Product technology imitation over the product diffusion cycle: Which companies and product innovations do competitors imitate more quickly?

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Abstract

We contribute to the imitation literature by shedding light on product imitation dynamics over the market evolution, a hitherto-overlooked level of analysis. First, we introduce product diffusion within a more integrative theory of product imitation. Second, we investigate the time to imitation of a new product technology: our baseline hypothesis is that the time to imitation decreases as the product diffusion in the market increases. Third, we extend our prediction by differentiating by the type of innovator—i.e., the market leader and a member of the same strategic group—and by the type of product technology—i.e., functionality-defining technologies and substitute technologies. We hypothesize that, over the product diffusion cycle, product technologies launched by market leaders are copied more quickly than ones launched by non-market leader firms; product technologies launched by members of a focal firm's own strategic group are copied more quickly than ones launched by outsiders; and substitute technologies are copied more quickly than functionality-defining technologies. We test our hypotheses in the context of the UK mobile phone industry, by exploiting a unique database on twenty-two product innovations introduced by thirteen mobile handset manufacturers between 1997 and 2008. The model estimations provide support for most of our hypotheses.

Keywords: Competitive advantage; Competitive strategy; Environment uncertainty; High velocity environment; Product development; New product technology introduction; Time to product technology imitation; Product diffusion cycle

Introduction

In many business contexts, product innovation is often considered as a potential strategy to improve a firm's competitive differentiation (e.g., Damanpour, 2010; Hamel, 2000; Sinha and Noble, 2008). However, product innovations can be imitated (Semadeni and Anderson, 2010; Simon and Lieberman, 2010), thus eroding the sought-after differentiation advantage (Christensen, 1997; D'Aveni, 1994; Ethiraj and Zhu, 2008; Markides, 2003; McGrath, 2013). Understanding imitation dynamics is therefore important, both from the perspective of the innovator (e.g., to understand how to protect itself from imitation), and from the perspective of the imitators (e.g., to understand what to imitate and when). It is therefore not surprising that research studies on imitation have been very popular in the management field. In their recent review of the extant imitation literature, Lieberman and Asaba (2006) identify two key mechanisms leading to imitation: firms may follow other competitors that are perceived as having superior information (i.e., information-based imitation), or firms may imitate rivals to maintain competitive parity (i.e., rivalry-based imitation). However, Lieberman and Asaba (2006) also state that the extant imitation theory still suffers from some theoretical shortcomings, which limit its predictive power. In this respect, our analysis of the literature shows that the existing imitation studies largely focus on imitation dynamics within a given phase of an industry's evolutionary cycle—e.g., new product category launch (Schnaars, 1994; Srinivasan et al., 2007)—and thus lack insights into imitation dynamics across industry phases and over time.

In this paper, we start to tackle this surprising shortcoming. First, we introduce *product diffusion* (Abernathy and Utterback, 1978; Levitt, 1965; St John et al., 2003)[1] as a construct that not only can help to capture time-related imitation dynamics, but also allow for a natural

[1] In this paper, by "product diffusion" we mean to say the diffusion among consumers of a product category as a whole—e.g., mobile phones—and not the diffusion of a single product model. Studies on the industry life cycle have shown that, in the early stages of the industry evolution, the product is poorly diffused in the market, while the level of diffusion increases as the industry matures (Klepper, 1996, 1997; Levitt, 1965) (e.g., while at the beginning of the 1990s the *number of handsets per hundred habitants*—a classical measure of product diffusion—was less than 10% in the UK, at the end of the 2000s it was largely above 100%).

combination of the different prevailing imitation theories (i.e., information-based imitation and rivalry-based imitation) into an integrative framework. In fact, product diffusion is linked to market and technological uncertainty and to competition dynamics, which are two distinctive triggers of information-based and rivalry-based motives for imitation, respectively. We focus on *time to new product technology imitation* (Lee and Smith, 2000) as a dependent variable, and, by integrating information-based and rivalry-based imitation arguments (Lieberman and Asaba, 2006) with the product life cycle literature (Abernathy and Utterback, 1978; Katz and Shapiro, 1986; Rogers, 2003; Utterback and Abernathy, 1975; Utterback and Suárez, 1993), we argue that, overall, the greater a product's diffusion in the market, the shorter the time to imitation. We subsequently extend our theory by differentiating by the type of innovator—i.e., the market leader and a member of the same strategic group—and by the type of product technology—i.e., functionality-defining technologies (technologies that perform a completely new function), and substitute technologies (technologies that replace already-employed technologies to perform a familiar function but by a different means). We predict that, over the product diffusion cycle, product technologies launched by the market leader are copied more quickly than those launched by non-market leader firms; product technologies launched by members of a focal firm's own strategic group are copied more quickly than those launched by companies outside the strategic group; and substitute technologies are copied more quickly than functionality-defining technologies. We test our hypotheses in the context of the UK mobile phone industry, by exploiting a manually collected unique database on twenty-two product innovations introduced by thirteen mobile handset manufacturers that launched 566 new mobile handsets between 1997 and 2008. The model estimations provide support for most of our hypotheses.

In this paper, we make two distinctive contributions to the imitation literature. First, we introduce product diffusion as a construct that can help to capture imitation dynamics over time, and we show theoretically how this construct can also enable the integration of the predictions of information-based and rivalry-based explanations to improve their predictive power. Second, by focusing on the time to imitation—as opposed to the more commonly used existence or inexistence of imitation—and by distinguishing between different types of innovators and different types of product technologies, we bring much-needed granularity to our understanding of which companies and which product innovations competitors imitate more quickly over time.

The structure of the remainder of the paper is as follows. First, we elaborate our hypotheses on the relationship between product diffusion and time to new technology imitation. Second, we describe our methods and present our results. Finally, we conclude the paper with a discussion of the contribution to the literature, managerial implications, research limitations and potential future extensions.

Hypotheses Development

The central tenet of this paper is that, if we are to improve the predictive power of the extant imitation theories, imitation dynamics should be studied in their temporal evolution, and not only in specific evolutionary phases of a given industry. Furthermore, in this paper, we argue that product diffusion is a construct that serves the purpose of capturing such time-related dynamics well. First, product diffusion is a dynamic construct. Product diffusion typically follows a pattern in which an initial period of slow growth in demand after the first commercialization is followed by a sharp increase or "sales takeoff"; then, the product diffusion rates may stabilize or even start to decline (Golder and Tellis, 1997; Klepper, 1997; Mahajan et al., 1990; Moore, 1991; Rogers, 2003). Second, product diffusion is strongly associated with uncertainty—mainly market and technological uncertainty—and with competitive intensity (Anderson and Zeithaml, 1984; Hill and Jones, 1998; Kim et al., 1999; Klepper, 1996; Lee and Veloso, 2008; Utterback, 1974). For instance, when a product is poorly diffused in a market, the uncertainty tends to be high and the competitive intensity tends to be low. Conversely, as a product diffuses in a market, the uncertainty tends to be resolved progressively while the competitive intensity becomes fiercer (Levitt, 1965). Therefore, product diffusion offers a natural integration platform for the predictions coming from information-based imitation (often associated with uncertainty), and rivalry-based imitation (often associated with competitive dynamics).

In the following, we develop our predictions on how the time to imitation may change over the product diffusion cycle.

Time to imitation and product diffusion. Low levels of product diffusion among consumers are usually associated with high levels of market and technological uncertainty (Levitt, 1965). For example, St. John et al. (2003) show that when the personal computer (PC) industry was in its initial stage of development at the end of the 1970s, firms were not able to understand customers' expectations and thus provide the most suitable product technologies (e.g., operating systems, keyboard functionality and software applications) to fulfill customers' needs. Klepper (1997) argues that, in the initial stage of development of an industry, because of the existing high level of uncertainty, firms tend to focus on internal experimentation rather than embarking on risky product imitations. Therefore, a high degree of uncertainty and a preference for internal experimentation are likely to delay the time to imitation of innovations introduced by competitors.

As the product diffusion increases, the market and technological uncertainty start to be resolved, and both demand and technological trajectories become more predictable (Lieberman and Asaba, 2006; Suárez and Lanzolla, 2007; Utterback and Suárez, 1993). Furthermore, the information asymmetries between industry players start to decrease (Abernathy and Utterback, 1978; Klepper, 1996). Lieberman and Asaba (2006) argue that, under decreasing uncertainty, firms are more likely to set "competitive parity" as a strategic priority to neutralize their competitors' actions. Therefore, in this scenario, firms are now likely to rapidly imitate the innovations realized by their competitors to neutralize their initial differentiation advantage. For instance, St. John et al. (2003) show that, as the market matured and PCs diffused among consumers, PC manufacturers began to aggressively imitate technologies introduced by their competitors to try to ease the competitive intensity. It follows that as the product diffuses among consumers, the time to new product technology imitation should decrease. Therefore, combining the arguments described above, we posit:

> *Hypothesis 1: All things being equal, the time to new product technology imitation is inversely related to the level of product diffusion in the market.*

Which companies are imitated more quickly? The extant imitation literature has often identified the market leader, usually defined as the firm with the largest market share, as a company that exerts a particular influence on the other industry members (Haveman, 1993). For low levels of product diffusion, when levels of market and technological uncertainty are high, authors in the information-based imitation literature argue that market leaders are often perceived as having better information, and can often become "fashion leaders" (Bikhchandani et al., 1992, 1998). Imitation of market leaders can then take place for "risk minimization" (Head et al., 2002), and to gain industry legitimacy (Fligstein, 1985; Haunschild and Miner, 1997). This suggests that, when the product is not widely diffused among consumers, companies will cope with uncertainty by imitating new technologies launched by market leaders more rapidly than those introduced by other rivals.

As the level of product diffusion increases and the initial uncertainty diminishes (Utterback and Abernathy, 1975; Utterback and Suárez, 1993), firms increase their knowledge about technologies and consumer preferences (Klepper, 1996, 1997), the information asymmetry between rivals diminishes (Lieberman and Asaba, 2006), and companies may choose to position themselves in specific segments of the market (Porter, 1980), with the aim of distancing themselves from the leader and avoiding the leader's dangerous retaliation (Chen and Miller, 1994). In this scenario, the strategic influence of the market leader is likely to decline and companies often revert to imitating innovations introduced by non-leader rivals, whose retaliation is less likely to hurt the imitator's performance. This logic suggests that as a product diffuses, firms scan their competitive environment more widely before making their product technology (imitation) decisions. It follows that, the greater the product diffusion, the shorter the gap between the time to imitation of the product technologies introduced by the market leader, and the time to imitation of those introduced by other industry players. Thus:

> *Hypothesis 2a: The time to imitation of new product technologies introduced by the market leader is shorter than the time to imitation of new product technologies introduced by other industry players.*

> *Hypothesis 2b: As the level of product diffusion in a market increases, the times to imitation of new product technologies introduced by the market leader and those introduced by other industry players tend to converge.*

Another reference point capable of attracting the attention of industry members is the strategic group to which a focal firm belongs (Fiegenbaum and Thomas, 1995). A strategic group is defined as a group of firms that compete against each other on the basis of similar combinations of strategic (resource and scope) commitments (Caves and Porter, 1977; Hunt, 1972; Scherer, 1980). Porter (1979) uses these notions of a strategic group to explain inter-group performance differences, and notes that firms in a group are likely to conform to group norms through imitation. As Porter states: "Firms within a strategic group resemble one another closely and, therefore, are likely to respond in the same way to disturbances, to recognize their mutual dependence quite closely, and to be able to anticipate each other's reactions quite accurately. Between strategic groups, however, the situation is different" (Porter, 1979, 215). Fiegenbaum and Thomas (1995) propose that a strategic group acts as a reference point in the process of strategic decision-making. This implies that a particular firm is more likely to mimic the actions of those firms within the same strategic group than firms belonging to other strategic groups. This is because firms in the same strategic group make similar assumptions about the future potential of the industry, tend to have similar strategic skills and capabilities, and are likely to compete for similar resources; thus, their lack of differentiation means, if collusion is absent, their rivalry could be substantially more intense than that between differently positioned competitors (D'Aveni, 1994; Gimeno and Woo, 1996). In line with the above perspective, since a firm is more likely to perceive its strategic group members as a competitive threat than other industry competitors, we expect it to feel more pressure to imitate technologies introduced by strategic group members, with the aim of maintaining competitive parity (rivalry-based motives for imitation). In this light, we propose that firms are likely to be quicker to adopt new technologies introduced by similar others—i.e., strategic group members.

Hypothesis 3a: The time to imitation of new product technologies introduced by a competitor that belongs to the firm's strategic group is shorter than the time to imitation of new product technologies introduced by other industry players.

We also expect that, when the level of product diffusion is low and the levels of market and technological uncertainty are high, the time to imitation of new product technologies introduced by the firm's strategic group members should not be that much shorter than the time to imitation of new product technologies introduced by other industry players. That is because, when the product is still only poorly diffused among consumers and the level of uncertainty is high, firms have not yet clearly identified their own market position (hence their strategic group), and are more likely to focus on developing product innovations internally. However, as the product diffuses and the uncertainty diminishes, firms will feel more pressure to maintain competitive parity with those firms they perceive to be more direct competitors. This is consistent with the predictions of the rivalry-based imitation literature, which maintains that imitation of close rivals is more likely to take place when the level of market and technological uncertainty is low, so firms have similar information (Lieberman and Asaba, 2006) and the outcome of imitative attacks is easier to predict (Gimeno and Woo, 1996). Therefore, we expect that as the product diffusion increases, firms will attempt to copy the technologies introduced by their strategic group members much more quickly, and will pay relatively less attention to the technologies introduced by other industry competitors.

> *Hypothesis 3b: As the level of product diffusion in a market increases, the times to imitation of new product technologies introduced by a competitor that belongs to the firm's strategic group and those introduced by other industry players tend to diverge.*

Which technologies are copied more quickly? Some authors have shown that the pace of imitation is related to the degree of innovativeness of the new technology (Abrahamson, 1996; Semadeni and Anderson, 2010). The general prediction here is that the greater the innovativeness of a new technology, the greater the uncertainty about its immediate success among consumers (Funk, 2008; Rogers, 2003), and therefore the longer the time to imitation (Abrahamson, 1996; Meyer and Rowan, 1977). In this study, we build on this general insight and differentiate between functionality-defining technologies, which enable the products concerned to offer brand new functionalities, and substitute technologies, which perform the same (or similar) function(s) as an existing technology, but by different means (Henderson and Richard, 1958; Porter, 1980). To illustrate, in the mobile phone industry, infrared was a functionality-defining technology that enabled connectivity, whereas Bluetooth was a substitute—it delivered the same functionality via a different technology (Baker, 2000). Functionality-defining technologies are assumed to be characterized by a higher level of innovativeness from the user's point of view, since they introduce new product functionality that may develop concepts and ideas previously unknown to the market. By contrast, substitute technologies are assumed to be characterized by a lower level of innovativeness from the user's point of view, since they only replicate what is already offered but via a different technological architecture.[2]

The traditional argument about the role of the degree of innovativeness of new product technologies in firms' propensity to imitate them suggests substitute technologies—which are lower in innovativeness from the user's point of view—are more likely to be imitated quickly, since the firm can more easily predict their likely acceptance within the market. By contrast, when the level of technological innovativeness is high, as in functionality-defining technologies, so is the uncertainty surrounding the success of the innovation—hence, the longer the time to imitation.

Hypothesis 4a: The time to imitation of new substitute technologies is shorter than the time to imitation of new functionality-defining technologies.

The time to imitation gap between functionality-defining and substitute technologies is also a function of the product diffusion cycle. On the one hand, when the product diffusion is

[2] It is important to note that the criteria used in this study to differentiate product technologies, i.e., functionality-defining vs. substitute technologies, differ from the radical–incremental typology (Chandy and Tellis, 2000). For example, substitute technologies are usually perceived by users as being less innovative than functionality-defining ones, but could be radical from an engineering perspective, fundamentally alter the product usability and have a greater impact on the overall product performance.

low, high levels of market and technological uncertainty combine with the relatively high level of uncertainty embedded in functionality-defining technologies, thus lengthening their time to imitation with respect to substitute technologies. In other words, when the product diffusion is low, the imitation of functionality-defining technologies is slowed down, not only because of the overall market and technological uncertainty in the environment, but also because of the superior uncertainty related to the (functionality-defining) technological innovativeness.

On the other hand, as the product diffuses and the market and technological uncertainty diminishes, market players may be led to imitate more quickly to keep competitive parity (rivalry-based motives for imitation), irrespective of the type of product technology. Although substitute technologies involve lower risk, they also usually provide firms with fewer opportunities to differentiate their products. Therefore, the strategic importance of not losing to rivals may lead to faster adoption of functionality-defining technologies, too. Combining the arguments described above, we therefore argue that the higher the level of product diffusion, the shorter the gap will be between the times to imitation of substitute technologies and those of functionality-defining technologies. Thus:

> *Hypothesis 4b: As the level of product diffusion in a market increases, the times to imitation of new substitute technologies and of new functionality-defining technologies tend to converge.*

Methods

Sample. The UK mobile phone industry from 1997 to 2008 is the reference setting for our analysis. We believe the reason why this setting is particularly suitable for testing our hypotheses is threefold. First, from the mid-90s to the end of the 2000s, the mobile phone diffusion rate (i.e., the number of handsets per 100 habitants) grew from 12% (first quarter of 1997) to 122% (first quarter of 2008—see Figure 1). Such variability of product diffusion is a key requisite for our analysis. Second, the progressive transition of handsets in the UK from niche to mass-market products encouraged the most important world competitors to launch their more advanced models and technologies in the market. Third, in the UK, special interest magazines published on a monthly basis provide detailed information about all the new handsets introduced in the market, and review their technical features and performance, thus offering an overview of how mobile phone models and their related technologies have evolved over time.

In this study, we analyse the innovation and imitation strategies of thirteen mobile handset manufacturers—i.e., Nokia, Motorola, Samsung, LG, Ericsson, Sony, Sony-Ericsson, Siemens, Philips, Panasonic, Sagem, NEC and Alcatel—operating in the UK market during the 1997–2008 period. Data about twenty-two product technologies incorporated by the aforementioned handset manufacturers into their product models were collected. Table 1 provides a complete list of the technologies and innovators. Overall, 566 new mobile phones were introduced in this period (see Table 2), with Nokia remaining the clear market share leader over this time. Information about technology adoption within the sampled firms was collected from specialist industry magazines (What Mobile, What CellPhone, Total Mobile), widely regarded as industry references. Data about handset technologies and industry dynamics were also triangulated in interviews with marketing and product managers of some of the main mobile phone manufacturers operating in the UK, including Sony-Ericsson, LG, Samsung, Motorola and NEC.

Measures

Dependent Variable: Time to new product technology imitation. Consistent with the extant technology adoption literature, the time to imitation was measured as the time (in months) a firm takes to adopt a new product technology first introduced by a technology pioneer (defined as the first mobile phone manufacturer to adopt a new technology in its mobile phones) (Damanpour and Gopalakrishnan, 2001; Giachetti, 2013; Prins and Verhoef, 2007). Although the whole observation period spanned from 1997 to 2008, we compute the times to imitation of the twenty-two new technologies first introduced between January 1997 and July 2004. The reason for starting the analysis in 1997 is data availability: the magazines from which we collected data began to offer detailed reviews of new handsets from 1997. The reason for interrupting the analysis in 2008 is the diffusion of smartphones over the second half of the 2000s: we intentionally excluded all smartphone devices (and also manufacturers entirely focused on these products, like BlackBerry and HTC) from our sample, because during this period these products targeted a distinctly different group of consumers and were based on a different mix of technologies, including advanced operating systems.[3] The reason for only considering technologies introduced prior to 2004 is to limit right-censoring in our regression model (we observed right-censoring only for those firms that shut down their operations before 2008).

Independent Variables:

Product diffusion. Authors in the technology adoption literature offer various measures of product diffusion in a market (Geroski, 2000; Klepper, 1997; Mahajan et al., 2000). Our chosen measure for testing the proposed hypotheses is the number of mobile handsets per 100 habitants (i.e., the mobile phone penetration rate) in the month when the technology is introduced in the UK market. Data about mobile phone diffusion in the UK market were collected from Ofcom (the UK telecom regulatory body). It is worth noting that, in this study, product diffusion is used to capture how the mobile phone industry has evolved over time and refers to whole mobile

[3] According to most of the definitions we collected from various secondary sources, a key feature of those products named smartphones is their *advanced operating system*, providing a graphic interface similar to that of a desktop computer and allowing additional applications to be installed. Examples of advanced operating systems for smartphones are BlackBerry OS, Mac OS, Microsoft Windows Mobile and Symbian OS, among others (Gartner Dataquest). We therefore used the variable *advanced operating system* as a demarcating criterion to exclude smartphones from our sample.

phone product categories—we do not measure the diffusion of each specific handset model (Figure 1).

Technology introduced by the market leader. To examine the differences among technologies first introduced by the market leader and technologies first introduced by other rivals, we use a dummy that assigns the value 1 to technologies introduced for the first time in the UK by the market share leader, and 0 to technologies introduced for the first time by other competitors.

Technology introduced by a firm's strategic group member. We again measure this variable as a dummy, which takes the value 1 when the technology was introduced for the first time in the UK by a firm's strategic group member, and 0 otherwise. The firms in our sample were clustered into two macro strategic groups, according to the firms' product line length (the number of handset models in the portfolio) at a certain time *t* with respect to the median product line length within the industry in the same period (Hunt, 1972).

Substitute technology. We measure this as a dummy variable, which takes the value 1 for substitute technologies and 0 otherwise. The distinction among mobile phone functionality-defining and substitute technologies was developed by means of an extensive search of technical descriptions in special interest magazines for consumer electronics and mobile phones in particular and in conjunction with a panel of industry experts, who understood our research goals. To define the two technology groups, we first clustered the product technologies into categories in terms of their function (from the user's point of view). Thus, for example, infrared, USB and Bluetooth were clustered into a "connectivity" category: although these technologies are based on significantly different components, from a user's perspective they perform the same function of enabling data transfer between mobile devices. We then identified the first technology to have been introduced in each category, labeling it as the functionality-defining technology, and the others in that category as substitutes.

Control variables. We include several control variables at the firm, technology and industry level. At the firm-level, we used the following controls: *Firm sales performance*, measured with the natural logarithm of the number of units sold in the UK market on a yearly basis. *Product line length*, measured with the natural logarithm of the number of handset models in the firm's portfolio at time *t* (Giachetti and Dagnino, 2014). *Product line length dissimilarity* (Lanzolla and Suárez, 2012), measured with the absolute value of the difference (i.e., the Euclidean distance) between the firm's product line length and the pioneer's product line length. *Firm effect*, measured with thirteen dummy variables, one for each sampled firm, to control for unobserved time-invariant differences across firms (Stock and Watson, 2007).

At the technology-level, we included the following controls: *Network effect* (Katz and Shapiro, 1986), with a dummy variable that takes the value 1 if the network effect is substantial and 0 otherwise. Network effect expresses the extent to which user utility was a function of the diffusion of the product technology itself. *IP protection*, measured with a dummy variable for each IP type in accordance with the following classification: 1) proprietary technology, not licensed; 2) licensed by a mobile phone manufacturer; 3) licensed by mobile phone suppliers.[4]

Finally, at the industry level we included the following controls: *Industry concentration* (Damanpour, 2010; Robertson and Gatignon, 1986; Wirtz et al., 2007) in the UK mobile phone industry (smartphone manufacturers excluded), measured as the aggregated market share of the four largest manufacturers (Mol and Kotabe, 2011; Porter, 1980); and *Bargaining power of network operators* (Vodafone UK, O2, Orange, T-Mobile and 3) over mobile phone

[4] It is worth noting that, over the analyzed time period (1997–2008), the mobile phone industry was characterized by few cases of patent litigation (Carrier, 2012). Patent wars in the mobile phone industry have been observed since the end of the 2000s—with the boom of smartphone devices and advanced operating systems driven by the success of Apple's iPhone—and therefore occurred after our study period.

manufacturers, measured as telecommunication companies' level of market concentration (Porter, 1980), calculated via the Herfindahl index (Cummins et al., 1972; Lustgarten, 1975), which takes into account both the number of network operators in the market and the proportion of the total users each represents.[5]

Tables 1, 2 and 3 and Figure 1 provide more details on the variables considered in this study, and Table 4 shows the variables' descriptive statistics. A summary of our variable definitions, data sources used to compute the variables, and some descriptive statistics on imitation dynamics are available in the Appendix (Table A1 and Table A2).

Please insert Tables 1, 2, 3 and 4 and Figure 1 about here

Models and Results

Although the procedure that has often been used for analyzing models with the "time of events" as their dependent variable involves hazard (survival) analysis, formal tests for the normality of residuals suggest that the use of an OLS (ordinary least squares) regression in our model would be appropriate. Thus, we decided to test our hypotheses using OLS, and repeat the analysis with a survival model as a robustness check (Bhattacharjee et al., 2007). In both the models' specifications, the interaction effects between the product diffusion (*PD*) and the dummy variables technology introduced by the market leader (*TIML*), technology introduced by a firm's strategic group member (*TIFSGM*), and substitute technology (*ST*) are used to test the relationships predicted by Hypotheses 2b, 3b and 4b.

[5] Network operators (i.e., telecommunication companies) aim to attract paying consumers to sign up for their services by buying stocks of handsets from manufacturers and then selling them on to consumers. Thus, we can expect that the greater their bargaining power in the UK market (i.e., higher Herfindahl concentration index), the more pressure they can put on mobile phone manufacturers to quickly deliver new handsets with advanced features, which would translate into shorter mobile phone manufacturers' adoption times.

As far as the OLS model is concerned, it takes the following form (equation 1):

1) $TTI_{i,t} = \beta_0 + \beta_1 PD_t + \beta_2 TIML_t + \beta_3 TIFSGM_t + \beta_4 ST_t + \beta_5 PD_t \cdot TIML_t + \beta_6 PD \cdot TIFSGM_t + \beta_7 PD_t \cdot ST_t + \beta_n controls + \varepsilon_{i,t}$

If a coefficient displays a negative sign, it implies that the variable decreases the time to new product technology imitation (*TTI*).

With regard to the survival model, let *T* be the non-negative random variable representing the moment at which a certain technology is adopted by a firm (i.e., failure time). We assume that the probability distribution of *T* is described by a density function *f*(*t*). The survival function *S*(*t*) is defined by:

2) $$S(t) = P(T \geq t)$$

The hazard function $\lambda(t)$ instead specifies the instantaneous rate of technology adoption at $T = t$ conditional upon survival to time *t* and is defined by the limit for $\delta \downarrow 0$ as follows:

3) $$\lambda(t) = \lim_{\delta \downarrow 0} \frac{P(t \leq T < t + \delta \mid T \geq t)}{\delta} = \frac{f(t)}{S(t)}$$

In our study, we consider a parametric survival model, in particular an exponential accelerated failure time (AFT) model (Cleves et al., 2002). AFT models are obtained by modeling the log failure time $Y = \ln(T)$ instead of the failure time itself (Hoesmer and Lemeshow, 1999). With these specifications, we introduced covariates by defining our hazard function $\lambda(t)$ as a function of a set of regressors:

4) $$\lambda_i = e^{-\beta x_i}$$

This model allows us to estimate the effect of each explanatory variable on the duration. If a coefficient displays a negative sign, it implies that the variable decreases the time to technology imitation (i.e., it increases the probability of earlier imitation). Therefore, the interpretation of coefficients' direction and significance in our survival model is the same as that in our OLS model.

In both the OLS model and the AFT model, we analyze the data with robust regressions that control for outliers and heteroskedasticity (Cameron and Trivedi, 2009).

In Table 5, Models 1–2 and Models 2–4 present the OLS and AFT estimation results, respectively. Models 1 and 3 are an examination of the effects of the control variables on the time to new technology imitation.[6] Our explanatory variables—product diffusion, technology introduced by the market leader, technology introduced by a firm's strategic group member and technology type—as well as the two-way interactions are included in Models 2 and 4. Figures 2 and 3 represent the significant interactions of the OLS model graphically, following the procedures proposed by Aiken and West (1991).

Please insert Table 5 and Figures 2 and 3 about here

Hypothesis 1 posits that the higher the level of product diffusion in a market, the shorter the time will be before a new technology is imitated by other industry players. As Models 2 and 4 show, the relationship between the level of product diffusion in a market and the time to technology imitation ($\beta_{OLS} = -.724$, $p < .001$; $\beta_{AFT} = -.037$, $p < .001$) is significant and negative;

[6] The control variables were standardized (mean-centered) before entering the regression models to prevent multicollinearity.

therefore Hypothesis 1 is supported.

Hypothesis 2a posits that the time to imitation of product technologies introduced by the market leader will be shorter than those of product technologies introduced by other players. Hypothesis 2b suggests the gap between the two diminishes as the product diffuses among consumers. Models 2 and 4 show that the coefficient of technology introduced by the market leader (β_{OLS} = –17.499, p < .01; β_{AFT} = –1.774, p < .001) is significant and negative, and the interaction between the level of product diffusion in a market and technology introduced by the market leader (β_{OLS} = .244, p < .01; β_{AFT} = .027, p < .001) is significant and positive. We plot the significant interaction of the OLS model according to standard procedures (Aiken and West, 1991) to assess whether the form of the interaction is consistent with our hypotheses: the Figure 2 graph shows that when the level of product diffusion in a market is low, technologies introduced by market leaders are imitated considerably more quickly than those proposed by other players, but the gap between the two times to imitation tends to decrease as the product diffusion gains pace. However, the interaction graph also shows the situation is reversed when the level of product diffusion is high—that is, the time to adoption of new product technologies launched by market leaders is slightly longer than that of new product technologies proposed by other industry players. Thus, our analysis supports Hypotheses 2a and 2b, but only up to a point.

Hypothesis 3a posits that the time to imitation of product technologies introduced by a firm's strategic group member will be shorter than that of product technologies introduced by other players. Hypothesis 3b suggests the gap between the two increases as the product diffuses among consumers. Both Model 2 and Model 4 show that the coefficient of technology introduced by a firm's strategic group member (β_{OLS} = –10.664, p < .05; β_{AFT} = –.468, p < .1) is significant and negative, while the interaction between the level of product diffusion in a market and technology introduced by a firm's strategic group member is positive and significant in the OLS model (β_{OLS} = .128, p < .1, Figure 3) but not significant in the AFT one (β_{AFT} = .004, p >

.1). Overall, these findings provide support for Hypothesis 3a, but not for Hypothesis 3b.

Figures 2 and 3 also point to the pronounced differences in the time to imitation at different levels of mobile phone diffusion in the UK market. For instance, when mobile phones were not widely diffused among consumers, the time elapsing between the point at which technology pioneers first introduced new handset technologies to the market and the point at which other handset manufacturers imitated those innovations was about 30–40 months. The time to technology imitation strongly diminished for high levels of product diffusion, scenarios in which handset manufacturers took 5–10 months to incorporate innovations introduced by technology pioneers into their handsets.

Hypothesis 4a proposes that, for any given level of product diffusion, the time to imitation of substitute technologies will be shorter than that of functionality-defining technologies. Hypothesis 4b proposes that the times to imitation of the two technologies will tend to converge as the level of product diffusion in a market increases. Contrary to our expectation, in both Model 2 (OLS) and Model 4 (AFT), the coefficient of substitute technologies ($\beta_{OLS} = 14.878$, $p < .01$; $\beta_{AFT} = 0.659$, $p < .05$) is significant and positive, showing that the time to imitation of substitute technologies is in fact longer than in the case of functionality-defining technologies. Moreover, the interaction between product diffusion and substitute technologies is not significant, meaning the slopes are not significantly different for the two groups of technologies (Aiken and West, 1991). Therefore, our results overall do not support either element of Hypothesis 4.

Robustness Tests

We test the robustness of our findings in several ways. First, we calculate variance inflation factors (VIFs) to determine whether there is multicollinearity in the analyses—but none of the VIF scores approach 10, the threshold commonly accepted as indicating a potential problem

(Chatterjee and Hadi, 2006), and the average VIF is 3.14, suggesting that multicollinearity is unlikely to affect our results.

Second, we repeat the analysis by adding the interaction between substitute technology and the dummy leader, and the interaction between substitute technology and the dummy strategic group, in order to check whether the time to imitation of substitute and functionality-defining technologies changes depending on the pioneer's type. We find these interactions to be not significant, while keeping the other coefficients and significance levels very similar to those presented in Table 5.

Finally, although our central hypothesis is that product diffusion influences the time to technology imitation, a counterargument could be made that when firms' technological knowledge is widely diffused, as in the mature stage of the industry evolution, the rapid imitation of new technologies fosters the diffusion of products. Thus, it could be argued that product diffusion is affected—at least partially—by the time to new product technology imitation. Under this scenario, the independent variable in our model would be endogenously determined. In order to test for the presence of endogeneity, we perform the Hausman–Wu test. In the test equation, we include the potentially endogenous variable and the instruments, which are those variables (omitted within the model) that are correlated with the endogenous and not correlated with the dependent variable (Davidson and McKinnon, 1993). We use as instruments two exogenous variables, related to changes in the macro-environment. The first is a dummy coded 1 in the years 2001 and 2002 and 0 otherwise, to capture the effect of the economic downturn in 2001 and 2002, which depressed the sales of various types of technology-based products both in the US and in Europe (Giachetti and Marchi, 2010). The second is a dummy coded 1 after 2003 and 0 otherwise, to capture the effect of the Universal Mobile Telecommunications System (UMTS), which in the UK diffused for commercial use in 2003 and marked a technological discontinuity in the downstream market, allowing for the entry of new network operators offering services based on this technology through agreements with mobile phone manufacturers. In turn, the introduction of the UMTS had important implications for the diffusion of advanced handsets among consumers. A chi-square test on the significance of these instrumental variables represented the exogeneity test. The test did not reveal any violations of the assumed exogeneity of the variable product diffusion (using a significance level of $p < 0.05$), indicating that the model specification is robust to this issue.

Discussion

This study makes two distinctive direct theoretical contributions to the imitation literature. First, we have shown that product diffusion is a dynamic construct that can capture time-related imitation dynamics and serve as a useful framework to combine the predictions of information-based and rivalry-based imitation theories, thus moving a step closer to an integrative imitation theory. Second, by focusing on the time to imitation, we have shown—both theoretically and empirically—that the time to product technology imitation decreases as the level of diffusion of a product category increases. The focus on the time to imitation, as opposed to the use of a dichotomous variable to measure imitation (e.g., Greve, 1998; Guler et al., 2002; Haunschild, 1993; Makadok, 1998), allowed us to better capture the differences in product imitation dynamics. Furthermore, this study has extended the technology imitation literature by undertaking a "multiple technologies–multiple innovators" nuanced approach.

With regard to "who is copied more quickly" (Hypotheses 2a, 2b, 3a and 3b), we have empirically shown that (in line with our hypotheses) the technologies developed by market leaders and by firms' strategic group members are imitated sooner than those launched by non-leaders and non-strategic group members. We have also found that as the product diffusion increases, the gap between the time to imitation of technologies developed by the market leader and the time to imitation of technologies developed by other players quickly diminishes

(Hypothesis 2b). However, different from what is predicted in Hypothesis 3b, the time to imitation of new product technologies introduced by a competitor that belongs to the firm's strategic group and those introduced by other industry players do not tend to diverge.

With regard to "which technologies are copied more quickly," our hypotheses (4a and 4b) were not supported. In fact, contrary to our predictions, both the OLS and the AFT model suggest that functionality-defining technologies are copied more quickly than substitute technologies over the whole product diffusion cycle. Ex post, we suggest that the reason for this finding could be that most of those firms that decide to adopt new substitute technologies may (in the short run) be forced to support high switching costs related to their need to reconfigure parts of their production processes, in terms of both machinery and components, as well as re-educating their technical personnel (Rosenberg, 1972), investments usually time- and resource-consuming (Smit and Trigeorgis, 2007).[7] The main risk for the firm is that it must invest resources in the production of a new substitute technology, which in the end may exhibit lower performance than those already in use.

Finally, our empirical findings, that firms increasingly rely on the imitation of rivals' product innovation (i.e., a higher speed of imitation) as the product diffuses in the market, complement the extant product diffusion literature. As Abernathy and Utterback (1978) argue, when a new product is introduced (and, arguably, before the consumer demand and preferences become clear), firms tend to have an internal focus and to experiment with product (as opposed to process) innovation: in contrast, as a product becomes more diffused and the consumer demands less uncertain, firms concentrate their efforts more on process innovation than on developing new products. Our findings complement Abernathy and Utterback's model (1978) suggesting that, even when the product is widely diffused among consumers, the rapid imitation

[7] It is interesting to note that we observed various cases of substitute technologies that determined the gradual decline of functionality-defining technologies. For example, the diffusion of Bluetooth caused the rapid decline of infrared, while the diffusion of downloadable ringtones caused the rapid decline of (pre-installed) ringtone composers.

of competitors' product innovations may be a key competitive strategy, implemented by most industry players in order to defend their status quo. In other words, according to Abernathy and Utterback's model (1978), in a stage of industry maturity (characterized by high levels of product diffusion among consumers), firms are usually expected to reduce the rate of product innovation in favor of process innovation, but the continuous introduction into the UK mobile phone industry of new revolutionary handset features and their rapid imitation, over the first and second halves of the 2000s, does not corroborate the industry life cycle prediction. Although other authors have pointed to the importance of speed of new technology imitation over the market evolution,[8] to the best of our knowledge, ours is one of the few studies to offer a longitudinal view of technology imitation decisions.

This study has several implications for managers. Companies can use the level of product diffusion in a market as a proxy to develop scenarios for industry evolution and projections of how competitors will respond to the introduction of new product technologies. Such an understanding may be particularly important when managers want to protect their innovations from imitation, but it can also be instrumental in helping to develop some guidelines as to when to hurry to imitate competitors' innovations in order to retain competitive parity. Our results suggest, for example, that imitation processes tend to be particularly rapid at higher levels of product diffusion—actually, when the level of product diffusion is high, firms imitate about four times faster than when the level of product diffusion is low (see Figures 2 and 3). In this scenario, companies of all sizes should be prepared both a) to respond to imitation attacks by launching new product technologies in order to differentiate their product offering, and b) to rapidly imitate innovations introduced by rivals to maintain competitive parity. On the other

[8] Damanpour and Gopalakrishnan (2001), also taking a longitudinal approach, show that in the long run firms emphasize imitating product over process innovations; while Reinganum (1981) proposes a multi-stage game theoretical model that shows a firm's time to technology imitation will depend on its perceptions of the costs and benefits of delaying the adoption of the technology; and Silverberg et al., (1988) find that a firm's propensity to accelerate the imitation of innovations is influenced by its competitive position (e.g., market share), which may change over time.

hand, when the product is not widely diffused among consumers, even though firms are likely to be particularly slow to imitate rivals' innovation, managers of market-leader firms are more subject to imitation attacks, and thus should readily prepare the resources necessary to protect the temporary competitive advantage offered by their innovations.

Limitations and Suggestions for Future Research

Some limitations of the current study suggest opportunities for future research. First, although our paper follows a "multiple technologies–multiple innovators" approach (by testing the imitation timing related to several items introduced by several firms), we do not consider the technical performance evolution of product technologies over time (e.g., increasing numbers of display colors or camera pixels), which could be a factor that might slow down or speed up the times to technology imitation. Therefore, future research might propose, for example, a number of indicators expressing performance improvement levels for each product technology, and test whether technological improvements and imitation timing are positively or negatively related. Second, this study is based on a single industry in a single country. Clearly, more cross-industry and cross-country studies could further test and develop our conclusions. Third, we do not distinguish between manufacturers with in-house R&D departments and those that outsource their product development efforts (although, we control for this to some extent, with firm dummies). Future research could control explicitly for the role of internal R&D and/or alliance contracts when examining comparative times to technology imitation. Likewise, imitation dynamics might be influenced by the mobile phone manufacturers' business model complexity (Aspara, Lamberg, Laukia and Tikkanen, 2013). Finally, different ways of clustering technologies may provide even finer granularity and clarity regarding the types of technologies more quickly imitated.

Appendix

Table A1. Summary description of the variables used in the analysis

Variables	Definition	Data source(s)
Time to new product technology imitation	The time (in months) a firm takes to adopt a new product technology first introduced by a technology pioneer	What Mobile, What CellPhone, Total Mobile
Product diffusion	Number of mobile handsets per 100 habitants in the month the technology is introduced in the UK market	Ofcom
Technology introduced by the market leader	A dummy that assigns the value 1 to technologies introduced for the first time in the UK by the market share leader (Nokia), and 0 to technologies introduced for the first time by other competitors	What Mobile, What CellPhone, Total Mobile
Technology introduced by a firm's strategic group member	A dummy which takes the value 1 when the technology was introduced for the first time in the UK by a firm's strategic group member, and 0 otherwise	What Mobile, What CellPhone, Total Mobile
Substitute technology	A dummy which takes the value 1 for substitute technologies, and 0 otherwise	What Mobile, What CellPhone, Total Mobile
Firm sales performance	Natural logarithm of the number of units sold in the UK market on a yearly basis	Mintel International Group, Euromonitor International, Factiva database
Product line length	Natural logarithm of the number of handset models in the firm's portfolio	What Mobile, What CellPhone, Total Mobile
Product line length dissimilarity	The absolute value of the difference between the firm's product line length and the pioneer's product line length	What Mobile, What CellPhone, Total Mobile
Firm effect	Thirteen dummy variables, one for each sampled firm	What Mobile, What CellPhone, Total Mobile
Network effect	A dummy that takes the value 1 if the network effect is substantial, and 0 otherwise	Interviews with industry specialists
IP protection	A dummy per each of the following categories: 1) proprietary technology, not licensed; 2) licensed by a mobile phone manufacturer; 3) licensed by mobile phone suppliers	United States Patent and Trademark Office, European Patent Office, World Intellectual Property Organization, Factiva database, interviews with marketing and product managers of mobile phone manufacturers operating in the UK
Industry concentration	Aggregated market share of the four largest manufacturers in the UK market	Mintel International Group, Euromonitor International, Factiva database
Bargaining power of network operators	Herfindahl index based on market shares of network operators in the UK market	Ofcom

Table A2. Technological innovation and time to imitation (1997–2008)

Firm	**No. of functionality-defining technologies introduced by firm**	**No. of substitute technologies introduced by firm**	**Firm's average TTI in months – *ordered from shorter to longer TTI* (S.D.)**	**Average position of a firm in terms of technology adoption order[a] (S.D.)**
Nokia	6	2	13.15 (12.46)	2.62 (1.80)
Sony-Ericsson	0	0	14.57 (8.75)	4.43 (1.40)
Ericsson	2	1	16.00 (6.46)	2.67 (1.61)
Motorola	2	2	19.00 (11.91)	3.91 (2.35)
Siemens	0	1	19.26 (11.45)	4.55 (2.16)
Sony	0	0	20.13 (11.68)	4.50 (2.20)
LG	0	0	20.25 (7.85)	5.50 (1.73)
Panasonic	1	1	27.18 (18.26)	6.21 (3.10)
Alcatel	0	0	27.32 (16.75)	7.05 (3.32)
Samsung	1	0	27.52 (14.72)	5.91 (2.41)
Philips	1	0	30.60 (18.42)	6.75 (2.79)
Sagem	0	0	33.85 (18.68)	7.10 (2.01)
NEC	1	1	39.50 (25.96)	7.33 (3.12)
TOTAL	*14*	*8*		
Mean			*23.72*	*5.27*
Median			*20.25*	*5.50*

Note: TTI = Time to technology imitation.

[a] e.g., 1 = on average the firm was the pioneer in the UK market, 10 = on average the firm was the tenth adopter in the UK market.

References

Abernathy, W.J., Utterback, J.M., 1978. Patterns of Industrial Innovation. Technology Review 80(7), 97–107.

Abrahamson, E., 1996. Management Fashion. Academy of Management Review 21(1), 254–285.

Aiken, L.S., West, S.G., 1991. Multiple Regression: Testing and Interpreting Interactions. Sage, Newbury Park, CA.

Anderson, C., Zeithaml, C., 1984. Stage of the Product Life Cycle, Business Strategy and Business Performance. Academy of Management Journal 27(1), 5–24.

Aspara, J., Lamberg, J.-A., Laukia, A., Tikkanen, H., 2013. Corporate business model transformation and inter-organizational cognition: The case of Nokia. Long Range Planning 46(6), 459-474.

Baker, S., 2000. A Wireless Revolution Called Bluetooth. Businessweek, September 17, 2000.

Bhattacharjee, S., Gopal, R., Lertwachara, K., Marsden, J., Telang, R., 2007. The Effect of Digital Sharing Technologies on Music Markets: A Survival Analysis of Albums on Ranking Charts. Management Science 53, 1359–1374.

Bikhchandani, S., Hirshleifer, D., Welch, I., 1992. A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. Journal of Political Economy 100(5), 992–1026.

Bikhchandani, S., Hirshleifer, D., Welch, I., 1998. Learning from the Behavior of Others: Conformity, Fads, and Informational Cascades. Journal of Economic Perspectives 12(3), 151–170.

Cameron, C.A., Trivedi, P.K., 2009. Microeconometrics Using Stata. Stata Press, College Station, TX.

Carrier, M., 2012. A Roadmap to the Smartphone Patent Wars and FRAND Licensing. CPI Antitrust Chronicle, Vol. 2.

Caves, R.E., Porter, M.E., 1977. From Entry Barriers to Mobility Barriers. Quarterly Journal of Economics 91(2), 241–261.

Chandy, R.K., Tellis, G.J., 2000. The Incumbent's Curse? Incumbency, Size, and Radical Product Innovation. Journal of Marketing 64(3), 1–17.

Chatterjee, S., Hadi, A.S., 2006. Regression Analysis by Example (4th Edition). Wiley, New York.

Chen, M.-J., Miller, D., 1994. Competitive attack, retaliation and performance: An expectancy–valence framework. Strategic Management Journal 15(2), 85–102.

Christensen, C.M., 1997. The Innovator's Dilemma: The Revolutionary Book That Will Change the Way You Do Business. Harvard Business Press, Cambridge, MA.

Cleves, M., Gould, W.M., Gutierrez, R.G., 2002. An Introduction to Survival Analysis Using Stata. Stata Press, College Station, TX.

Cummins, J.D., Denenberg, H.S., Scheel, W.C., 1972. Concentration in the U.S. Life Insurance Industry. Journal of Risk and Insurance 39(2), 177–199.

D'Aveni, R.A., 1994. Hypercompetition: Managing the Dynamics of Strategic Maneuvering. Free Press, New York.

Damanpour, F., 2010. An integration of research findings of effects of firm size and market competition on product and process innovations. British Journal of Management 21, 996–1010.

Damanpour, F., Gopalakrishnan, S., 2001. The Dynamics of the Adoption of Product and Process Innovations in Organizations. Journal of Management Studies 38(1), 45–65.

Davidson, R., MacKinnon, J.G., 1993. Estimation and Inference in Econometrics. Oxford University Press, New York.

Ethiraj, S.K., Zhu, D.H., 2008. Performance effects of imitative entry. Strategic Management Journal 29(8), 797–817.

Euromonitor (Annual directories 2003–2008). Mobile Phones in the UK. Euromonitor International Ltd, London.

Fiegenbaum, A., Thomas, H., 1995. Strategic groups as reference groups: Theory, modeling and empirical examination of industry and competitive strategy. Strategic Management Journal 16(6), 461–476.

Fligstein, N., 1985. The Spread of the Multidivisional Form Among Large Firms, 1919–1979. American Sociological Review 50(3), 377–391.

Funk, J., 2008. Components, systems, and technological discontinuities: Lessons from the IT sector. Long Range Planning 41(5), 555–573.

Geroski, P.A., 2000. Models of technology diffusion. Research Policy 29(4-5), 603–625.

Giachetti, C., 2013. Competitive Dynamics in the Mobile Phone Industry. Palgrave Macmillan, UK.

Giachetti, C., Dagnino, G. B., 2014. Detecting the relationship between competitive intensity and product line length: evidence from the worldwide mobile phone industry. Strategic Management Journal 35: 1398–1409.

Giachetti, C., Marchi, G., 2010. Evolution of Firms' Product Strategy over the Life Cycle of Technology-Based Industries: A Case Study of the Global Mobile Phone Industry, 1980–2009. Business History 52(7), 1123–1150.

Gimeno, J., Woo, C.Y., 1996. Hypercompetition in a multimarket environment: The role of strategic similarity and multimarket contact in competitive de-escalation. Organization Science 7(3), 322–341.

Golder, P.N., Tellis, G.J., 1997. Will It Ever Fly? Modeling the Takeoff of Really New Consumer Durables. Marketing Science 16, 256–270.

Greve, H.R., 1998. Performance, Aspirations, and Risky Organizational Change. Administrative Science Quarterly 43(1), 58–77.

Guler, I., Guillen, M.F., MacPherson, J.M., 2002. Global Competition, Institutions, and the Diffusion of Organizational Practices: The International Spread of ISO 9000 Quality Certificates. Administrative Science Quarterly 47(2), 207–232.

Hamel, G., 2000. Leading the Revolution. Harvard Business School Press, Cambridge, MA.

Haunschild, P.R., 1993. Interorganizational Imitation: The Impact of Interlocks on Corporate Acquisition Activity. Administrative Science Quarterly 38(4), 564–592.

Haunschild, P.R., Miner, A.S., 1997. Modes of Interorganizational Imitation: The Effect of Outcome Salience and Uncertainty. Administrative Science Quarterly 42(3), 472–500.

Haveman, H.A., 1993. Follow the Leader: Mimetic Isomorphism and Entry into New Markets. Administrative Science Quarterly 38(4), 593–627.

Head, K., Mayer, T., Ries, J., 2002. Revisiting Oligopolistic Reaction: Are Decisions on Foreign Direct Investments Strategic Complements? Journal of Economics & Management Strategy 11(3), 453–472.

Henderson, J.M., Richard, E.Q., 1958. Microeconomic Theory: A Mathematical Approach. McGraw-Hill Book Company, New York.

Hill, C., Jones, G.R., 1998. Strategic Management Theory: An Integrated Approach (4th Edition). Houghton Mifflin Company, Boston, MA.

Hoesmer, D., Lemeshow, S., 1999. Applied Survival Analysis. John Wiley, New York.

Hunt, M.S., 1972. Competition in the major home appliance industry, 1960–1970. Unpublished doctoral dissertation. Harvard University.

Katz, M., Shapiro, C., 1986. Technology Adoption in the Presence of Network Externalities. Journal of Political Economy 94(4), 822–841.

Kim, N., Bridges, E., Srivastava, R., 1999. A simultaneous model for innovative product category sales diffusion and competitive dynamics. International Journal of Research in Marketing 16(2), 95–111.

Klepper, S., 1996. Entry, Exit, Growth, and Innovation over the Product Life Cycle. American Economic Review 86(3), 562–583.

Klepper, S., 1997. Industry Life Cycles. Industrial and Corporate Change 6(1), 145–181.

Lanzolla, G., Suárez, F.F., 2012. Closing the Technology Adoption-Use Divide: The Role of Contiguous User Bandwagon. Journal of Management 38(3), 836–859.

Lee, H., Smith, K., 2000. Timing, order and durability of new product advantages with imitation. Strategic Management Journal 21(1), 23–30.

Lee, J., Veloso, F.M., 2008. Interfirm Innovation Under Uncertainty: Empirical Evidence for Strategic Knowledge Partitioning. Journal of Product Innovation Management 25(5), 418–435.

Levitt, T., 1965. Exploit the Product Life Cycle. Harvard Business Review 43, 81–94.

Lieberman, M.B., Asaba, S., 2006. Why Do Firms Imitate Each Other? Academy of Management Review 31(2), 366–385.

Lustgarten, S.H., 1975. The Impact of Buyer Concentration in Manufacturing Industries. Review of Economics and Statistics 57(2), 125–132.

Mahajan, V., Muller, E., Bass, F.M., 1990. New Product Diffusion Models in Marketing: A Review and Directions for Research. Journal of Marketing 54(1), 1–26.

Mahajan, V., Muller, E., Wind, Y., 2000. New Product Diffusion Models. Kluwer Academic, New York.

Makadok, R., 1998. Can first-mover and early-mover advantages be sustained in an industry with low barriers to entry/imitation? Strategic Management Journal 19, 683–696.

Markides, C., 2003. Racing to be second: Innovation through imitation, in: Birkinshaw, J., et al. (Eds.), The Future of the Multinational Company. Wiley, Chichester, UK, pp. 211–221.

McGrath, R.G., 2013. The End of Competitive Advantage: How to Keep Your Strategy Moving as Fast as Your Business. Harvard Business Review Press, Cambridge, MA.

Meyer, J., Rowan, B., 1977. Institutionalized Organizations: Formal Structure as Myth and Ceremony. American Journal of Sociology 83(2), 340–363.

Mintel International Group Limited (Annual directories 1997–2008). Mobile phones and network providers in the UK. Mintel International Group Ltd, London.

Mol, M.J., Kotabe, M., 2011. Overcoming Inertia: Drivers of the Outsourcing Process. Long Range Planning 44(3), 160–178.

Moore, G.A., 1991. Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers. Harper, New York.

Porter, M.E., 1979. The structure within industries and companies' performance. Review of Economics and Statistics 61, 214–229.

Porter, M., 1980. Competitive Strategy. New York, Free Press.

Prins, R., Verhoef, P.C., 2007. Marketing Communication Drivers of Adoption Timing of a New E-Service Among Existing Consumers. Journal of Marketing 71(2), 169–183.

Reinganum, J.F., 1981. On the Diffusion of New Technology: A Game Theoretic Approach. Review of Economic Studies 48(3), 395–405.

Robertson, T.S., Gatignon, H., 1986. Competitive Effects on Technology Diffusion. Journal of Marketing 50(3), 1–12.

Rogers, E.M., 2003. Diffusion of Innovation. Free Press, New York.

Rosenberg, N., 1972. Factors affecting the diffusion of technologies. Explorations in Economic History 10(1), 3–33. Reprinted in Rosenberg, N., 1976. Perspectives on Technology. Cambridge University Press, Cambridge.

Scherer, F.M., 1980. Industrial Market Structure and Economic Performance (2nd edition). Rand McNally College Publishing Co., Chicago, IL.

Schnaars, S.P., 1994. Managing imitation strategies: How late entrants seize marketing from pioneers. The Free Press, New York.

Semadeni, M., Anderson, B.S., 2010. The Follower's Dilemma: Innovation and Imitation in the Professional Services Industry. Academy of Management Journal 53(5), 1175–1193.

Silverberg, G., Dosi, G., Orsenigo, L., 1988. Innovation, Diversity and Diffusion: A Self-Organisation Model. Economic Journal 98, 1032–54.

Simon, D., Lieberman, M., 2010. Internal and external influences on adoption decisions in multi-unit firms: the moderating effect of experience. Strategic Organization 8(2), 132–154.

Sinha, R., Noble, C., 2008. The adoption of radical manufacturing technologies and firm survival. Strategic Management Journal 29(9), 943–962.

Smit, H.T.J., Trigeorgis, L., 2007. Strategic Options and Games in Analysing Dynamic Technology Investments. Long Range Planning 40(1), 84–114.

Srinivasan, R., Haunschild, P., Grewal, R., 2007. Vicarious Learning in New Product Introductions in the Early Years of a Converging Market. Management Science 53(1), 16–28.

St. John, C.H., Pouder, R.W., Cannon, A.R., 2003. Environmental Uncertainty and Product-Process Life Cycles: A Multi-Level Interpretation of Change Over Time. Journal of Management Studies 40(2), 513–541.

Stock, J.H., Watson, M.W., 2007. Introduction to Econometrics. Addison Wesley, United States.

Suárez, F.F., Lanzolla, G., 2007. The Role of Environmental Dynamics in Building a First Mover Advantage Theory. Academy of Management Review 32(2), 377–392.

Utterback, J., 1974. Innovation in Industry and the Diffusion of Technology. Science 183(4125), 620–626.

Utterback, J., Abernathy, W., 1975. A dynamic model of process and product innovation. Omega 3, 639–656.

Utterback, J., Suárez, F.F., 1993. Innovation, competition and industry structure. Research Policy 22(1), 1–21.

Wirtz, B.W., Mathieu, A., Schilke, O., 2007. Strategy in High-Velocity Environments. Long Range Planning 40(3), 295–313.

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Table 1. Mobile phone technologies introduced by manufacturers in the UK market (January 1997–July 2008) and mobile phone penetration in the month of technology introduction

Product technology	**Firm introducing the technology**[a]	**Month of introduction**	**UK mobile phone penetration rate**[b]
-	-	Jan. 97[c]	12.05%
Voice dialing	Philips	Jul. 97	13.40%
Composer	Ericsson	Aug. 97	13.40%
Infrared	Nokia	Oct. 97	14.29%
Games	Nokia	Jan. 98	15.27%
Downloadable ringtones	Nokia	Feb. 98	15.27%
Email client	Nokia	Mar. 98	15.27%
WAP	Nokia	Feb. 99	25.35%
EMS	Motorola	Aug. 99	33.10%
Polyphonic ringtones	Panasonic	Jan. 00	45.76%
Recordable ringtones	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	Aug. 01	77.11%
USB	Motorola	Sep. 01	77.11%
Color screen	Ericsson	Dec. 01	77.11%
MMS	Motorola	May. 02	80.71%
Photocam	Nokia	Aug. 02	82.59%
True 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[c]	122.36%

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

[b] Product diffusion, measured as the percentage of handsets per 100 habitants, computed the month in which the technology was introduced in the UK by the first adopter.

[c] Beginning and end of the observation 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

Source: our elaboration from *What Mobile?*, *What CellPhone?* and *Total Mobile*.

Table 3. Technology categories' description

Categories of technologies and description	**Functionality-defining technologies**	**Substitute technologies**
Phone call: *Technology helping the user to make a phone call without entering a number manually or from the phone book, but just speaking the name concerned.*	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 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 send messages that include multimedia objects (images, audio, video, rich text), not just as short message service (SMS) texts.*	EMS	MMS
Advanced ringtone sound: *Technologies allowing the ringtone to be of several notes/sounds.*	Polyphonic ringtone	True tone
Instant messaging: *Technology allowing the user a 'chat' session similar to an Internet chat session.*	SMS chat	-
Music: *Technology allowing the user to 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 four 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	Mean	S.D.	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11
1	**Time to technology imitation (TTI)**	25.29	17.32	2	90	1										
2	**Product diffusion**	52.00	29.94	13.4	93.56	–0.40†	1									
3	**Technology introduced by market leader (TIML)**	0.35	0.48	0	1	0.08	–0.41†	1								
4	**Technology introduced by a firm's strategic group member (TIFSGM)**	0.43	0.49	0	1	–0.14†	–0.008	–0.05	1							
5	**Substitute technology**	0.35	0.47	0	1	0.03	0.38†	–0.20†	–0.04	1						
6	**Firm sales performance**	5.96	1.41	3.21	8.94	–0.37†	0.30†	–0.13†	0.20†	0.10	1					
7	**Product line length**	1.02	0.69	0	2.30	–0.36†	0.27†	–0.10	0.46†	0.08	0.54†	1				
8	**Product line length dissimilarity**	0.81	0.58	0	2.39	0.03	0.12†	0.01	–0.56†	0.03	–0.10	–0.45†	1			
9	**Network effect**	0.50	0.50	0	1	–0.06	0.15†	0.09	0.08	0.10	0.07	0.14†	–0.10	1		
10	**Industry concentration**	76.44	3.45	71.81	82	–0.19†	0.40†	–0.40†	–0.21†	0.05	0.05	–0.01	0.21†	0.05	1	
11	**Bargaining power of clients**	0.26	0.01	0.24	0.28	0.31†	–0.92†	0.40†	–0.008	–0.31†	–0.27†	–0.25†	–0.06	–0.21†	–0.47†	1

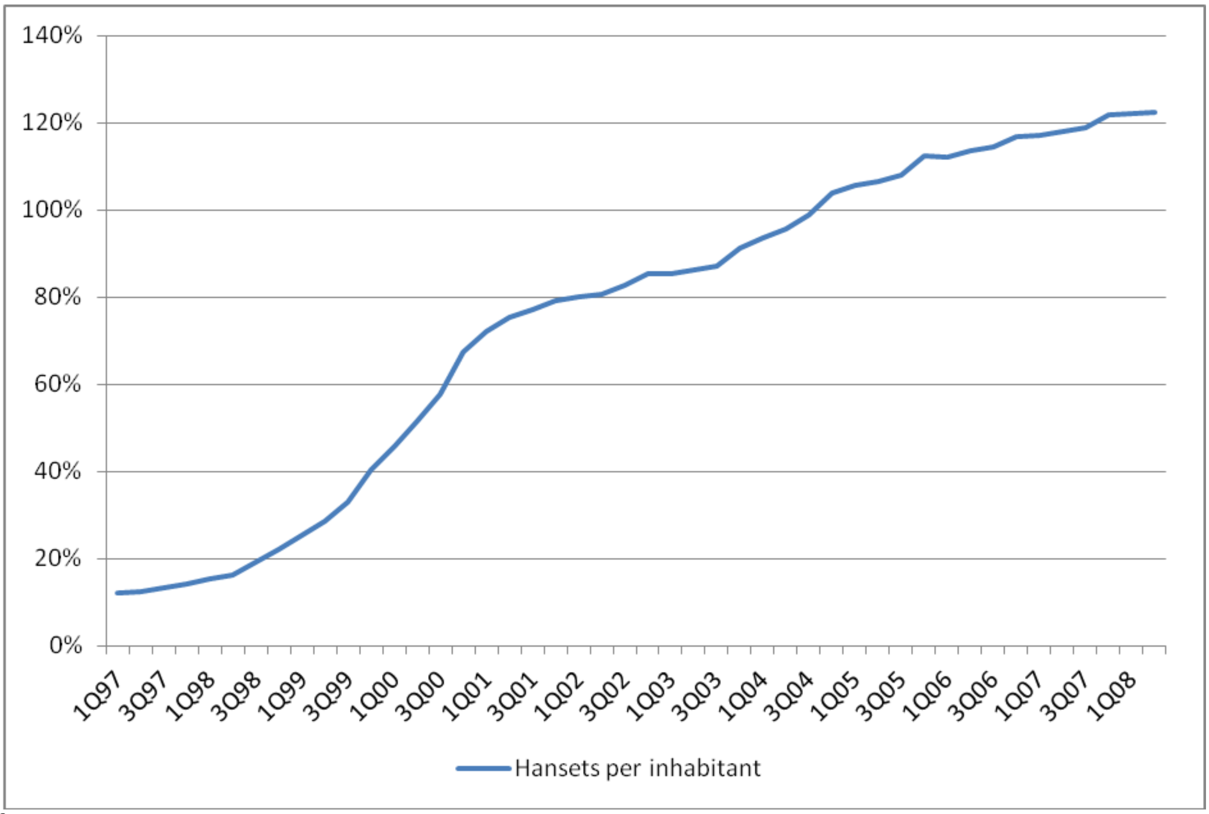
Significance: † $p < 0.1$.
N = 187.

Table 5. Model estimations for predicting the time to technology imitation

	OLS		AFT	
Dependent variable: time to technology imitation	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Product diffusion	-	–0.724*** (0.151)	-	–0.037*** (0.007)
Technology introduced by market leader	-	–17.499** (5.225)	-	–1.774*** (0.335)
Technology introduced by a firm's strategic group member	-	–10.664* (5.184)	-	–0.468† (0.272)
Substitute technology	-	14.878** (5.346)	-	0.659* (0.296)
Product diffusion × TIML	-	0.244** (0.071)	-	0.027*** (0.005)
Product diffusion × TIFSGM	-	0.128† (0.068)	-	0.004 (0.004)
Product diffusion × substitute technology	-	–0.074 (0.070)	-	–0.003 (0.004)
Firm sales performance	1.287 (2.733)	0.885 (2.210)	0.018 (0.130)	–0.673 (0.126)
Product line length	–3.484† (1.863)	–0.699 (1.792)	–0.184 (0.112)	–0.100 (0.113)
Product line length dissimilarity	–2.687* (1.352)	–1.316 (1.247)	–0.154* (0.070)	–0.102 (0.078)
Network effect	2.207 (1.363)	–0.050 (1.358)	0.208** (0.078)	0.154† (0.080)
Industry concentration	–0.764 (1.328)	–3.821** (1.331)	–0.228*** (0.065)	–0.476*** (0.088)
Bargaining power of network operators	4.774** (1.746)	–9.173* (4.297)	–0.027 (0.084)	–0.656*** (0.177)
Constant	20.850*** (5.436)	51.377*** (8.317)	3.205*** (0.365)	4.861*** (0.436)
IP dummies	*Included*	*Included*	*Included*	*Included*
Firm dummies	*Included*	*Included*	*Included*	*Included*
R-sq	0.347	0.481	-	-
F	5.76***	7.06***	-	-
ΔF	-	5.52***	-	-
Log pseudolikelihood	-	-	–82.354	–69.088
Wald chi2	-	-	109.42***	207.49***
Δ Wald chi2	-	-	-	43.53***
N. obs.	187	187	216	216

† $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Robust standard error in parentheses.

Figure 1. Mobile phone penetration rate (handsets per 100 inhabitants) in the UK market[a]



[a] 100% = 1 handset for every inhabitant.
Source: our elaboration from Ofcom.

Figure 2. Interaction effect of product diffusion with technology introduced by the market leader, DV: time to technology imitation (OLS model)

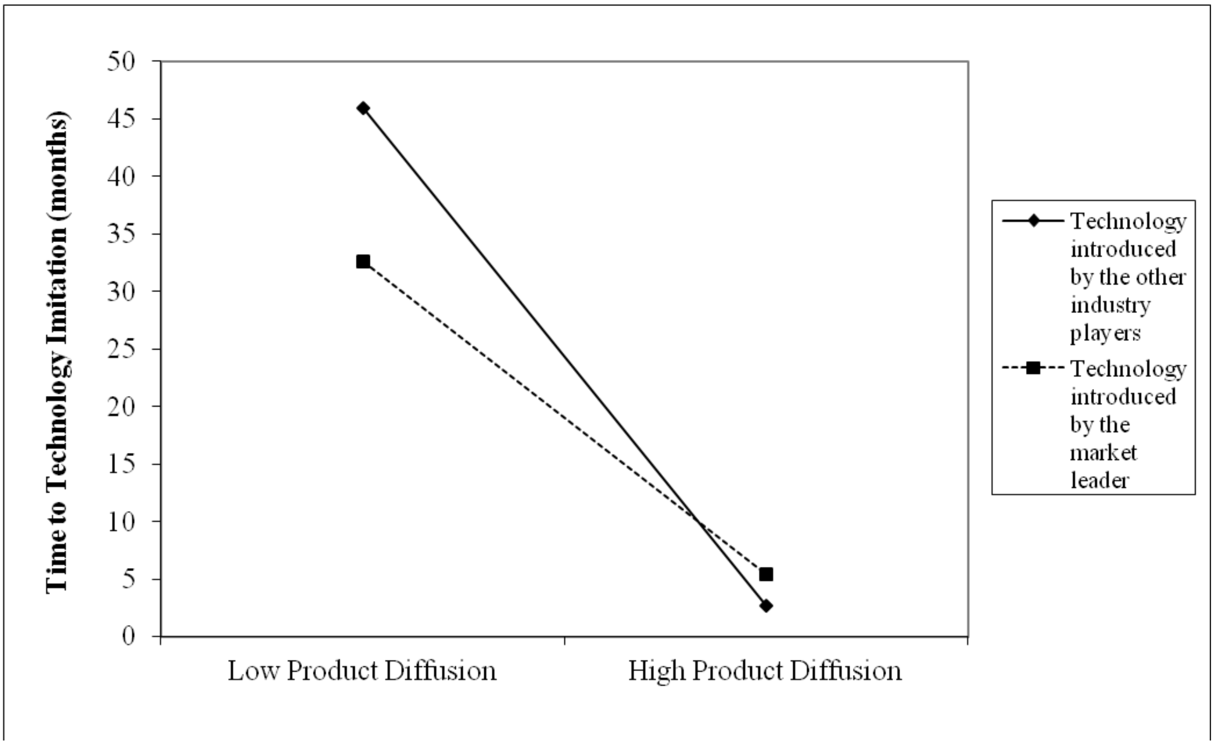


Figure 3. Interaction effect of product diffusion with technology introduced by a firm's strategic group member, DV: time to technology imitation (OLS model)