%, nearly two times that of Nokia and three times that of Apple (*Euromonitor International*). Nokia failed to surf the wave of the mobile phone commoditization in China mainly because its weakened brand identity with respect to the Korean rival, both in the low-end and high-end market (Ewing, 2009). We found that nearly half of the global market share lost by Nokia from 2010 to 2012 was in the Chinese market.

From the end of the 2000s, Samsung was able to gradually catch-up with Nokia not only at the global level (Figure 1), but also in most geographic markets (Table 1).

Tables 5 and 6 about here
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4. Discussion and conclusions

Our analysis of leadership changes in the mobile phone industry has sought to contribute to three streams of literature concerned with: (i) the role of radical discontinuities in technology (Tushman and Anderson, 1986), (ii) processes of catching up by latecomer firms (Malerba and Nelson, 2012), and (iii) the competitive dynamics of firms and industries (Ferrier et al., 1999). More specifically, it has relied on Lee and Malerba's (2015) extended concept of windows of opportunity in the context of successive stages in industry catch-up cycles. Drawing on these insights, the analysis suggests that, to gain a better understanding of the causes of leadership changes, both windows of opportunity in the changing technological, demand and regulatory environment (i.e., *macro-level* determinants of leadership change episodes) and firms' strategic actions (i.e., *micro-level* determinants of leadership change episodes) should be considered jointly.

In particular, by drawing on the concept of action aggressiveness (Ferrier, 2001; Ferrier and Lee, 2002), we offer a fine-grained representation of the mechanisms lying behind the effectiveness of the incumbent and latecomer firms' responses in relation to the opening up of a window of opportunity. Over the industry evolution, we found that market leaders are likely to be caught up by those challengers that compete more aggressively and adapt their capabilities more rapidly to exploit the advantages offered by changes in the macro environment. These changes open transitory windows of opportunity during which every competitor, both leader and challengers, is like a 'beginner' (Perez and Soete 1988; Park and Lee, 2006) and differences among firms, in terms of

core competencies needed to capture the advantage from changing conditions, are not so large. More specifically, our findings suggest two patterns.

First, winning challengers showed greater 'strategic intensity' than market leaders, by exploiting more promptly the opportunities related to the rapidly changing environment. In fact, in both leadership change episodes, Nokia in the late 1990s and Samsung at the beginning of the 2010s demonstrated an extraordinary ability to carry out in rapid succession a number of competitive actions significantly larger than market leaders and other incumbents. For example, Nokia was the firm that, at the end of the 1990s, introduced the highest number of innovations related to the digital standard, while Samsung was the first to quickly increased the number of Android-based smartphones in its portfolio from the end of the 2000s, resulting in a longer product line with respect to direct competitors.

Second, the winning challengers showed also a higher 'strategic complexity' than market leaders. In a relatively short period, first Nokia and later Samsung, were able to carry out a complex sequence of competitive actions, including massive R&D (e.g., new technologies embedded in the devices, fashionable handset design) and marketing investments (e.g., investments in brand equity, relationships with main network operators), as well as the ability to rapidly cover with their product lines the largest new segments formed in the market. In other words, in both leadership change episodes, the two challengers rapidly adopted a wide repertoire of competitive actions that allowed them to be the first in addressing with successful new product lines the pressing 'demand for newness' fueled by changes in the macro environment.

Moreover, our results show that, together with the performance advantages obtained by firms taking an aggressive competitive posture when windows of opportunity were open, successful challengers attained the number one position also because old leaders were not able to avoid the competency trap, and their competitive actions were not adequate to successfully compete in the changing environment. First, at the beginning of the 1990s, the Motorola's delay in adopting the leading digital standard and reluctance to cannibalize profits from products based on analog technologies, made the subsequent inevitable transition to the digital standard very slow and costly. Second, over the second half of the 2000s, Nokia's mistaken belief that Symbian OS would have necessarily performed better than Apple and Google's revolutionary operation systems, progressively weakened its industrial leadership. In sum, old leaders tended to adopt competitive actions mainly aimed to exploit the knowledge cumulated in the past and to capitalize the investments in the old technology, and paid scarce attention to take competitive actions fitting the changing technologies, consumer demand and regulatory environment.

Our paper is not without limitations, that suggest opportunities for future research. First, our analysis does not examine whether windows of opportunity (1) followed a different chronological sequence in the two catching-up episodes, and (2) were self-reinforcing over time. We thereby hope that future research will investigate more deeply the joint effect of macro- and micro-level determinants of changes in industrial leadership through an approach that explicitly considers the sequence of windows of opportunity and their self-reinforcement over time. Second, since our analysis is mainly focused on the forging-ahead phase of the industry catch-up cycle, in this paper we offered only scattered evidence of longer processes of technological and marketing capabilities accumulation that typically characterize fast-growing latecomer firms in the gradual industry catch-up stage. Future research should take a more systematic examination of the evolutionary nature of those specific capabilities that make challengers able to identify the new opportunity and then to behave aggressively in their strategic actions as soon as the windows of opportunity emerge (Lee and Malerba, 2015). Third, our analysis does not examine the strategic behavior and rapidly strengthening competitive position of Chinese vendors (Lee, Cho and Jin, 2009). Our longitudinal narration of events in the global mobile phone industry ends in 2012, a year when Chinese mobile phone vendors had already gained solid market shares in their home country, and were rapidly surpassing Western rivals, like Motorola and Sony-Ericsson, by means of aggressive pricing, product imitation and innovation, together with a strong support of the local government and an impressively fast growing local demand. We believe that if vendors based in developed countries will not be able to respond to the action aggressiveness of Chinese rivals, we might observe a third catching-up in a decade or so, hopefully a new research issue for strategy and innovation scholars. Finally, we hope future research will explore leadership changes from different angles, considering other dimensions of industrial leadership. In fact, on the one hand, our analysis examines changes in industrial leadership in terms of market share in the mobile phone industry as a whole, without distinguishing between industry segments. For example, although at the whole product category level Apple's market share in units sold was relatively low in 2012 with respect to Samsung and Nokia, in the smartphone segment the US vendor sold a number of devices close to the leader Samsung. On the other hand, other than units sold, there could be other measures of industrial leadership appropriate for our analysis, like profitability. For instance, while Apple and RIM of Canada that had focused only on the sales of smartphones, together owned just about 3-4% global market share at the end of the 2000s, they had much higher shares in terms of industry operating profits.[13]

[13] Data about shares in industry profits were collected from *Asymco*.

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Table 1. Number of countries in which the firm is #1, #2 or #3 in terms of market share (based on units sold).

	1990s	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Motorola #1	#1 in the US with decreasing shares; #1 in China till 2002; decreasing market share in Europe.	4	4	4	5	3	1	1	1	0	0
Motorola #2		12	10	9	6	5	4	2	0	2	0
Motorola #3		7	8	6	8	6	7	3	2	2	2
Nokia #1	Increasing leadership in Europe (with Ericsson); Slow increasing shares in the US; leading positions in China (with Motorola and Ericsson); #1 in India.	38	38	39	38	39	39	39	35	27	13
Nokia #2		5	4	3	4	3	1	1	5	9	19
Nokia #3		0	1	0	0	0	1	2	2	4	9
Samsung #1	#1 in South Korea in the late 1990s; Increasing shares in China, till about 8-10% at the end of the 1990s – beginning of the 2000s. Rapidly increasing market share in India.	1	2	1	1	1	4	5	8	15	29
Samsung #2		11	12	15	18	22	27	27	27	25	12
Samsung #3		14	13	15	14	14	7	9	5	3	3
Apple #1	-	-	-	-	-	0	0	0	1	2	3
Apple #2		-	-	-	-	0	0	1	4	5	8
Apple #3		-	-	-	-	0	0	2	7	9	9

Sources:

- Over the 1990s (are reported information only for some geographic markets): various articles from business magazines (mainly Businessweek).
- From 2003 to 2012: our elaboration from Euromonitor International (information available on 46 countries).

Table 2. Mobile phone vendors market share ranking in the analog standards (selected years).

	Analog standards			
	US AMPS		NMT	TACS
	1989	*1996*	*1991*	*1994*
Motorola	1	1	1	1
Nokia	10	2	2	2
Ericsson	9	8	3	3
Matsushita	2	6	5	
Mitsubishi	3	5		
Philips			4	
Toshiba	4	9		

Source: adapted from Funk (2002).

Table 3. Some of the main product technologies introduced by mobile phone vendors in their new models

Product technology	Firms introducing the technology[a]	Year of introduction
SMS	Nokia	1992
Composer	Ericsson	1997
Infrared	Nokia	1997
Games	Nokia	1997
Voice recorder	Sony	1997
Touchscreen	Alcatel	1998
Email client	Nokia	1998
Radio	Sagem	1998
WAP	Nokia	1999
MP3 player	Samsung and Siemens	2000
Color screen[b]	Nokia and Ericsson	2000-2001
Bluetooth	Ericsson	2001
Photocam	Sharp	2001
Videocam	Nec and Panasonic	2003
iTunes	Motorola	2005
Multi-touch display	Apple	2007
Android OS	T-Mobile	2008

Notes:

[a] The first firm adopting the new product technology in its product portfolio.

[b] More than 200 colors.

Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Table 4. Percentage of smartphones per OS

		1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Motorola	*Symbian*	-	-	-	-	100%	14%	14%	0%	20%	8%	0%	0%	0%	0%
	Windows	-	-	-	-	0%	43%	14%	0%	20%	8%	30%	3%	0%	0%
	Android	-	-	-	-	0%	0%	0%	0%	0%	0%	20%	97%	100%	100%
	Others	-	-	-	-	0%	43%	71%	100%	60%	85%	50%	0%	0%	0%
Nokia	*Symbian*	0%	100%	-	100%	100%	100%	100%	100%	100%	100%	95%	100%	76%	21%
	Windows	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	12%	79%
	Android	0%	0%	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Others	100%[a]	0%	-	0%	0%	0%	0%	0%	0%	0%	5%	0%	12%	0%
Samsung	*Symbian*	-	-	-	-	100%	17%	50%	0%	0%	50%	11%	0%	0%	0%
	Windows	-	-	-	-	0%	33%	50%	100%	100%	50%	56%	16%	4%	5%
	Android	-	-	-	-	0%	0%	0%	0%	0%	0%	22%	68%	88%	93%
	Others	-	-	-	-	0%	50%	0%	0%	0%	0%	11%	16%	7%	2%

Numbers may not add to 100% due to rounding.
[a] Advanced version of GEOS operating system.
Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Table 5. Number of smartphones introduced per year (selected mobile phone vendors)[a]

	1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Nokia	1	1	0	2	5	10	13	9	15	15	20	18	17	14
Motorola (acquired by Google in 2011)	0	0	0	0	2	7	7	2	5	13	10	29	34	31
Samsung	0	0	0	0	1	6	4	5	4	14	18	37	68	61
Sony-Ericsson (Ericsson before 2001; Sony from 2012)	0	0	0	1	1	1	1	3	1	4	1	8	14	22
LG			0	0	0	0	0	0	1	1	7	21	30	35
RIM (Blackberry)					3	5	1	5	8	6	7	8	11	2
Apple									1	1	1	1	1	4
HTC								8	12	11	18	18	32	31
ZTE									0	0	2	5	14	37
Huawei									0	0	2	6	14	21
Industry average	*0.1*	*0.2*	*0.1*	*0.2*	*0.7*	*1.7*	*1.7*	*1.8*	*2.2*	*2.3*	*3.3*	*5.2*	*7.5*	*8.8*

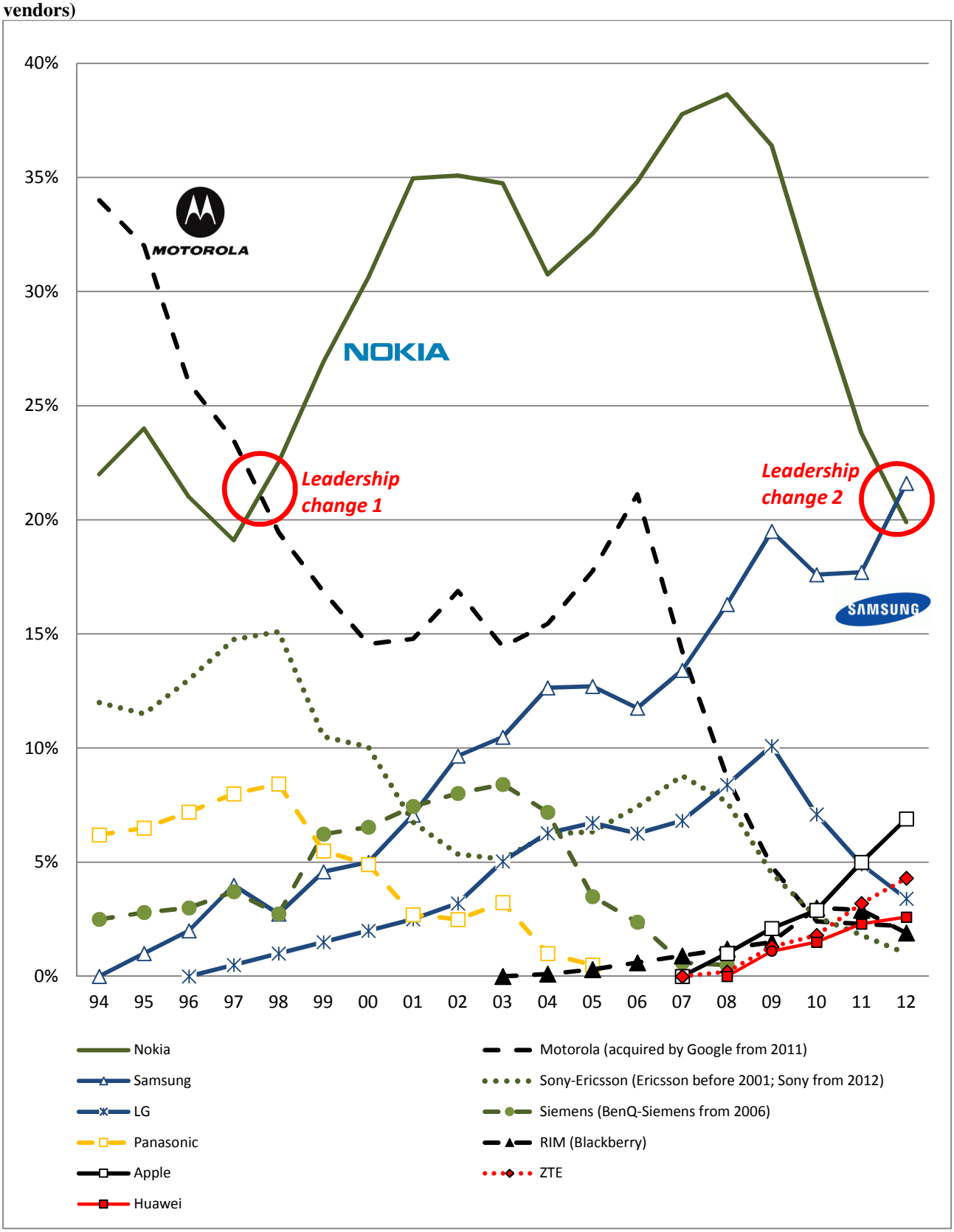
[a] are included also tablet devices with phone call capabilities.
Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Table 6. Number of Android-based smartphones introduced per year (selected mobile phone vendors)[a]

	2008	*2009*	*2010*	*2011*	*2012*
Nokia	0	0	0	0	0
Motorola (acquired by Google in 2011)	0	2	28	34	31
Samsung	0	4	25	60	57
Sony-Ericsson (Sony from 2012)	0	0	0	14	22
LG	0	1	14	29	35
RIM (Blackberry)	0	0	0	0	0
Apple	0	0	0	0	0
HTC	0	6	10	27	27
ZTE	0	0	2	14	35
Huawei	0	2	6	14	21
T-Mobile	1[b]	3	7	9	4
Industry average	*0.02*	*0.58*	*3.03*	*6.21*	*8.11*

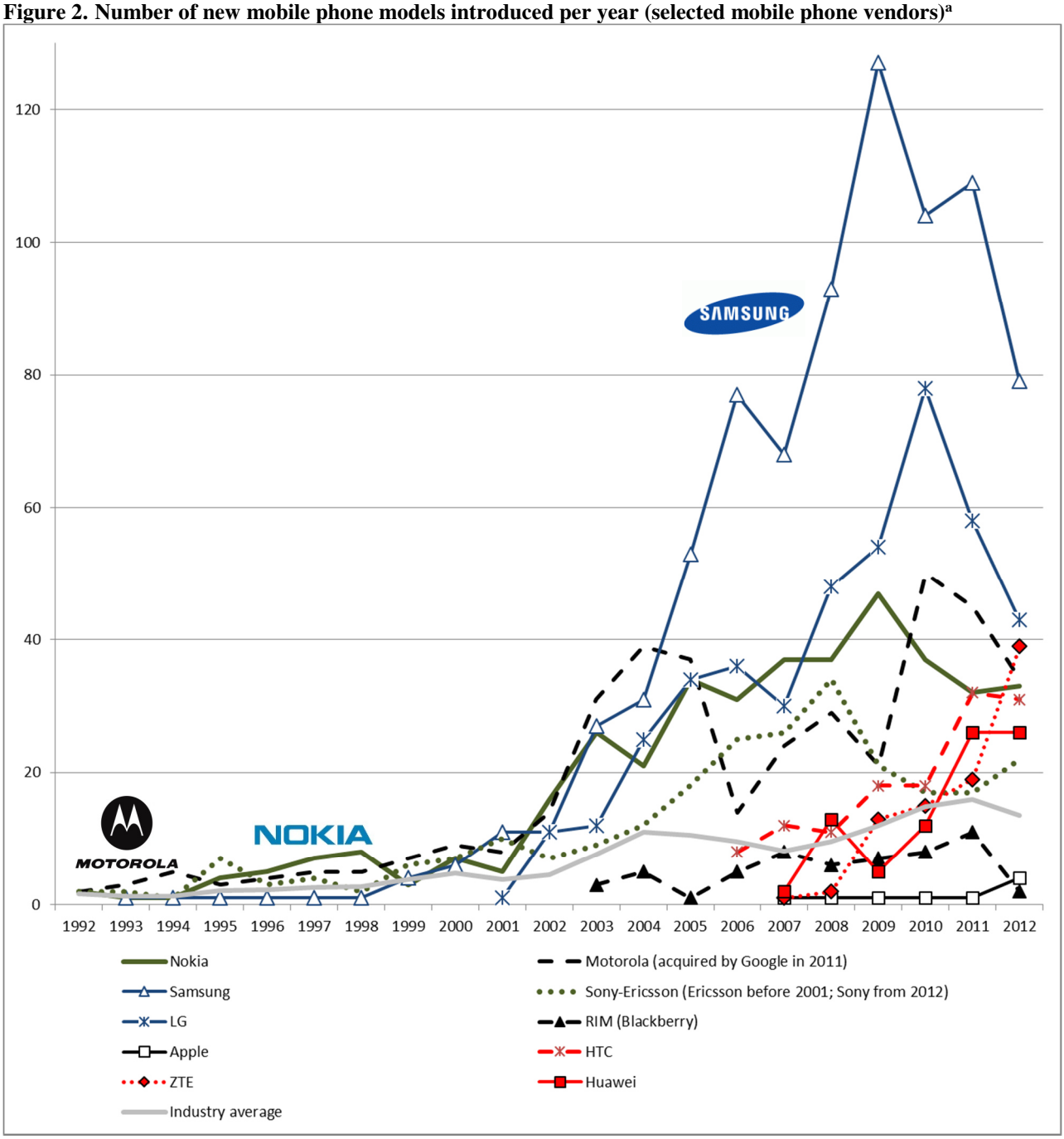
[a] are included also tablet devices with phone call capabilities.
[b] Google phone (G1).
Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Figure 1. Mobile phone vendors' global market shares in terms of units sold (1994–2012) (selected mobile phone vendors)



Notes:
European vendors in green (including Sony-Ericsson and BenQ-Siemens), US and Canadian vendors in black, Japanese vendors in yellow, South Korean vendors in blue, Chinese vendors in red.
Sources: our elaboration from Gartner Dataquest and other archival data.

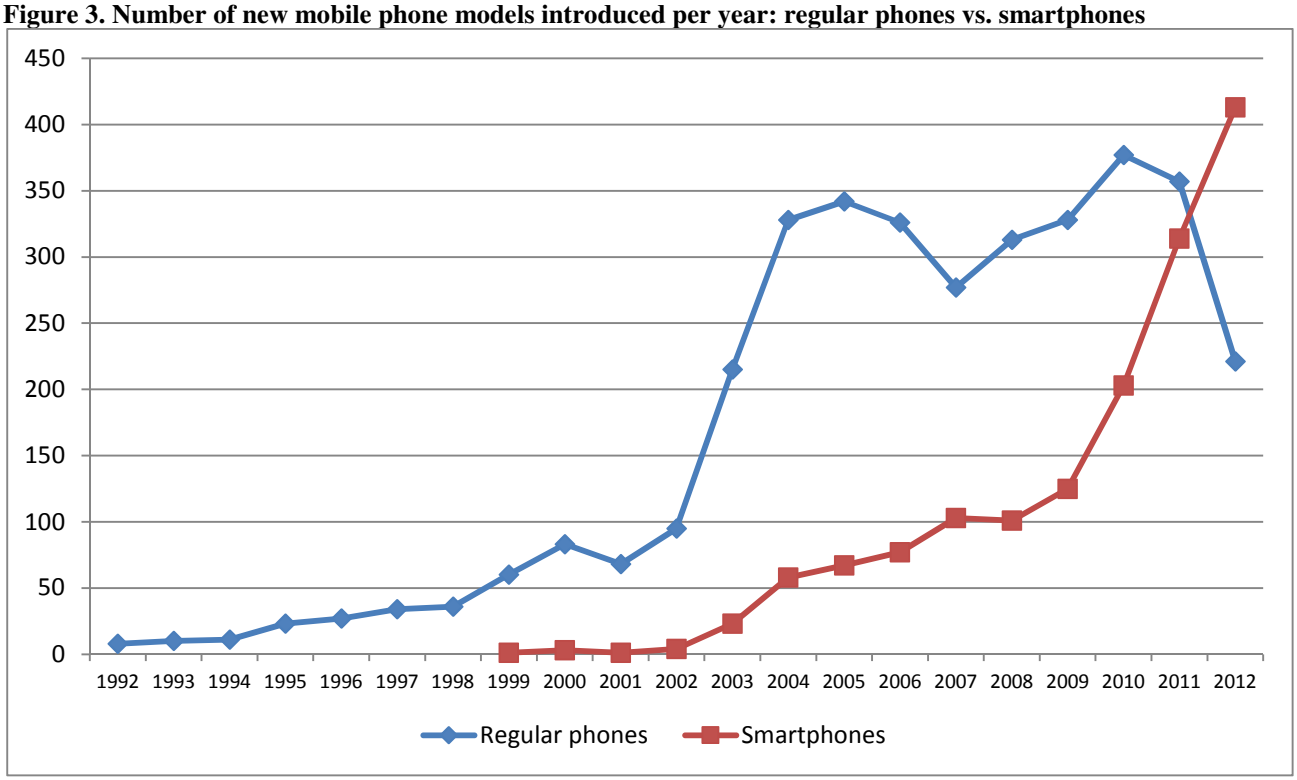
Figure 2. Number of new mobile phone models introduced per year (selected mobile phone vendors)[a]



[a] Are included also tablet devices with phone call capabilities; are excluded (1) car phones, (2) multiple versions of the same handset model with different colors, (3) re-branded versions by network operators of handsets previously introduced by mobile phone vendors.

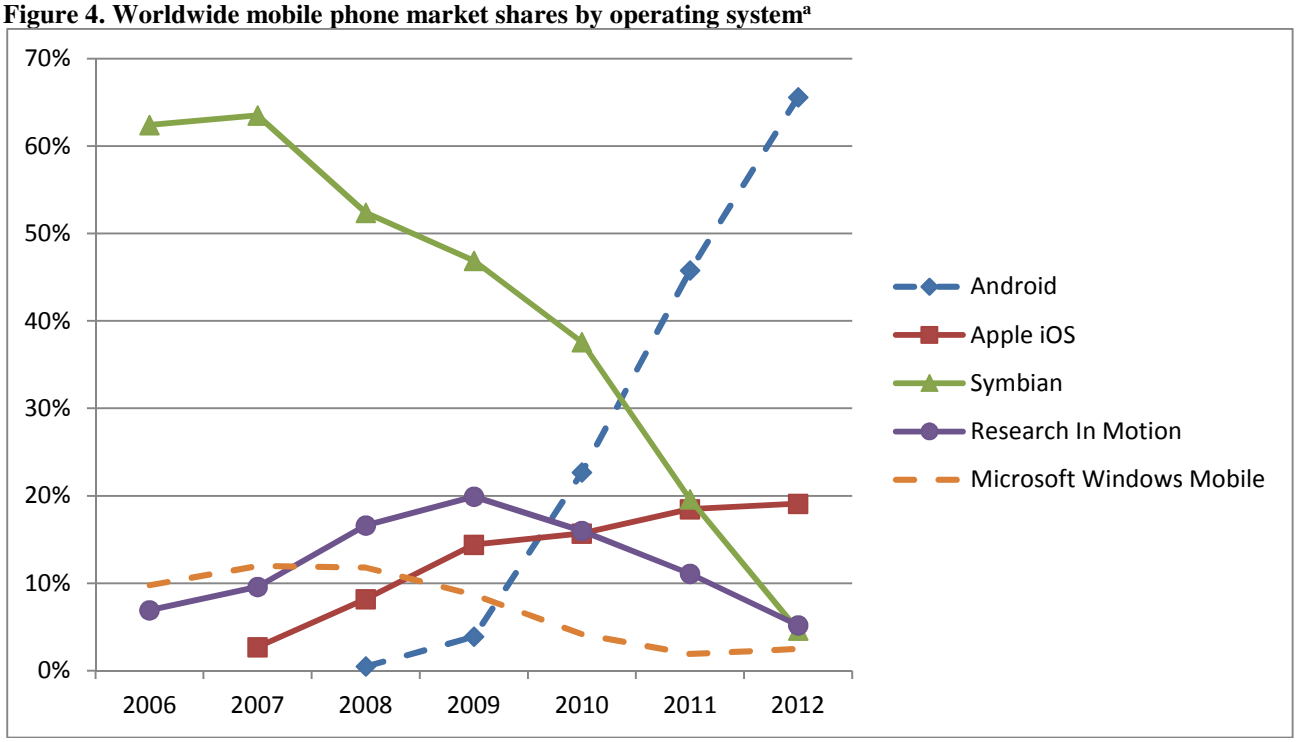
Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Figure 3. Number of new mobile phone models introduced per year: regular phones vs. smartphones



Sources: our elaboration from GSMArena.com, mobile.softpedia.com, imei.info/phonedatabase/ and various archival data.

Figure 4. Worldwide mobile phone market shares by operating system[a]



[a] are included also sales of tablet devices with phone call capabilities.
Sources: our elaboration from Gartner Dataquest