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Catching up with the market leader: Does it pay to rapidly imitate its innovations?

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Abstract

In this study we attempt to shed more light on the relationship between *speed of new technology imitation* and the sales performance of the imitator compared to the innovator, with a particular focus on the performance outcomes resulting from the rapid imitation of technologies introduced by the market leader. Using data on handset technologies mounted on more than 600 devices introduced to the UK market by 14 mobile phone vendors operating from 1997 to 2008, we study hundreds of imitative actions to test hypotheses on the extent to which an imitator can catch up (i.e., reduce the market share gap) with the market leader by rapidly imitating its innovations. First, we show that gaining advantage by rapidly imitating a technology pioneer is contingent on whether the pioneer is the market leader or a non-leader rival. Second, we find that the risks of rapid imitation of the market leader's technologies are mitigated when industry clockspeed is high, i.e., during a period of fast innovation and imitation cycles in an industry, resulting in rapid variations in product design. Third, we observe that the degree of competitive responsiveness of the technology pioneer when its innovations are imitated represents an important mechanism that can explain why speed of imitation may affect how an imitator can improve its market share gains relative to the pioneer. This paper advances competitive dynamics and imitation as predictive theories of how rapid imitators might catch up with market leaders in technology-intensive industries.

Keywords: speed of imitation; competitive dynamics; windows of opportunity; catching up; clockspeed; mobile phone.

JEL codes: L11, L63, O33

1. Introduction

A central issue for managers in high-tech industries is that of timing (Eisenhardt, 1989; Lieberman and Montgomery, 1988; Lieberman and Montgomery, 2013; Markides and Geroski, 2004). Firms have to grasp not only which new product technology to adopt but also *when* to do so, and *which competitors* should be imitated (Giachetti and Lanzolla, 2016; Jenkis, 2014; Sharapov and Ross, 2019). This echoes the seminal work of Levitt when he argued that: "There is usually a great premium on speed. One wants not just to catch up quickly with the *successful* innovator but, more particularly, to do so *faster* than other would-be imitators who are also working against the clock" (Levitt, 1966: 64). In his study on innovative imitation, Levitt found that firms were often far too slow to imitate competitors' new product offerings, to the detriment of their sales performance. Fifty years later, Levitt's analysis still holds true, in that the imitation of rivals' innovations remains common practice for many companies, who nevertheless fail to do so effectively (Markides and Geroski, 2004; Schnaars, 1994; Shenkar, 2010).

Since Levitt's work (1966), the topic of imitation has received attention from various scholars in the field of management literature (Lieberman and Asaba, 2006). Despite this, surprisingly few studies have focused on the speed of imitation of rivals' innovation, with the majority investigating the most likely targets of rapid imitation or the antecedents of imitation timing (e.g., Giachetti, Lampel and Li Pira, 2017; Giachetti and Lanzolla, 2016). The analysis of the *performance consequences of the speed of imitation of competitors' innovation* has received scant attention (Ethiraj and Zhu, 2008; Giachetti et al., 2017; Lee and Zhou, 2012): "The question of the performance effects of imitation [of innovation] is much less studied. The explanations for why imitation [of innovation] may be (un)successful are mostly conceptual in nature" (Ethiraj and Zhu, 2008: 798). This neglect is troubling since in various high-tech industries the speed of competitive response (e.g., Boyd and Bresser, 2008; Chen and Hambrick, 1995; Lieberman and Montgomery, 2013; Smith et al., 1991) with an emphasis on rapid imitation (Ethiraj and Zhu, 2008; Lee, Smith, Grimm, and Schomburg, 2000), has been regarded as a key weapon for maintaining competitiveness, such that firms that fall behind can expect their market share to be considerably eroded (Pacheco-de-Almeida, 2010).

In this study we attempt to contribute to the extant competitive dynamics and imitation literatures by examining whether, and in which circumstances, rapidly imitating rivals' innovation pays off. Perhaps because the trade-off between the benefits and costs of rapid imitation in technology intensive industries is complex, the strategy literature has yet to provide a clear picture about the link between imitation speed and performance. While some studies have shown that there are performance advantages in imitating rapidly new technologies (e.g., Giachetti et al., 2017; Lee et al., 2000), others have emphasized performance advantages for maintaining flexibility and imitating later (e.g., Ethiraj and Zhu, 2008). In light of these mixed arguments, competitive dynamics scholars have called for more research on the performance implications of a firm's imitation speed that takes into account possible contingences. For example, there has been a call to examine imitation dynamics in rapidly vs slowly changing technological environments (e.g., Pacheco-de-Almeida, 2010). We respond to this call by developing a framework that integrates the competitive dynamics literature with studies on imitation and technological change. In particular, we show how the relationship between the speed of new technology imitation and performance changes when technology factors at pioneer-level and industry-level are taken into account.

With regard to pioneer-level factors, by using market share leadership to distinguish between the different types of pioneer, we can provide clear guidelines about which technology pioneers in an industry a firm should rapidly imitate to capture their first-mover advantage, and which technology pioneers are more likely to obstruct the effectiveness of the rapid imitation of their new technologies. Although the extant imitation literature has offered various insights into the role of the market leader in driving the imitation processes (e.g., Giachetti and Lanzolla, 2016; Haveman, 1993), we have found no studies that explore whether and how technology pioneers with different market powers variously affect the chance of a focal firm gaining market share vis-à-vis the technology pioneer by rapidly imitating its innovations. In order to address this point, our theory of the performance implications of imitative actions considers two agents: (1) a *focal imitator*, i.e., a firm adopting a certain new product technology introduced by a technology pioneer, and (2) a *technology pioneer*, i.e., a firm introducing a certain technology in the market, whose market position (i.e., being the market leader or a non-leader rival) and technological innovation are scrutinized by the focal imitator to decide whether and when to adopt the technological innovation. Therefore, it is worth noting that the technology pioneer can be either the market leader or a smaller rival.[1]

With regard to industry-level factors, by building on the competitive dynamics literature centered on leader-challenger rivalry in hypercompetitive environments (e.g., Pacheco-de-Almeida, 2010) and technological change studies centered on leader-challenger catching-up dynamics (e.g., Christensen, Suarez, and Utterback, 1998; Lee, 2013; Lee and Malerba, 2017; Li, Capone, and Malerba, 2019; Park and Lee, 2006), we investigate whether rapidly imitating the product technologies introduced by firms with strong market dominance leads to higher or lower market share gains for the imitator compared to the pioneer, depending on the pace of technological change in an industry; a phenomenon known as *industry clockspeed* (Fine, 1998; Mendelson, 2000; Nadkarni and Narayanan, 2007; Pacheco-de-Almeida, 2010).

[1] On the difference between the technology pioneer and the market leader, previous studies have noted that being the technology pioneer on the market is certainly an advantage (Lieberman and Montgomery, 1988), but that the pioneer is not necessarily the largest competitor and that being the pioneer is not a sure-fire way to obtain or keep a leadership position (Markides and Geroski, 2004; Schnaars, 1994). Interestingly, there is a paucity of case studies on the performance implications of imitation of technologies pioneered by market leaders.

This refers to a period of fast innovation and imitation cycles in an industry, resulting in rapid and marked industry variations in product design. A high level of industry clockspeed is an indication that the business environment is unstable and hypercompetitive. In such an environment, old technologies and their related knowledge become quickly obsolete since the changing technological environment requires firms to acquire brand new knowledge to compete (Lee, 2013; Park and Lee, 2006), and thus any performance advantages are short-lived (Nadkarni and Narayanan, 2007). A central concern for studies on competitive dynamics and industry evolution has been how firms that hold greater market leadership can sustain their dominance in hypercompetitive industries where the pace of technological evolution is high (e.g., D'Aveni, 1994; Eisenhardt, 1989; Pacheco-de-Almeida, 2010). These studies have typically explored how a leading firm is likely to respond to its rivals in highly unstable environments, with few studies taking the perspective of the imitator. We therefore examine whether it pays to rapidly imitate the product technologies introduced by a pioneer who wields strong market power when industry clockspeed escalates. By building on the competitive dynamics literature that explores how market leaders navigate fast-clockspeed industries (Barnett and McKendrick, 2004; Pacheco-de-Almeida, 2010) and technological change studies on the speed of knowledge obsolescence (Lee, 2013; Park and Lee, 2006), we argue that the market leader's retaliation –i.e. its degree of competitive responsiveness– is lower when the pace of technological evolution is high. A period of high clockspeed thus constitutes a less risky environment for firms that are considering rapid imitation of the technologies introduced by the industry's market leader. Thus, we also respond to research in the leader-challenger catching-up literature, which notes a shortage of studies examining how market leader- and exogenous industry-level factors can jointly influence the extent to which a firm can reduce its performance gap with a leading rival (Ansari and Krop, 2012; Lee and Malerba, 2017; Miao, Song, Lee, and Jin, 2018). In fact, "authors of extant studies failed to address this multi-level issue[, and] failed to recognize contingencies (at different levels) that can moderate or differently shape the main [catching-up] relationships" (Miao et al., 2018: 665).

In this article we develop a set of hypotheses with data on handset technologies introduced to the UK market and imitated at different speeds by 14 mobile phone vendors operating from 1997 to 2008.

2. Theory and hypotheses

2.1. Speed of imitation of new technologies and the sales performance of the imitator relative to the technology pioneer

Our first hypothesis is about the effect of speed of imitation of a new technology on the performance of the imitator relative to the technology pioneer, regardless of whether the pioneer is the market leader or a non-leader rival. This will be our baseline hypothesis upon which we build our theory.

The literature on first-mover advantage suggests that a product or technology pioneer gains an advantage by securing a temporary monopoly position in the market due to the imitator's lag (D'Aveni, 1994; Lieberman and Montgomery, 1988; Makadok, 1998). For example, in technology-intensive industries, fast-moving firms can potentially exploit learning curve effects in the use of their pioneering technologies before the imitators can catch up. While the first-mover literature argues in favor of being a pioneer, there is less consideration of rapid imitation as a successful strategic alternative to moving first. By drawing on the first-mover advantage and competitive dynamics literatures, we argue that in technology-intensive industries, the first-mover advantage of the technology pioneer can also be exploited by rapid imitators who gain the main advantage of facing lower competition from late imitators. In fact, by imitating quickly, firms can avoid or attenuate (at least in the short run) the competition of late imitators (Chen and Miller, 1994) while maintaining technological parity with the pioneer (Giachetti et al., 2017). Essentially, faster imitators will face direct competition from only the technology pioneer and its other rapid imitators.

This line of logic suggests that in technology-intensive industries, firms that are slow to imitate pioneers' new technology will be at a competitive disadvantage with respect to the technology pioneer. We thus propose the following hypothesis:

Hypothesis 1. *An increase in a firm's speed of imitation of a new technology leads to greater market share gains for the firm relative to the technology pioneer.*

2.2. Speed of imitation of new technologies introduced by the market leader

In this section, we turn to examine the role that the pioneer's market position plays on its degree of responsiveness to rapid imitation, with the pioneer's degree of responsiveness being the mechanism explaining why the rapid imitation of technology pioneers with different market positions can lead to higher or lower sales performance for the imitator relative to the pioneer.

Studies in the competitive dynamics literature suggest that a firm's competitive attacks that severely threaten the competitive position of a rival will usually elicit a sizeable degree of responsiveness from that rival (e.g., Chen and Miller, 1994; Rindova, Becerra and Contardo, 2004). Authors have also noted that speed of imitation represents a threat for technology pioneers (Lee et al., 2000), and in technology-intensive industries the more rapidly a technology pioneer is imitated, the more likely it is that its temporary competitive advantage will be eroded if it does not respond (e.g., Giachetti et al., 2017). Competitive dynamics scholars have also shown that the magnitude of competitive responsiveness matters for the performance of the firm that provoked the response. For example, Smith et al.'s (1991) study of competitive dynamics in the airline industry showed that when rivals counterattack more strongly, the performance of the focal firm will decrease. Similarly, Derfus, Maggitti, Grimm, and Smith (2008), using the lens of Red Queen competition, showed that as the number/speed of rivals' actions increases, focal firm performance decreases. This would suggest that the greater the degree of competitive responsiveness of the technology pioneer when its innovations are imitated, the more the sales performance of the imitator relative to the technology pioneer will be damaged. But who are the technology pioneers best able to unleash competitive responses that penalize the imitator's attempt to increase its market share?

Scholars of competitive dynamics have argued that a market leader is likely to exert a strong influence on the speed with which rivals will imitate its actions. For example, a market leader may find that its actions are imitated quickly by smaller firms that view the leader's market power as the outcome of successful strategic decision making (Giachetti and Lanzolla, 2016). However, as some authors have shown, mimicking the actions of a strong market leader may also intensify competition (Chen, Su, and Tsai, 2007), with negative effects on the imitators' performance (Chen and Hambrick, 1995). By drawing on arguments proposed by competitive action-response studies (e.g., Smith et al., 1991), we contend that rapid imitators of the market leader run a high risk of dangerous retaliation, which will hurt their performance. Consistent with the findings of the literature on competitive dynamics, firms that carry out actions that do not trigger much response from their rivals experience better performance than firms that open themselves up to a flurry of responses (Chen and Miller, 1994). But under direct competitive attack, large and small firms will vary in their responsiveness to the threat (Chen and Hambrick, 1995). Some authors have demonstrated that firms endowed with greater resources are more likely to respond (Smith et al., 1991). Market share leaders are generally endowed with more resources than their smaller counterparts and can mobilize these to expeditiously respond to rivals' rapid imitative attacks. In contrast, smaller firms under attack suffer resource constraints and so may not be able to retaliate even if they wish to do so. As noted by Berry (2006: 154), "non-dominant firms are those firms that are smaller than the largest firms in their industry and that do not have the same advantages or resources for retaliating and damaging challengers." Moreover, since firms are usually motivated to respond to rivals' attacks to defend their reputations (Fombrun and Shanley, 1990), the market leader's greater reputation generates increased pressure to respond to rivals' attacks. In fact, since the decision to rapidly attack the market leader is likely to receive industry-wide publicity because of its association with many stakeholders (Fombrun and Shanley, 1990), the market leader may be especially motivated to show its teeth against rapid imitators, whereas firms that imitate it later may slip under the radar (Chen and Hambrick, 1995). For example, a market leader pioneer might leverage its dominant market position in response to rapid imitators by establishing exclusive contracts with distributors (thus preempting an important asset), or by strengthening its brand recognition through massive investment in advertising (thereby raising its rivals' switching costs). Therefore, all other things being equal, when the market leader introduces a new product technology, it will be highly motivated to mobilize its extensive resources to see off rapid imitators; moreover, given its resource endowment, the market leader's retaliation is likely to seriously constrain the performance of the rapid imitators' products.

For example, at the beginning of the 2010s, as Apple was solidifying its lion's share of the tablet industry thanks to the success of the iPad, its legal costs for lawsuits against quick imitators skyrocketed (The Economist, 2012). As a result of the company's success in these legal battles, many countries banned the sale of several of its competitors' models, to the detriment of the performance of those companies. Following this line of logic, we should expect that a firm's speed of imitation will elicit a greater degree of competitive responsiveness by the technology pioneer if the technology pioneer is also the market leader (instead of a non-leader rival). And, in turn, the effect on the imitator's performance of the technology pioneer's degree of responsiveness will be more detrimental for the imitator if the technology pioneer is also the market leader. This leads to the second hypothesis of our theory:

Hypothesis 2. *An increase in a firm's speed of imitation of a new technology leads to lower market share gains for the firm relative to the technology pioneer if the technology pioneer is also the market leader (instead of a non-leader rival).*

2.3. Rapid imitation of the market leader at varying levels of industry clockspeed

Fine (1998) presented the concept of industry clockspeed to capture the velocity of industry change driven by factors related to the turnover in the technologies used to enhance the competitiveness of products. Industry clockspeed increases in two ways: firstly, by an increase in the number of innovations introduced in an industry, and secondly, with accelerations in the speed with which these innovations are adopted by industry rivals, resulting in quicker product obsolescence rates. As noted by Pacheco-de-Almeida (2010), this creates a competitive environment in which advantages are created and eroded so rapidly, it takes all the running a firm can do to keep pace with the rapidly changing technologies, a phenomenon known as Red Queen competition (Barnett and Hansen, 1996). This type of competition is akin to what the economist Joseph Schumpeter (1942) named 'creative destruction', and it is particularly prevalent in technology-intensive industries, where new product technologies are continuously introduced to stimulate replacement purchases, and where rivals must conform to these technological advancements if they are to survive (Barnett and McKendrick, 2004; Christensen et al., 1998).

Lee (2013) and Park and Lee (2006) have also found empirical support for their hypothesis that knowledge becomes obsolete over time, especially in rapidly changing technological environments, and that the speed of knowledge obsolescence may affect a firm's chances of catching up with technology pioneers. These authors have noted that if the knowledge required to compete takes some time to be assimilated by firms and if it does not change significantly over time (i.e., the scenario is one of low industry clockspeed), it might be more difficult for a firm to catch up with the technology pioneers who are likely to have more experience with the technologies they introduced, and who are better able than their followers to manage that knowledge. However, if the continuous introduction of new technologies means there is a rapid turnover in the knowledge required to compete (i.e., the scenario is one of high industry clockspeed), technology pioneers have no advantage over their followers when it comes to exploiting the advantages of the new technologies because everyone has equal standing as a novice.

We therefore expect that agility in imitating new product technologies introduced by rivals is particularly beneficial for the performance of the imitator compared to the innovator when industry clockspeed is high. In fact, imitating slowly in such circumstances leaves the imitator at risk of imitating something that is already obsolete, and thus it will squander its resources for a negligible improvement in performance. By contrast, fast imitators in high-clockspeed industries can, by keeping pace with the rapidly changing environment in terms of new knowledge and resources, build temporary advantages similar to those created by the first-mover (Lieberman and Montgomery, 1988; Makadok, 1998). Indeed, the rapid imitator must invest in these short-lived innovations if it is to sustain its growth and survive within such a hypercompetitive environment. Thus, we should expect that rapid imitation of new technologies leads to higher performance especially when industry clockspeed is high. This leads to the following hypothesis:

Hypothesis 3. *The relationship between a firm's speed of new technology imitation and its market share gains relative to the technology pioneer becomes more positive the higher the industry clockspeed.*

Given our view that industry clockspeed can shape the performance of rapid imitators, we then ask: does industry clockspeed make the rapid imitation of a market leader's innovation more or less detrimental to the performance of the imitator compared to the innovator? Although authors in the competitive dynamics literature have noted that retaliation from leading firms usually exerts more damage than retaliation dealt by smaller rivals (Chen and Hambrick, 1995), it is not clear how the changing characteristics of the business landscape might make the retaliation of leading firms more or less dangerous for industry rivals, such as those who rapidly imitate market leaders' innovation. We explore whether or not it is worth rapidly imitating the technologies introduced by the market leader in rapidly changing technological environments by drawing on the competitive dynamics studies that examine how market leaders respond to technological changes, and in particular on the literature on *leader self-displacement* in fast-clockspeed industries (Pacheco-de-Almeida, 2010).

The theory of leader self-displacement (Pacheco-de-Almeida, 2010) proposes that market leaders may hold off on investing resources to sustain their market share leadership when industry clockspeed is high. This is because when the technological environment changes rapidly as a consequence of rapid innovation and imitation cycles, the leader's strategy of devoting resources to heavily retaliation against rivals is likely to erode its sales performance, not to mention its profits and shareholder value. In fact, although a hypercompetitive environment renders current competitive advantages short-lived (D'Aveni, 1994), it also "erodes the expected returns from new advantages, which reduces leaders' incentives to accelerate investments" (Pacheco-de-Almeida, 2010: 1499). Since accelerating investments also increases costs, we contend that market leaders may delay or eschew actions that would renew their competitive advantages (e.g., they retaliate less aggressively against rapid imitators), and thus they deliberately increase the likelihood of their leadership being weakened. This theory echoes findings from previous Red Queen studies, showing that market leaders' inertia and unwillingness to deviate from established, programmatic technological trajectories, may render leaders less responsive than small organizations to fast innovation and imitation cycles (e.g., Barnett and McKendrick, 2004).

In the context of our theory of imitation speed we expect that since high industry clockspeed results in high rates of product obsolescence, the leader is less likely to invest resources in retaliating against rapid imitators because it knows that its innovations are in any event likely to become obsolete soon. The leader is instead likely to preserve its resources until the technological environment stabilizes and a clearly dominant design emerges, at which time investments will generate better returns.

During periods of high industry clockspeed, this shift in the leader's attention from retaliation to the conservation of resources for use in a more stable future means that rapid imitation of the leader's innovations is less risky, resulting in a lower negative impact on the rapid imitator's performance. Rapidly imitating a market leader's innovations in a fast industry clockspeed scenario will translate into smaller reprisals that are less detrimental to the performance of the imitator. In fact, as also shown by previous competitive dynamics studies, leaders that are slow in their retaliatory actions will have a higher rate of market share erosion (Ferrier et al., 1999).

In the reverse situation, when an industry is going through a period of low clockspeed, we expect that firms that rapidly imitate a pioneer with strong market leadership will suffer heavier retaliation. This is because the slowly changing technological environment gives longevity to the market leader's innovations and thus it gains a measure of competitive advantage that is worth protecting. Moreover, by using the lens of Park and Lee (2006), we expect that when industry clockspeed is low, the knowledge the market leader must master in order to profit from the technologies it has introduced will not significantly change over time. Thus, late adopters will likely find it difficult to use that knowledge with an effectiveness comparable to that of the market leader, given its superior experience and resource endowment. In turn, in such a stable environment, the leader is unwilling to be self-displaced; it will therefore be certain about taking the appropriate retaliatory actions to compete and preserve its leadership against rapid followers. Therefore, we should expect that in a scenario of low clockspeed, at least in the short run, rapid imitation attempts are likely to suffer most from the leader's retaliation.

In sum, the above line of logic suggests that rapidly imitating innovations introduced by the leader when industry clockspeed is high leads to a lower level of responsiveness by the leader against the imitator, which in turn results in a less negative effect on the imitator's performance. Hence, we posit:

Hypothesis 4. *While rapidly imitating technologies introduced by the market leader will lead to a reduction in the market share gains for the firm relative to the market leader (H2), this negative impact lessens during periods of high industry clockspeed.*

Figure 1 synthesizes our research model.

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3. Methods

3.1. Sample

The UK mobile phone industry was the empirical setting for our hypotheses. For the purposes of this study, 28 product technologies introduced in the UK mobile phone industry and imitated at different speeds by 14 handset vendors, operative from 1997 to 2008, were extracted from the specialist industry magazines *What Mobile*, *What CellPhone*, and *Total Mobile*, which every month published a review of the new handset devices launched in the UK, with information on the launch dates (month of launch) and technical features. We selected the following product technologies, each of which was clearly reviewed in these special interest magazines over the analyzed time period: voice dial, ringtone composer, infrared, games (pre-installed), downloadable ringtone, email client, WAP, EMS, polyphonic ringtone, recordable ringtone, SMS-chat, MP3 player, GPRS, Bluetooth, USB, color screen, MMS, photo-camera, true ringtone, video-camera, UMTS, EDGE, video call, Wi-Fi, touchscreen, advanced Internet (HTML), document viewer, and advanced operating system (OS). Although the observation period spanned from 1997 to 2008, the 28 new technologies were first introduced between January 1997 and July 2004. We used the 2004 cut-off point to allow enough time (from 2004 to 2008) to observe the imitation of the technologies. Overall, 631 new mobile phone models were introduced in the UK market over the 1997–2008 study period. Industry competitors were Nokia, Motorola, Samsung, LG, Ericsson, Sony, Sony Ericsson, BlackBerry, Siemens, Philips, Panasonic, Sagem, NEC, and Alcatel, which represented almost the entire industry in the UK at that time in terms of both market share and number of products launched. Throughout our observation period, the aggregate annual market shares of these vendors covered from 90% to 99% of the market, depending on the year, and we inferred from secondary sources that the special interest magazines we used reviewed virtually all of the models effectively introduced in the UK over our observation period. Our sample contains 566 feature phones, i.e., "regular" phone devices that offered phone calls and basic multimedia functionalities, and 65 smartphones, i.e., phones equipped with an advanced operating system making them similar to portable personal computers.[2] Smartphone devices boomed in 2008 after the launch of the Apple iPhone and Google's Android but prior to this they were niche products, mainly targeted at business users and tech-savvy early adopters (Giachetti and Marchi, 2017; Klingebiel and Joseph, 2016). The unit of analysis in our model is the firm's speed of imitation of a given technology; thus, if a firm imitated every one of the selected 28 technologies within the 1997–2008 time period, our

[2] The product technology "advanced operating system" is used to distinguish between smartphones and feature phones. During our observation period (i.e., 1997–2004) of the sampled firms, we observed the following advanced operating systems: Symbian OS, BlackBerry OS, and Microsoft Windows Mobile OS.

model would have 28 observations for that firm. Consistent with previous imitation studies (Lee et al., 2000) we computed a firm's speed of imitation for each product technology by reference to the first model a firm introduced with that technology.

We believe that there are four key reasons the UK mobile phone industry from 1997 to 2008 is a particularly suitable setting for testing our hypotheses about speed of imitation. First, the mobile phone industry, like other consumer electronics industries, has often been described as a fast-changing environment characterized by rapid new product introduction and quick technological obsolescence, two factors that underline the importance of the speedy adoption of new technology by handset vendors in order to remain competitive (Fine, 1998). The result of this high turnover of technology is that since the digital revolution in the mid-1990s, mobile phones transformed from being devices for making telephone calls to quintessential representations of technological convergence. Second, while the patent protection available in many product-based industries imposes barriers to the imitation of new products, it was only in the second half of the 2000s, prompted by the boom in smartphone devices, that patent wars in the mobile phone industry exploded (Paik and Zhu, 2016), putting it outside of our study period. Third, most of the technologies introduced in the mobile phone industry over our study period originate from other product categories (e.g., photo-camera, MP3 player, USB port, etc.) and they are often patented by suppliers who license them to mobile phone vendors (Funk, 2008). Moreover, even new technologies patented by mobile phone vendors can easily be copied by means of reverse-engineering to avoid the risk of being sued (Lee and Lim, 2001). These conditions lead to few legal impediments to technology imitation. Fourth, mobile phone vendors in our sample are very large firms that usually conduct massive advertising of product innovations in TV commercials, newspapers, or special interest magazines. This means that competitive actions related to product innovations are usually highly visible. Finally, the smartphone revolution triggered in 2008 by

Apple's iPhone and Google's Android meant that mobile phones thereafter became fairly homogenous in their incorporation of the iPhone's dominant design, with competition centering on (a) incremental improvements in existing features, and (b) the accommodation of a dizzying number of applications. This was not the case in the pre-iPhone era (i.e., our observation period) where competition revolved around dreaming up and integrating new features that have become standard in today's smartphones. This makes our observation period and data used appropriate for the analysis.

3.2. Dependent variable

Relative market share gain. Consistent with previous studies in the competitive dynamics literature (Ferrier et al. 1999; Tsai, Su, and Chen, 2011), we computed a firm's market share gain relative to the technology pioneer's by first calculating the difference between the market shares of the imitator *i* and the pioneer *j* at time *t*:

(1) $Gap_t = (MS_{i,t} - MS_{j,t})$

where $MS_{i,t}$ represents the focal imitator *i*'s market share at time *t* and $MS_{j,t}$ represents the technological pioneer *j*'s market share at time *t*. Next, we measured the market share gain as the change in the market share gap from year to year as follows:

(2) $Relative\ market\ share\ gain_{t+1} = (Gap_{t+1} - Gap_t)$

A positive value of *relative market share gain* when the imitator has lower market share than the pioneer indicates that the former has reduced the market share gap with the latter. A positive value of *relative market share gain* when the imitator has higher market share than the pioneer indicates that the former has widened the market share gap with the latter. A negative value represents the opposite situations (Tsai, Su, and Chen, 2011). Data on handsets sold in the UK per vendor were collected from Mintel International Group Limited (1997–2008), Euromonitor International (2003–2008), and firms' archival data. This variable was computed at year *t*+1 while all independent variables are at year *t*.

3.3. Independent variables

Speed of new technology imitation (SOI). Consistent with previous studies, the first measure of imitation speed was operationalized in terms of imitation *timing* (e.g., Ethiraj and Zhu, 2008; Giachetti et al., 2017), namely the time it takes for a mobile phone vendor to adopt a new technology introduced by the pioneer. More specifically, imitation timing represents the elapsed time, in months, between the date of a new technology's introduction by the pioneer *j* and the date of imitation of the technology by the imitator *i*. To transform the imitation timing into a variable that increases with the speed with which the focal imitator takes action, we developed the following indicator:

(3) $SOI_{i,k} = 1 - (timing_{i,k} / maxtiming_{i,k})$

$SOI_{i,k}$ is the speed of imitation of the technology *k* by firm *i*, $timing_{i,k}$ is the imitation timing of the technology *k* by firm *i*, and *maxtiming* is the maximum imitation timing in the sample in a given year. SOI_i ranges from 0 to 1; the greater its value (i.e., the closer it is to 1) the higher the focal firm's imitation speed.

It is worth noting that although feature phones and smartphones are devices that belong to the overall mobile phone industry, they were, especially during our observation period, targeted at very different types of consumers. As a consequence, we observed different innovation and imitation patterns between the feature phone and smartphone segments; thus, 22 of the 28 product technologies listed above were pioneered in the feature phone segment, while 6 technologies were initially diffused within smartphones and only later adopted by feature phones. The smartphone-related technologies in our sample (aside from the advanced operating systems) were video call, Wi-Fi, touchscreen, advanced Internet (HTML), and document viewer. Therefore, with the aim of separating out the smartphone and feature phone imitation dynamics, we expect that the decision to imitate a new product technology, whether this is mounted on a smartphone or a feature phone, is a response to a rival product in the smartphone or feature phone segment, respectively. As explained below, we also introduced a dummy (*smartphone*) to control for possible performance differences resulting from imitation dynamics in different segments.

Market leadership of the pioneer (Leader). We assume the market share leader to be a clearly distinct entity from the other rivals (Ferrier et al., 1999). Therefore, consistent with other studies, we used a dummy variable to detect whether the technology pioneer is the market leader (dummy = 1) or another competitor (dummy = 0). The market leader was defined as the firm with the largest market share in the UK market. Over the entire 1997–2008 period Nokia was the market share leader.

Industry clockspeed. The extant literature has proposed various empirical measures of industry clockspeed, some based on the number of innovations introduced in an industry within a certain time window (e.g., Fine, 1998; Mendelson, 2000; Mendelson and Pillai, 1999), and others focusing on the extent to which these innovations are rapidly imitated by rivals (e.g., Giachetti et al., 2017). Still others have considered both the speed of innovation and the imitation cycles (Pacheco-de-Almeida, 2010). By comparing these measures, Pacheco-de-Almeida (2010) has noted that industry clockspeed can be examined as a continuum, where the most turbulent hypercompetitive environments are those occurring when there is, within a relatively short time frame, a high rate of both product innovation and imitation, resulting in a quick and marked deviation from established standards that render competitive advantages particularly short-lived. And this is exactly the kind of scenario we want to capture to test our theory. By building on the work of Pacheco-de-Almeida (2010) we thus propose an indicator of clockspeed that takes into account the number of new technologies (i.e., innovations) introduced by technology pioneers, and the imitations of the new technologies introduced over the previous 24 months. We use a 24-month time span because: (a) the average imitation timing in our sample was two years, with rapid imitators taking less time than the industry average; and (b) it is the rapid imitation of new product technologies, i.e., the extent to which rivals decide to “follow” the first mover, that contributes to the pace of technological change in a technology intensive industry (Suárez and Lanzolla, 2005). In other words, this is a count measure of the number of new technologies and imitations of new technologies for handsets introduced over the past 24 months in the UK market. We measured this variable from the time the technology was introduced in the market by the pioneer. In practice, a pioneer introduces a certain product technology to better navigate specific competitive conditions, which we assume are assessed the year the technology is introduced (Nadkarni and Narayanan, 2007), and it will take some months for a pioneer in the mobile phone market to understand how industry structural characteristics have changed (Giachetti et al., 2017).

3.4. Control variables

We included several control variables at both the firm- and industry-level.

3.4.1. Firm-level controls

Technology pioneer’s responsiveness to imitation. The degree of competitive responsiveness of the technology pioneer to the imitation of its new technologies is used in our model as both a control variable and in a set of additional analyses we present later in the paper, after the hypothesis test section, to test the mechanisms behind the speed of imitation-performance relationship. Consistent with previous studies in the competitive dynamics literature (e.g., Chen and Hambrick, 1995; Yu, Subramaniam, and Cannella, 2009), we used content analysis to collect information on a technology pioneer’s competitive actions undertaken after its innovations (i.e., new product technologies) are imitated by industry rivals. Similarly to what we did to calculate the *patent war intensity* variable, we used LexisNexis as our main source of data when building this measure. Specifically, first we collected media articles that discuss mobile phone vendors' competitive actions in the UK.[3] LexisNexis provides a number of filters at the "industry-" and "geography-" level that serve to orient the search toward articles related to specific topics. We selected "mobile and cellular telephone" as the industry-level filter, while "UK" was the geography-level filter. We drew on previous studies to add to LexisNexis industry- and geographic-level filters a list of 125 keywords related to our purpose, such as "rivalry," "competition," "war," and their synonyms (e.g., "to counteract", "to act against", "to keep the pace with") that were likely to indicate competitive events (a full list of keywords is available from the authors upon request). Next, we searched among all articles published during our observation period to identify those that mentioned two or more of our sample firms and included at least one of our listed keywords. This step yielded 8,829 news articles. Then, for each year, we counted the number of articles published over the 365 days that followed the month the technology pioneer was imitated, and which described rivalry dynamics in which both the technology pioneer and the specific innovation-imitating rival were involved (Rindova et al., 2004). Finally, we computed the rate of growth of the rivalry dynamics between a pioneer and imitator by the articles discussing such rivalry dynamics with respect to the previous year, in order to capture whether the imitation of its technologies at year *t* determined a change in the magnitude of rivalry between the two firms with respect to year *t*-1.

Average imitation order. Imitation order reflects the position occupied by the new technology imitators in a temporal series of imitators, going from the first imitator to the last (e.g., Lee et al., 2000). Although the imitation timing gives an absolute idea of the velocity of adoption of a certain technology, imitation order is useful to assess whether the imitator is in a favorable position with respect to both the first-mover and the laggards (Lieberman and

[3] The text search in LexisNexis includes all English and non-English published news (covered by the search engine). By restricting the search to only those articles published in the major international newspapers (this is a filter available in LexisNexis) we would obtain a much lower number of articles, though the effect of the variable in our model would not change.

Montgomery, 2013). It is important to control for a firm's average imitation order within a given time period because it represents the firm's ability to anticipate rivals' imitative decisions (Pacheco-de-Almeida, Hawk and Yeung, 2015). To calculate this firm-level measure, we computed a firm's average order of imitation for all the new product technologies imitated within the last 12 months.[4]

Number of innovations. Although our arguments are mainly centered around the performance implications of rapid imitation, the extant literature on first-mover advantage has long argued for and provided empirical evidence of the performance advantage of pioneer firms (Lieberman and Montgomery, 1988, 2013). Thus, we want to account for the extent to which the imitator was also a pioneer in the year in which it imitated a new technology. This variable was measured by the count of new product technologies introduced by the imitator in the year *t*.

Group R&D intensity. Industry clockspeed studies have argued that a firm's strategy and performance in turbulent environments can be influenced by its propensity to invest in research and development (R&D) (Mendelson and Pillai, 1999). However, because mobile phone vendors often function as business units of diversified corporations, R&D data are often not available at the mobile phone business unit level. We thus relied on R&D intensity (R&D expenditures divided by total assets) of a mobile phone vendor's group as a measure of inventive effort, assuming the propensity to invest in R&D at the group level is representative of what happens at the level of the mobile phone business units. Data on the corporate groups' R&D expenditures and total assets were collected from COMPUSTAT Global, the Orbis Dataset (Bureau van Dijk), and corporate groups' annual reports.

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[4] For example, suppose a firm in the year *t* imitated three technologies, A, B, and C. Suppose the firm was the second to imitate technology A, the fifth to imitate technology B, and the eighth to imitate technology C. The computation of the average imitation order for the firm in year *t* would be (2+5+8)/3 = 5.

Smartphone dummy. We also wanted to control whether the focal imitator's performance changed depending on whether the imitated product technology was mounted by the focal imitator on a smartphone or on a feature phone. Therefore, we used a dummy that was coded 1 for product technologies adopted on smartphones, and 0 for product technologies adopted on feature phones.

3.4.2. Industry-level controls

Patent war intensity. Although, as discussed above, it is reasonable to assume that over our observation period patents did not represent a big deterrent to technology imitation in the mobile phone industry (compared to more recent years), we wanted to take into account whether the intensity of patent enforcement strategies in the UK constrained the performance of handset vendors. Following previous studies (Onoz and Giachetti, 2021; Paik and Zhu, 2016), we used LexisNexis to construct a measure of *patent war intensity* in the UK mobile phone industry based on media articles. Specifically, first we collected media articles that discuss mobile phone vendors' patent litigation cases in the UK. Next, we counted the number of media articles discussing patent lawsuits in the UK and related developments (e.g., patent acquisition, cross-licensing agreements, settlement agreements, or the amount of penalties infringers had to pay to plaintiffs) covered in all published news identified by LexisNexis, on the grounds that as patent wars in a given year escalate, the level of media coverage of patent disputes (and related events) increases, thus improving handset vendors' knowledge about these conflicts. This measure captures the importance of patent litigation events by the frequency of their appearance in media articles. Minor events, which are not likely to have much impact on vendors' strategies, will receive commensurately light coverage. For each month, the variable controls for the number of articles published in the previous 12 months that contained the keywords "mobile phones," "patents," "litigation," and other combinations of these on the grounds that these articles include information on events related to firms relying on patents to obstruct their rivals. This variable was computed the month a technology was imitated by a focal firm.

Competitive intensity. Since previous studies have argued that a firm's attempts to catch up may be affected by the intensity of competition in its industry (e.g., Ferrier et al. 1999), we adopted our procedure for computing a technology pioneer's degree of responsiveness to control for competitive intensity in the UK mobile phone industry with a variable counting the number of media articles discussing competitive actions undertaken in the UK in a given year *t* by all our sampled handset vendors.

Year dummies. Year dummies capture the time dimension and the possible change in market conditions from one year to another. Therefore, they reflect the influence of aggregate (time-series) trends on the dependent variable (Wooldridge, 2002).

Table 1 presents the descriptive statistics for the variables.

Please insert Table 1 about here
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4. Results

4.1. Hypothesis test

Our empirical models were estimated using fixed-effects regression with robust standard errors clustered at the firm-level (Cameron and Miller, 2015; Wooldridge, 2002). A Hausman test suggested that the use of fixed-effects was preferable over random-effects. Since not all technologies were adopted by all firms, and not all firms were active in the UK market over the entire time period analyzed, we ended up with an unbalanced panel. Each observation corresponds to the imitation of a certain technology by a focal firm. Moreover, all variables were standardized (mean-centered) to prevent multicollinearity (Aiken and West, 1991). We calculated variance inflation factors (VIFs) to determine whether there was multicollinearity in the analyses. For the regression models (including the control and independent variables but excluding the interaction terms and the year dummies) the average VIF is 1.50, with the highest VIF value being 1.88, suggesting that multicollinearity was not a problem (Chatterjee and Hadi, 2006).

In what follows we present the results related to our Hypotheses 1-4 (Table 2).

Please insert Table 2 about here

Hypothesis 1 predicted that an increase in a firm's speed of imitation of a new technology leads to greater market share gains for the firm relative to the technology pioneer. As Model 3 in Tables 2 shows, the relationship between *SOI* and relative market share gains is positive and significant (β = .193, p <.1), thereby supporting Hypothesis 1. However, as can be noted in the other models of Table 2, where the effect of *SOI* on relative market share gains was tested only with controls and moderating variables (i.e., Models 1 and 2), its coefficient was not significant. This suggests that the main effect of *SOI* on relative market share gains is rather weak, and thus our Hypothesis 1 should be considered as only marginally supported. Interestingly, this reinforces our idea that to better comprehend if and how a rapid imitator can outperform a technology pioneer we need to take into account various contingencies.

Hypothesis 2 predicted a negative moderating effect of the *Leader* variable on the relationship between *SOI* and the imitator's market share gains. The interaction between *Leader* and *SOI* is negative and significant in all models (*SOI* × *Leader* in Table 2: β = -.276, p < .05), supporting Hypothesis 2.

In Hypothesis 3 we predicted a negative moderating effect of *industry clockspeed* on the relationship between *SOI* and the imitator's market share gains. The coefficient of the interaction is not significant in Model 3 (*SOI* × *Industry clockspeed*: β = .065, p >.1), therefore Hypothesis 3 is not supported.

Hypothesis 4 predicted that *industry clockspeed* can shape the negative relationship between a firm's speed of imitation of technologies introduced by the market leader and the imitator's market share gains. The three-way interaction between *industry clockspeed*, *Leader*, and *SOI* in Model 3 is positive and significant (Table 2: *SOI* × *Leader* × *Industry clockspeed*: β = .407, $p < .05$). In Figure 2, using the procedure outlined by Aiken and West (1991), we plotted the high and low levels of each variable (one standard deviation above and below the mean). By performing a simple slope test (Dawson and Richter, 2006), we could observe that the relationship between imitation speed of technologies introduced by the leader and the imitator's relative market share gains is negative and significant for low industry clockspeed (Simple slope test: β =-.561, $p < .05$), but positive and significant for high industry clockspeed (Simple slope test: β = .382, $p < .01$). This provides support for Hypothesis 4.

Please insert Figure 2 around here

4.2. Additional analyses: Testing the mechanisms explaining the relationship between SOI and market share gains

When deriving our four hypotheses, we contended that a technology pioneer's degree of competitive responsiveness is an important mechanism that explains why the speed of imitation of a technology pioneer may influence the sales performance of the imitator compared to the pioneer. However, although we controlled for the degree of responsiveness of the technology pioneer in our regression models, we did not test empirically (a) whether the speed of imitation effectively leads to greater responsiveness of the pioneer, (b) if this greater responsiveness penalizes the sales performance of the imitator, and (c) if the degree of responsiveness is contingent on the market position of the technology pioneer and industry clockspeed. Therefore, in this section we offer an empirical test of a set of relationships related to the mechanisms we discussed in the hypotheses, centered on the drivers and the performance outcomes of the degree of competitive responsiveness of the technology pioneer against imitators. Figure 3 synthesizes these relationships related to the mechanisms, which we name Mechanisms (M) 1a-b, 2a-b, and 4a-b, where the numbers denote the hypotheses to which given mechanisms are related, while the label "a" refers to mechanisms that are centered on the "drivers" of a technology pioneer's competitive responsiveness, and the label "b" refers to mechanisms that are centered on the "performance outcomes" of a technology pioneer's competitive responsiveness.

Please insert Figure 3 around here

More specifically, as we discussed when deriving our hypotheses, we should expect the following relationships related to the mechanisms centered on a technology pioneer's degree of responsiveness to imitators: An increase in the speed with which a firm's new technologies are imitated increases the degree of its competitive responsiveness against imitators (Mechanism 1a); An increase in the degree of competitive responsiveness of a firm whose new technologies are imitated (i.e., the technology pioneer) is negatively related to the market share gains for the imitator relative to the technology pioneer (Mechanism 1b); The positive relationship in M1a becomes more positive if the imitated firm (i.e., the technology pioneer) is the market leader (instead of a non-leader rival) (Mechanism 2a); The negative relationship in M1b becomes more negative if the imitated firm (i.e., the technology pioneer) is the market leader (instead of a non-leader rival) (Mechanism 2b); While rapidly imitating technologies introduced by the market leader will lead to a greater competitive responsiveness of the market leader against the imitating firm (M2a), this positive impact lessens during periods of high industry clockspeed (Mechanism 4a); While a greater competitive responsiveness of the market leader against a firm imitating its new technologies will lead to a reduction in the market share gains for the firm relative to the market leader (M2b), this negative impact lessens during periods of high industry clockspeed (Mechanism 4b).

Table 3 presents the results of the regression analyses to test how *SOI* affects a technology pioneer's competitive responsiveness, i.e., Mechanisms 1a, 2a, and 4a. As shown in Model 6, the effect of *SOI* on *Technology pioneer's responsiveness* is positive and significant (β = .248, p <.01), thereby Mechanism 1a is supported. However, the moderating effect of the *Leader* variable on the relationship between *SOI* and *Technology pioneer's responsiveness* is negative and significant (*SOI* × *Leader* in Table 3: β = -.292, p < .05), the opposite of what we predicted. It means that the market leader's degree of responsiveness to rapid imitation of its innovations is lower than the degree of responsiveness of non-leader technology pioneers whose innovations are rapidly imitated. Hence, Mechanism 2a is not supported. Finally, we predicted that *industry clockspeed* can shape the relationship between a firm's speed of imitation of technologies introduced by the market leader and the leader's degree of responsiveness in that industry clockspeed reduces the degree of competitive responsiveness of the leader. The three-way interaction between *industry clockspeed*, *Leader*, and *SOI* in Model 6 is negative and significant (Table 3: *SOI* × *Leader* × *Industry clockspeed*: β = -.306, p < .05). As can be seen in Figure 4, when industry clockspeed is low, the market leader's degree of responsiveness to imitators increases the greater the speed at which its innovations are imitated (Simple slope test: β =.255, p < .05). When industry clockspeed is high, the market leader's degree of responsiveness to imitators decreases the greater the speed at which its innovations are imitated (Simple slope test: β =-.306, p < .05). Mechanism 4a is therefore supported.

Model 7 in Table 4 presents the results of the regression analyses to test how a technology pioneer's competitive responsiveness affects the imitating firm's market share gains, i.e., Mechanisms 1b, 2b and 4b. As shown in Model 7, the effect of *Technology pioneer's responsiveness* on the imitating firm's market share gains is negative and but not significant (β = -.053, p >.1), thereby Mechanism 1b is not supported. However, the moderating effect of the *Leader* variable on the relationship between *Technology pioneer's responsiveness* and the imitating firm market share gains is negative and significant (*Technology pioneer's* *responsiveness* × *Leader* in Model 4: β = -.453, p < .1), thereby supporting Mechanism 2b. Interestingly, looking at this result in conjunction with the non-supporting result for Mechanism 2a, we suggest that the leader's degree of competitive responsiveness when its technologies are imitated is lower than the responsiveness of non-leader rivals when their technologies are imitated, but the leader's responsiveness causes more damage to the imitator. Finally, we predicted that *industry clockspeed* reduces the impact of the leader's degree of competitive responsiveness on the imitator's market share gains. The three-way interaction between *industry clockspeed*, *Leader*, and *Technology pioneer's responsiveness* in Model 7 is positive and significant (Table 4: *Technology pioneer's responsiveness* × *Leader* × *Industry clockspeed*: β = .376, p < .1). As can be seen in Figure 5, when industry clockspeed is low, the imitator's market share gain decreases the greater the market leader's degree of responsiveness to the imitator (Simple slope test: β =-.629, p < .01). However, when industry clockspeed is high, the negative effect of the market leader's degree of responsiveness on the imitator's market share gain is weakened and becomes not significantly different from zero (Simple slope test: β =-.385, p > .1). This provides support for Mechanism 4b.

Interestingly, in Figure 5 we can also observe that when industry clockspeed is low, the greater the competitive responsiveness of pioneers that are non-leader rivals, the greater the market share gain of the imitator relative to the pioneers (Simple slope test: β =.204, p < .1). An explanation for this counterintuitive result could be that non-leader pioneers might be very heterogeneous in terms of the resources they have to respond to the imitator. And thus, although in a low clockspeed environment the knowledge pioneers must master in order to profit from the technologies they have introduced does not significantly change over time (Park and Lee, 2006), their resource endowment to respond to imitators often might not be adequate. An increase in competitive responsiveness without the adequate resources to undertake such competitive responses is likely to make these responses a double-edged sword for the respondent (i.e., the pioneer), and thus favor the imitator vis-à-vis the pioneer.

Please insert Tables 3 and 4, and Figures 4 and 5 around here
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5. Discussion

5.1. Implications for the imitation and competitive dynamics literatures

The model that we developed in this study suggests that an imitator's sales performance relative to the imitated rival is determined by the firm's *velocity* of imitation, by the choice of imitation target, and by the pace of technological evolution in the industry. As recently noted by imitation dynamics scholars, "as prior work has commonly assumed the industry leader, a strategic group, or the industry average as competitive referent […] the link between the focus of attention on specific rivals and performance remains unexplored" (Sharapov and Ross, 2019: 3). To fill this gap, our study shows that the performance outcomes resulting from the rapid imitation of technologies introduced by the market leader vs those introduced by non-leader rivals differ. Overall, the best performing challengers—in terms of positive change in market share gap with respect to the technology pioneer—are not necessarily those that most rapidly imitate new product technologies introduced by rivals. In fact, we found contingencies that make rapid imitation detrimental for the imitator's sales performance. While, all other things being equal, speed of imitation in our main full model (Model 3, Table 2) seemed to have overall a positive effect on the imitator's performance relative to the pioneer (Hypothesis 1), we also observed that rapid imitators obtain higher performance than slow imitators only in specific scenarios. These results complement the extant technology imitation literature that has so far focused on comparing the performance of innovators and rapid imitators (Ethiraj and Zhu, 2008; Lee et al., 2000), with scant attention being paid to examining the performance differences among firms imitating at different speeds (Giachetti et al., 2017), and in particular their ability to catch up or widen the performance gap with technology pioneers holding different market leaderships. More specifically, we found support for our hypothesis that quickly imitating technologies introduced by the market leader (as opposed to technologies introduced by non-leader rivals) may be detrimental to the imitator's performance (Hypothesis 2).

Interestingly, in our additional analyses section, by disentangling the role of a technology pioneer's competitive responsiveness to rapid imitation, we observed that although a rapid imitator's performance will be more impaired by the competitive responsiveness of a market leader than by that of a non-market leader (Mechanism 2b, Figure 3), a leader's degree of responsiveness to rapid imitation is likely to be lower than that of non-leader rivals (which is contrary to what we predicted in Mechanism 2a, Figure 3). In practical terms, this means that although the volume of competitive responses by the leader against rapid imitators of its innovations is lower than the volume of competitive responses of non-leader pioneers in similar circumstances, the competitive responses undertaken by market leaders are more harmful. These results are somehow consistent with the findings of Chen and Hambrick (1995), who noted that small firms may be capable to execute their responses in a more timely manner than larger firms because of their flexibility, while larger firms (market leaders in our case) may be constrained by structural complexity and slower information processing, which impair their degree of responsiveness to rivals' attack. However, given the larger firms' greater experience and resource endowment, the effectiveness of the competitive weapons they use to retaliate against attackers are likely to have a greater negative impact on the attackers' performance. Therefore, our findings highlight the risks a firm runs when using rapid imitation to catch up with pioneers that have strong market leadership, and complement studies on rivalry-based imitation (e.g., Giachetti et al., 2017; Lieberman and Asaba, 2006; Smith et al., 1991), the literature on leader-challenger catching up dynamics (e.g., Chen et al., 2007; Ferrier et al., 1999; Pacheco-de-Almeida, 2010), and studies on the competitive responsiveness of larger vs smaller firms (Chen and Hambrick, 1995).

5.2. Implications for the windows of opportunity and technological change literatures

Although authors from the technological change literature have noted that rapid changes in technologies may represent "windows of opportunity" for challengers since market leaders are usually less willing to adapt their resources and capabilities to exploit emerging technologies (e.g., Christensen et al., 1998; Lee and Malerba, 2017; Li et al., 2019; Park and Lee, 2006), these studies have not dug deep into the performance implication of imitation timing, and thus do not capture its effect on the catching-up processes. This is surprising since, as noted by some authors, market leaders are likely to respond differently to rivals depending on the characteristics of the competitive environment (Barnett and McKendrick, 2004; Pacheco-de-Almeida, 2010). With our Hypotheses 3 and 4 we attempted to contribute to this literature by exploring whether or not it is worth rapidly imitating the technologies introduced by rivals, and the market leader in particular, as industry clockspeed escalates.

Contrary to our expectation, we found that, overall, imitating rapidly when an industry experiences high rates of imitation and innovation—i.e., high industry clockspeed—does not help the imitator's performance compared to the innovator's (Hypothesis 3). Ex-post, a possible explanation for this result could be that imitating rapidly during high industry clockspeed runs the risk of imitating something that fails to gain consumer approval; holding fire on imitating might enable a firm to wait until the water has been tested by the first imitators (Lieberman and Montgomery, 1988). In other words, imitating a new technology without haste can help imitators understand its weaknesses and the consumer response to it, and to think about how to modify the technology before installing it on their products.

Furthermore, we found support for our hypothesis that when industry clockspeed is high, rapid imitation of the leader's innovations is less detrimental for the rapid imitator's performance and may help the rapid imitator to catch up with the leader (Hypothesis 4). Grounded in the literature of leader self-displacement in hypercompetitive environments (Pacheco-de-Almeida, 2010), our theory proposes that in such a turbulent environment, market leaders are less likely to be incentivized to incur the costs of retaliating aggressively against rapid imitators (as we noted in the Mechanism 4a, Figure 3); instead, they are more likely to make a deliberate decision not to rush to defend their short-term competitive advantage and may even perhaps accept a higher probability of being temporarily displaced by rapid imitators while they wait for the market to stabilize. It is thus in this scenario of high industry clockspeed that rapidly imitating market leaders' innovations will result in lower reprisals that are less detrimental for the performance of the imitator. This, in turn, will positively affect the performance of those in the forefront of rapid imitation. We also found that the higher the industry clockspeed, the lower the negative effect of the market leader's responsiveness on the focal imitator's performance (Mechanism 4b, Figure 3). Our findings contribute to the extant technological change literature (Ansari and Krop, 2012; Barnett and McKendrick, 2004; Christensen et al., 1998; Lee and Malerba, 2017) by shedding more light on the role played by an industry's structural characteristics in making market leader retaliation less risky for rapid followers (in our case, rapid imitators). For example, consistent with previous studies on windows of opportunity (Lee, 2013), we observed that the pace of technological evolution may help smaller firms to catch up with larger rivals.

The way Nokia responded to an escalating industry clockspeed in the early 2000s is an interesting example corroborating our theory and findings. With solid market leadership in most geographic markets, and while navigating a competitive environment in which new mobile phone technologies popped up every month, Nokia suddenly changed its competitive behavior against industry rivals. As noted by Doz and Wilson (2017: 88) in their analysis of Nokia's response to rivals in the early 2000s, "scale rather than speed became the dominant paradigm. It seemed that being late to market [with both product technology innovations and retaliations against rapid imitators] became the accepted way of doing things". In other words, in such a turbulent competitive environment Nokia preferred to wait for new product technologies (whether these were its own or generated by others) to consolidate among industry rivals before investing resources in their mass production. This meant that the company not only slowed down the speed with which it imitated its rivals' innovations, but it also took the decision to allow other firms to imitate its innovations so as to ensure their acceptance by consumers before asking its suppliers to undertake high volume production. This strategy caused the company to lose ground to rivals like Samsung and Sony Ericsson, which were able to rapidly increase their product sales through their early adoption of the latest technological advancements for handsets; at that time being at the forefront of innovation was a key prerequisite for being allocated space on telecom carriers' shelves.

5.3. Limitations and avenues for future research

As with any study, this has its limitations. One important concern has to do with the generalizability of the results. We conducted our study in the UK, a developed country characterized by a relatively high mobile phone diffusion rate where most established vendors have expanded their sales activities, and with Nokia being the market leader over our entire observation period. Further related research could extend our model to other developed countries, such as the United States and Germany, and also to emerging economies where handsets and related technologies have taken time to diffuse, such as China and India, and where other handset vendors played a role as market leaders.

Second, although we expect that our results can be generalized to all sectors of consumer electronics and not just to mobile phones, there are other technology-intensive industries whose products are characterized by a lower level of "technological convergence", such as the pharmaceutical and chemical industry, and these industries may show different imitation dynamics. Likewise, industry clockspeed, one of our key independent variables, is likely to have more meaning and empirical traction in a multi-industry study that considers, for example, consumer electronics products other than mobile phones, in order to provide a greater variation to this variable. Therefore, we hope future research will expand our research model by adding contingencies related to the type of high-tech industry, and by using as the research setting multiple industry environments.

Third, as explained in the method section, although our observation period was characterized by low patent litigation intensity (Paik and Zhu, 2016), patent wars in the mobile phone industry, as well as in other technology-intense industries (Cohen, Gurun, and Kominers, 2016), exploded at the end of the 2000s, inevitably influencing firms' imitation dynamics and related performance. Future studies might replicate our analysis by testing the relationships we propose with a wider time window, comparing periods of low vs high levels of patent litigation intensity, and then adding patent-related variables into the model.

Fourth, as far as our additional analyses related to the test of mechanisms are concerned, it is worth noting that, although we believe LexisNexis database is a quite complete and reliable source for studying competitive actions and reactions in many industries, the mobile phone industry included, it may not be comprehensive in reporting on all competitive actions. Some important competitive actions by handset vendors in the UK we used to measure the degree of responsiveness of the technology pioneer may not have been captured by online publications reached by LexisNexis search engine, or they may have been discussed only marginally, though having a profound impact on the imitator's performance. Moreover, with our approach to identifying competitive responsiveness we could not always tell precisely the real intention behind each action and reaction. Therefore, future studies could replicate our analysis of imitation dynamics by using alternative research methodologies, like recent techniques for topic modelling based on textual analysis (e.g., Hannigan et al., 2019) or the case study analysis based on in-depth interviews with top management teams (e.g., Peprah et al., 2022).

Finally, our study faces a fundamental identification problem: does speed of imitation enhance performance or is the speed of imitation spuriously correlated with performance because superior firms are better able to imitate rapidly? By computing independent variables always in instances preceding the dependent variable, our study design and empirical models attempted to control for much of the unobserved heterogeneity underlying this criticism, enabling us to interpret our results with greater confidence (Jacobson, 1990). For example, the dependent variable measuring the imitator's market share gain was computed the year after the imitation occurred. Likewise, with regard the technology pioneer's responsiveness variable, we used media articles discussing the pioneer's competitive responses pursued during the year following the imitation of its innovations. However, future research could overcome this identification problem by examining the interrelated dynamics and evolution of imitative actions and firms' resource endowment by employing fine-grained qualitative studies or laboratory simulation methodologies (Chen and Miller, 2012).

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Table 1. Descriptive statistics

		Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1	Relative market share gain	-0.004	0.066	-0.237	0.143	1.000										
2	SOI	0.732	0.199	0.000	0.983	-0.054	1.000									
3	Responsiveness	-0.241	1.042	-1.000	8.000	-0.152*	0.189**	1.000								
4	Leader	0.361	0.481	0.000	1.000	-0.147*	-0.139^{+}	0.029	1.000							
5	Industry clockspeed	10.660	7.329	1.000	28.000	0.140^{+}	0.305**	-0.156*	-0.144*	1.000						
6	Average imitation order	4.384	1.919	1.000	9.000	0.205**	-0.288**	-0.133^{+}	-0.057	0.014	1.000					
7	Number of innovations	0.624	1.032	0.000	5.000	0.000	0.108	-0.119^{+}	-0.049	-0.120^{+}	-0.062	1.000				
8	Group R&D Intensity	0.089	0.086	0.010	0.672	-0.028	0.135^{+}	0.269**	-0.022	0.191**	-0.421**	0.019	1.000			
9	Smartphone dummy	0.093	0.291	0.000	1.000	0.047	-0.308**	-0.055	0.204**	0.090	-0.243**	-0.073	0.246**	1.000		
10	Patent war intensity	23.206	6.580	1.000	41.000	0.069	-0.301**	-0.227**	-0.073	0.337**	0.200**	-0.314**	-0.028	0.212**	1.000	
11	Competitive intensity	171.376	31.386	95.000	221.000	-0.147*	-0.164*	0.120+	-0.025	0.330**	0.236**	-0.190**	-0.018	0.128^{+}	0.326**	1.000

Notes:
N = 194. Mean, SD, Min and Max values are based on unstandardized variables.
Significance: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table 2. Fixed-effects regression: Speed of imitation of new product technologies on firm's relative market share gain

	Model 1	Model 2	Model 3
Constant	0.594	0.637	1.527^{+}
	(1.459)	(1.490)	(1.970)
Main effects			
Speed of imitation (H1)	0.030	0.081	0.193^{+}
	(0.513)	(0.957)	(1.893)
Moderators			
Leader		-0.231	-0.270
		(-1.206)	(-1.687)
Industry clockspeed		-0.107	-0.235**
		(-1.617)	(-3.260)
Interactions			
Speed of imitation × Leader (H2)			-0.276*
			(-2.436)
Speed of imitation × Industry clockspeed (H3)			0.065
			(1.129)
Leader × Industry clockspeed			0.593**
			(4.148)
Speed of imitation × Leader × Industry clockspeed (H4)			0.407*
			(2.310)
Controls			
Responsiveness	-0.057	-0.066	-0.073
	(-1.232)	(-1.385)	(-1.442)
Average imitation order	-0.013	-0.001	-0.011
	(-0.134)	(-0.014)	(-0.131)
Number of innovations	0.083	0.076	0.068
	(0.830)	(0.783)	(0.620)
Group R&D intensity	-0.069	-0.049	-0.014
	(-1.029)	(-0.801)	(-0.154)
Smartphone dummy	0.112	0.170	0.091
	(0.481)	(0.623)	(0.325)
Patent war intensity	0.223**	0.208**	0.331*
	(3.771)	(3.092)	(2.491)
Competitive intensity	0.048	0.057	0.027
	(0.536)	(0.645)	(0.277)
Year dummies	Included	Included	Included
N	194	194	194
Within R^2	0.273	0.289	0.402

Notes:
Estimates are based on standardized variables; *t*-statistics are reported in parentheses.
Significance: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table 3. Fixed-effects regression: Speed of imitation of new product technologies on the technology pioneer's responsiveness

	Model 4	Model 5	Model 6
Constant	1.647*	1.331⁺	1.044
	(2.529)	(1.879)	(1.634)
Main effects			
Speed of imitation (M1a)	0.006	0.113⁺	0.248**
	(0.181)	(2.105)	(3.300)
Moderators			
Leader		0.031	0.153
		(0.283)	(1.513)
Industry clockspeed		-0.176**	-0.247**
		(-3.528)	(-3.361)
Interactions			
Speed of imitation × Leader (M2a)			-0.292*
			(-2.789)
Speed of imitation × Industry clockspeed			0.040
			(0.512)
Leader × Industry clockspeed			0.157⁺
			(1.958)
Speed of imitation × Leader × Industry clockspeed (M4a)			-0.306*
			(-2.449)
Controls			
Average imitation order	0.131	0.113	0.098
	(1.281)	(1.001)	(0.898)
Number of innovations	0.036	0.012	0.013
	(0.455)	(0.152)	(0.166)
Group R&D intensity	0.411**	0.386**	0.357**
	(5.184)	(4.656)	(5.870)
Smartphone dummy	-0.008	-0.062	-0.235
	(-0.048)	(-0.319)	(-1.161)
Patent war intensity	-0.013	-0.031	-0.102
	(-0.112)	(-0.270)	(-0.834)
Competitive intensity	0.526*	0.539*	0.567*
	(2.583)	(2.621)	(2.646)
Year dummies	Included	Included	Included
N	194	194	194
Within R^2	0.443	0.453	0.468

Notes:
Estimates are based on standardized variables; *t*-statistics are reported in parentheses.
Significance: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table 4. Fixed-effects regression: Technology pioneer's responsiveness on firm's relative market share gain

	Model 7
Constant	0.921
	(1.212)
Main effects	
Responsiveness (M1b)	-0.053
	(-0.494)
Moderators	
Leader	-0.022
	(-0.122)
Industry clockspeed	-0.181*
	(-2.776)
Interactions	
Responsiveness × Leader (M2b)	-0.453^{+}
	(-1.973)
Responsiveness × Industry clockspeed	-0.253*
	(-2.206)
Responsiveness × Leader × Industry clockspeed (M4b)	0.376^{+}
	(2.003)
Controls	
Speed of imitation	-0.010
	(-0.131)
Average imitation order	-0.011
	(-0.117)
Number of innovations	0.067
	(0.654)
Group R&D intensity	0.073
	(0.547)
Smartphone dummy	-0.040
	(-0.176)
Patent war intensity	0.233^{+}
	(2.127)
Competitive intensity	0.071
	(0.749)
Year dummies	Included
N	194
Within R^2	0.440

Notes:
Estimates are based on standardized variables; *t*-statistics are reported in parentheses.
Significance: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

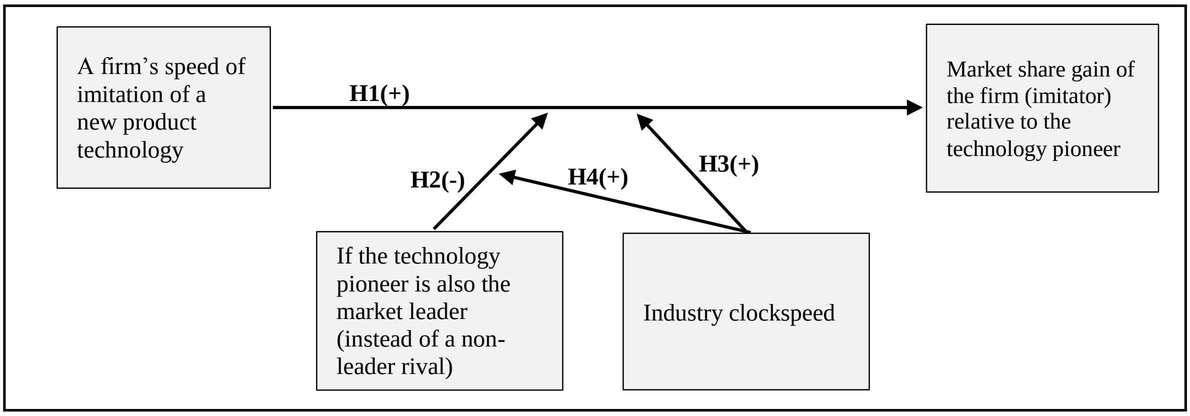

Figure 1. Research model

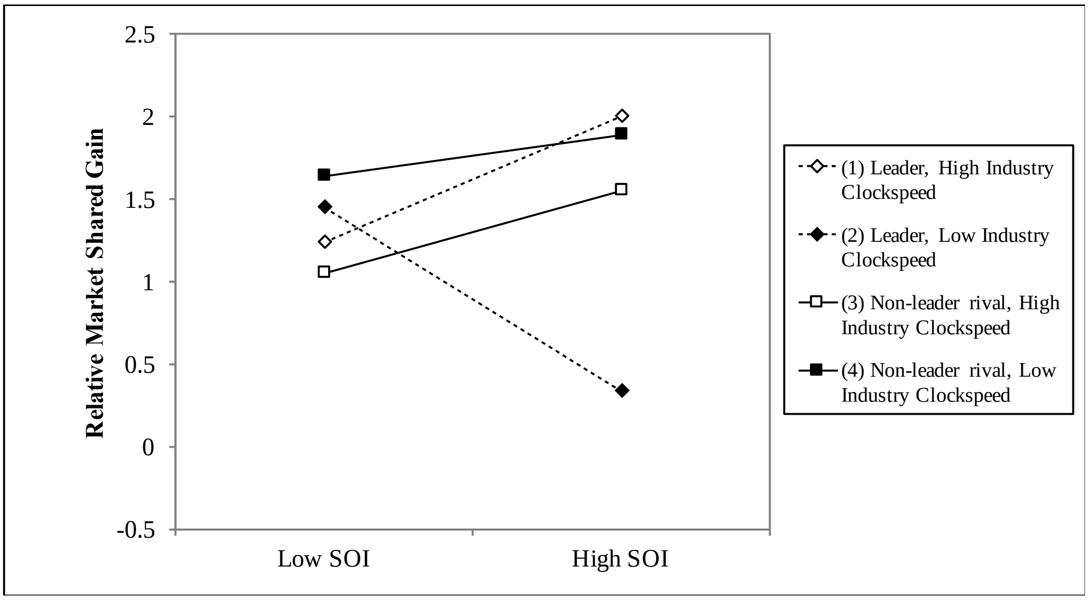

Figure 2. Three-way interaction (SOI × Leader × Industry clockspeed) on Relative market share gain
Notes: The figure is based on standardized variables.

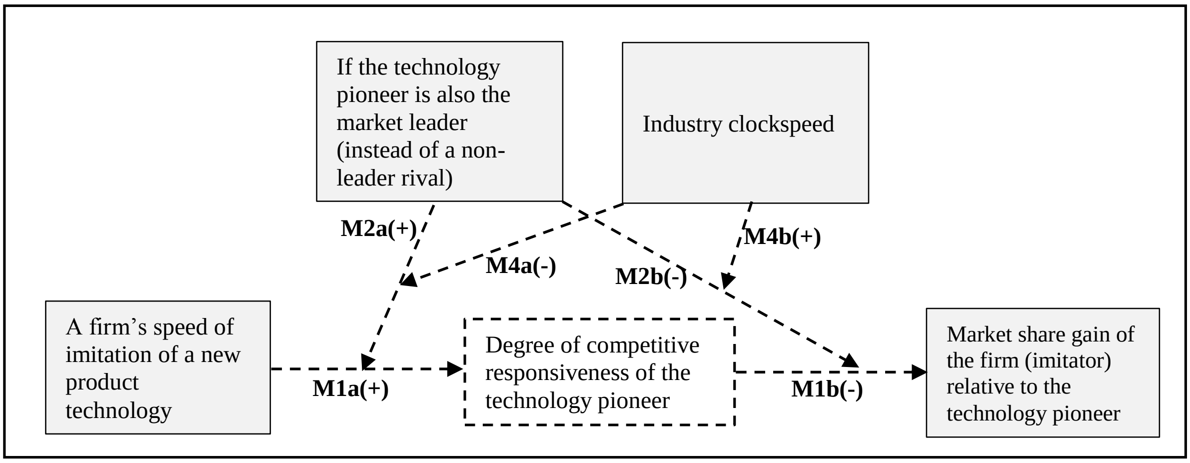

Figure 3. The mechanisms explaining the relationship between speed of imitation and market share gains
Notes: Dotted lines denotes the relationships related to the mechanisms (M), which are centered on the drivers and performance outcomes of the degree of competitive responsiveness of the technology pioneer.

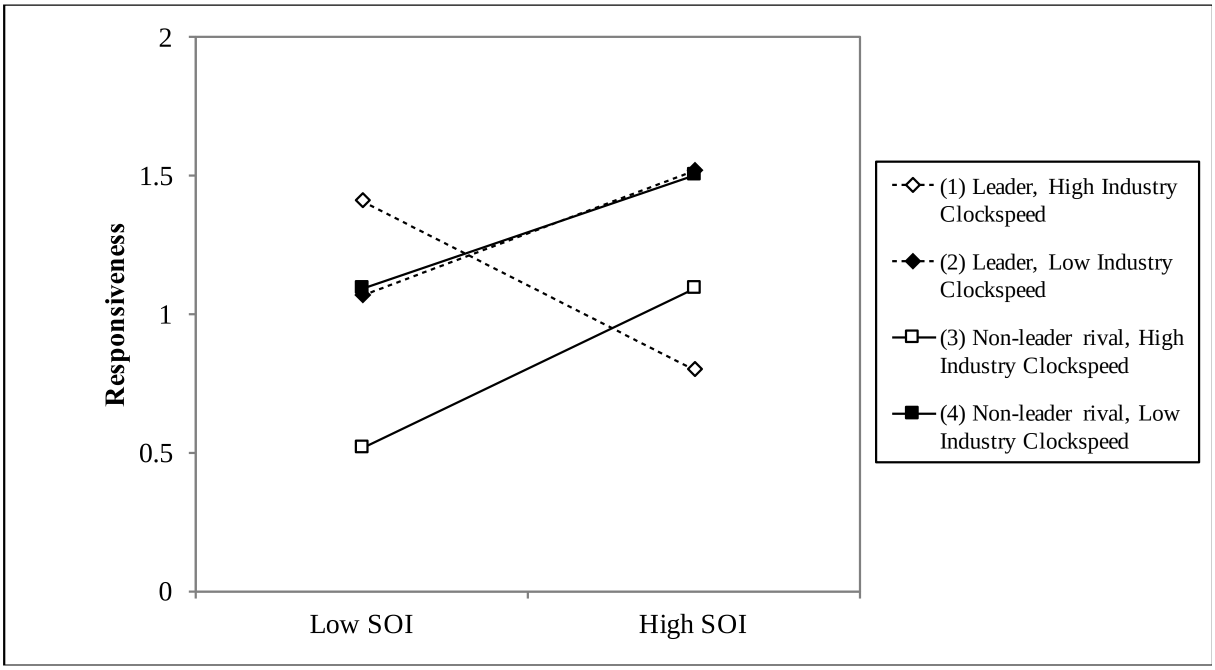

Figure 4. Three-way interaction (SOI × Leader × Industry clockspeed) on Responsiveness
Notes: The figure is based on standardized variables.

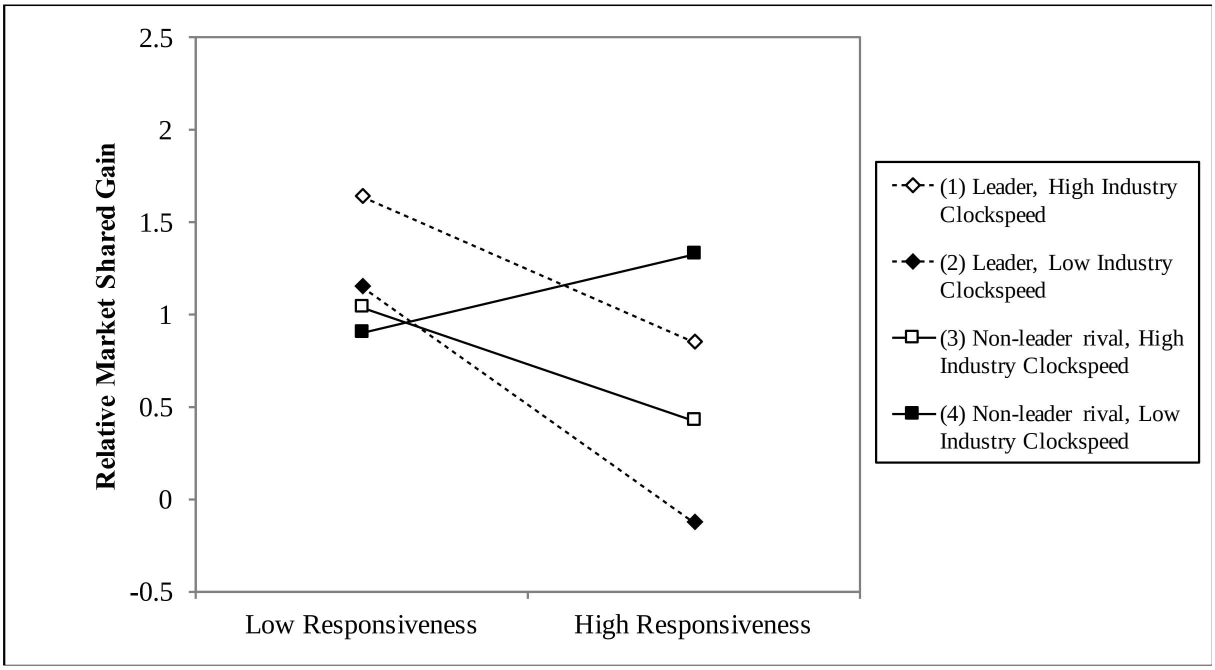

Figure 5. Three-way interaction (Responsiveness × Leader × Industry clockspeed) on Relative market share gain
Notes: The figure is based on standardized variables.

Highlights

- We investigate whether it pays for a firm to rapidly imitate a technology pioneer
- The performance of the imitator is contingent on whether the pioneer is the market leader or a non-leader rival
- The risk of rapidly imitating the market leader changes depending on the level of industry clockspeed
- The competitive responsiveness of the pioneer is a key mechanism to explain the performance of rapid imitation
- Data on technologies mounted on more than 600 mobile phones introduced to the UK market by 14 vendors