



Hold or hurry? Speed of imitation of rivals' innovations in changing technological landscapes

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ABSTRACT

Firms seeking fast-mover advantages often confront a critical challenge: not only whether to imitate rivals' innovations but also how quickly to do so. Fast imitation, however, entails risks, particularly in highly uncertain environments. By bridging information-based and rivalry-based theories of imitation with the technological change literature, we investigate how firms adjust their speed of imitation of rivals' technological innovations during periods of technological transition and technological stability. Using a database of 9060 mobile phones and 156 mobile-phone-related technological innovations introduced from 1992 to 2019, we find that a firm's speed of imitation is lower during periods of technological transition following a technological discontinuity compared to periods of technological stability where a dominant design is established. Furthermore, we find that the relationship between technological transitions and a firm's speed of imitation is shaped by three moderating factors: the firm's pioneering orientation, the relative market share position of the technology pioneer, and the visibility of the technological innovation. Our study contributes to the imitation and technological change literature by providing a nuanced understanding of the trade-offs associated with speed of imitation in the context of industry-wide technological shifts.

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1. Introduction

Strategic management scholars have noted that “rivals imitate increasingly faster, and the race to take on new market opportunities has accelerated” (Pacheco-de-Almeida et al., 2015, p. 159). In this context, firms must balance the benefits and risks of *imitation speed*, which has emerged as a determinant of *fast-mover advantages* (e.g., Makadok, 1998; Pacheco-de-Almeida, 2010). When imitating rivals' technological innovations, rapid imitation enables firms to swiftly adopt cutting-edge technologies (Lee et al., 2000; Markides and Geroski, 2004), whereas slower imitation allows firms to carefully assess the effectiveness of innovations, thereby reducing the risk of adopting unsuccessful ones (Ethiraj and Zhu, 2008).

Drawing on competitive dynamics theories of imitation tied to *rivalry*

(e.g., Fiegenbaum and Thomas, 1995; Lee et al., 2000) and sociological and economic theories tied to *information* (e.g., Bikhchandani et al., 1998; Haunschild and Miner, 1997), research shows that *environmental uncertainty* shapes motives for imitation (Lieberman and Asaba, 2006): when uncertainty is low, firms prioritize matching close rivals (i.e., rivalry-based motives), whereas under high uncertainty, they focus on following firms perceived to possess more reliable information (i.e., information-based motives). However, despite recognition that balancing imitation speed is critical, especially in *technology-intensive industries* (e.g., Giachetti et al., 2017; Giachetti and Li Pira, 2022), theories have addressed imitation broadly, treating velocity marginally and rarely focusing on rivals' *innovations*. We address this gap.

Environmental uncertainty often stems from major technological change—“when the firm is unsure about whether its technology will eventually become dominant in the industry” (Toh and Kim, 2013, p. 1214). For instance, prior literature has focused on how firms respond to a *technological discontinuity*, defined as a breakthrough innovation that reshapes product development and consumption and makes existing technologies less competitive (Anderson and Tushman, 1990; Tushman and Anderson, 1986). This situation forces firms to navigate a *period of*

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ferment—that is, a *technological transition*—in which firms experiment with the new technology while the industry shifts to a new product generation (Lawless and Anderson, 1996). This scenario is inherently uncertain, as firms must reconfigure to accommodate a new generation of products and treat the transition as a “window of opportunity” (Lee and Malerba, 2017), making it challenging to predict the likely outcome of their technology adoption decisions. Such a transition lasts until a dominant design is established, leading to a period of *technological stability*—that is, a phase in which subsequent innovations no longer revolutionize the product category’s underlying technological architecture. During this period, uncertainty about technology adoption decisions is substantially reduced (Ozalp et al., 2023), and it persists “until a major technological discontinuity occurs” (Utterback and Suarez, 1993, pp. 2–3).

For example, in the early 1990s, mobile phone makers faced a shift from analog to digital, during which rivals introduced innovations such as SMS, mini-SIM, and new form factors. Yet, in this generational transition, firms could not predict which features would become part of the dominant design. Some firms failed to grasp this transition promptly, and laggards saw their competitive positions weakened. As Nokia’s CEO Jorma Ollila later observed: “1991 to 1993 were the defining years for who understood what that business was really about” (Doz and Wilson, 2018, p. 39). This illustrates how technological discontinuities create uncertain environments for decisions on whether and how quickly to imitate rivals’ innovations.

In strategic management, how firms respond to technological transitions remains debated (Cohen and Tripsas, 2018; Eggers and Park, 2018). Studies note that “incumbent firms’ struggles to adapt to discontinuous change, [...] some incumbents defy the odds and overcome such organizational inertia” (König et al., 2021, p. 771). Periods of transition, marked by uncertainty, pose a dilemma: firms must weigh competitive gains from imitation against long-term risks of adopting innovations that may fail. These contrasting views suggest firms adjust their imitation speed by balancing rivalry pressures with the risks posed by environmental uncertainty.

To clarify these ambiguities, we integrate imitation and technological change literature. We argue that uncertainty during technological transitions makes firms more reluctant to imitate rivals’ innovations, slowing the pace of imitation relative to periods with a dominant design. In such times, priority shifts from rapidly matching rivals to cautiously scanning the environment, despite opportunities that transitions may offer (Lee and Malerba, 2017). We further contend that the extent of this slowdown depends on factors related to the imitator, the pioneer, and innovation itself. First, firms with a high *pioneering orientation*—“those firms with a proclivity toward pioneering with uniquely innovative products” (Mueller et al., 2012, p. 1523), due to their higher tolerance for risk—may be more inclined to maintain competitive parity by imitating rivals’ innovations more quickly, even when such motives are generally weakened during periods of high uncertainty. Second, although imitation may be slowed during technological transitions, the effect of the *technology pioneer’s market share advantage relative to the focal firm*, signaling greater resources and information (Giachetti and Li Pira, 2022), can yield opposite moderating effects depending on the theoretical lens. From a rivalry-based view, it signals greater resource differentials and a higher risk of costly retaliation, making the focal firm more hesitant to imitate, particularly under uncertain conditions; whereas from an information-based view, it signals superior knowledge about which innovations to launch, potentially accelerating imitation during periods of high uncertainty. Third, building on competitive dynamics research on object visibility (Chen and Miller, 2012) and organizational sociology studies on refracted signals (Pollock and Rindova, 2003), we introduce the concept of *technology visibility*: the degree to which a technology is noticeable to external actors, as reflected in its coverage across information sources. We argue that the speed-dampening effect of technological transition is attenuated when the imitated innovation exhibits high technology visibility.

We test our hypotheses using a sample of 9060 mobile phones and 156 innovations introduced by 114 mobile phone manufacturers between 1992 and 2019. This period saw two shifts: from analog to digital in the early 1990s and from digital phones to smartphones in the late 2000s. Our study contributes to the existing literature in various ways. First, it bridges studies on imitation speed with literature on technological transitions by illustrating how a firm’s speed of imitation of rivals’ innovations changes over an industry’s evolution. Furthermore, we incorporate contingencies at the imitator-, target-, and object-level. At the imitator level, we theorize that pioneering orientation accelerates imitation during transitions. This responds to the call by strategy scholars to investigate “the attributes of the new markets being entered” (Mueller et al., 2012, p. 1543) as potential factors affecting how a firm’s pioneering orientation affects its competitive strategies. At the target level, we move beyond absolute rival traits such as market leadership (Chen and Hambrick, 1995; Giachetti and Li Pira, 2022) to examine the focal firm vis-à-vis the technology pioneer. The same pioneer may appear larger than the focal firm in some contexts, reflecting greater resource and information endowment, while smaller in others. This advantage can trigger contrasting motives for imitation, and we show which motive prevails during periods of transition. At the object level, prior research on the characteristics of technologies that affect imitation speed has examined factors such as whether they build on existing knowledge, expected outcomes, patenting, and whether the innovation is a product or process (e.g., Cohen et al., 2002; Damanpour and Gopalakrishnan, 2002; Jonsson and Regné, 2009; Lee et al., 2003). Such studies illuminate object-level factors, but overlook how visible a technology is within the industry—a construct we introduce in this paper.

2. Theoretical background and hypotheses development

2.1. Rivalry-based and information-based theories of imitation

A central debate in the literature on imitation concerns the underlying motives that drive firms to replicate rivals’ actions. Lieberman and Asaba (2006) identify environmental uncertainty as the primary factor influencing a firm’s various motives for imitation. Particularly, they note a distinction between *rivalry-based* and *information-based* imitation theories. Rivalry-based theories, rooted in competitive dynamics literature, focus on imitating rivals to maintain competitive parity, assuming low information asymmetry, typically found in more certain environments (e.g., Fiegenbaum and Thomas, 1995; Lee et al., 2000). When uncertainty is low, typically, firms tend to orient their imitative actions toward closer rivals, those with similar resources, as a means to mitigate rivalry. Information-based theories instead, which arise from the fields of economics and sociology, assert that firms imitate as a strategy to navigate environmental uncertainty (e.g., Haunschild and Miner, 1997; Semadeni and Anderson, 2010). When uncertainty is high, firms tend to follow the behavior of those firms that are perceived as possessing superior information, usually more visible firms, with a larger market share.

Although the value of these two conceptual bases for explaining imitation is widely recognized, empirical research directly comparing their predictions with respect to the *speed of imitating technological innovations* remains limited (Giachetti and Lanzolla, 2016; Giachetti et al., 2017). This gap is surprising because the speed at which firms imitate rivals’ innovations is likely to be shaped in systematically different ways depending on the underlying motive. When imitation is rivalry-based, firms may accelerate imitation to avoid competitive disadvantages and preserve market parity, while bearing the risk of committing prematurely to innovations that may later prove unprofitable. In contrast, when imitation is information-based, firms may deliberately slow the pace of imitation in order to reduce uncertainty and learn from others’ experiences before committing resources, while bearing the risk of forfeiting early-mover advantages to faster rivals. In light of our focus on

the dynamics of the speed of imitation across technological cycles, this raises important questions: during periods of technological transitions, when does rivalry-based imitation dominate over information-based imitation, and when does the reverse hold? Conversely, how do these motives influence the speed of imitation during periods of technological stability? In the next section, we review the literature on the antecedents of imitation speed before presenting our hypotheses.

2.2. Antecedents of imitation speed

For years, scholars approached imitation under the “prevalent assumption” that “there is only one imitation strategy” (Posen et al., 2023, p. 75), which partly left a theoretical puzzle about the nuanced dimensions behind imitation strategies. Accordingly, researchers have shifted from this overly simplistic “one imitation strategy” view to the “many different imitation strategies assumption,” which suggests that imitation involves more than a binary yes-or-no choice (Posen et al., 2023, p. 93). Relatedly, scholars have explored various factors that influence the speed at which firms imitate rivals' products, processes, technologies, or strategic decisions more generally. Here, we review these drivers of speed of imitation, organized into four categories: focal firm (i.e., the imitator) characteristics, target (i.e., “who” is imitated at different speeds) characteristics, object (i.e., “what” is imitated at different speeds) characteristics, and environmental (i.e., “where” the imitation is undertaken) characteristics.

Regarding the *focal firm* characteristics, speed of imitation is affected, for example, by organizational rigidities and resource availability. Quick imitators are those with low levels of organizational inertia (MacMillan et al., 1985), low ownership resistance to challenging the status quo, and high levels of fit with dominant norms (Jonsson and Regné, 2009). As regards resources, quick imitators are firms with great resource slack, positive prior performance (Haleblian et al., 2012), large market shares (Gimeno et al., 2005), and those possessing industry-specialized assets (Mitchell, 1989). Also, the home-country culture could affect imitation speed, with quick imitators coming from collectivistic (rather than individualistic) and/or high power distance countries à la Hofstede (Li and Parboteeah, 2015).

Regarding the *target rival*, previous studies have examined a firm's speed of imitation of pioneers of new products, processes, and technologies (MacMillan et al., 1985), first entrants into a country (Delios et al., 2008), strategic group members, and market leaders (Giachetti and Lanzolla, 2016). Imitation speed is positively affected by the target visibility (MacMillan et al., 1985), international experience (Delios et al., 2008), being in the same imitator's strategic group (Gimeno et al., 2005), high flow of key human resources from the pioneer to its rivals (Zander and Kogut, 1995), and high social proximity with the first mover (Greve, 1996).

Previous studies have explored as *objects* of imitation mainly new products, technologies, and market entry decisions. For example, authors have found contrasting results about the effect of the degree of novelty of the object on imitation speed: while MacMillan et al. (1985) and Mansfield (1961) found that when innovations pioneer a novel knowledge base are imitated more slowly than innovations that build on existing knowledge, Lee et al. (2003) obtained opposite results. A group of studies highlighted that the expected outcomes of imitation affect the speed at which imitation is executed (MacMillan et al., 1985). Additionally, products are imitated more rapidly than processes (Damanpour and Gopalakrishnan, 2002), and patented objects are imitated more slowly than non-patented ones (Cohen et al., 2002).

Finally, a number of *environmental* characteristics affect the speed of imitation, such as the industry's competitive structure, the number of previous imitators, and the level of environmental uncertainty. For example, various studies have found that competitive intensity (Delios et al., 2008; Mitchell, 1989) often accelerates imitation by incentivizing firms to rapidly maintain competitive parity. Additionally, as the number of previous imitators increases, it reduces perceived risks associated

with specific strategic actions, thereby hastening a firm's decision to imitate that action (Delios et al., 2008; Mitchell, 1989; Ozalp and Kretschmer, 2019). Regarding environmental uncertainty, the high uncertainty firms have to cope with in the initial stages of the industry life cycle (Giachetti and Lanzolla, 2016) and the uncertainty about the industry's future policies (Henisz and Delios, 2001) hinder the speed of imitation.

2.3. Technological transitions and the speed of imitation of rivals' technological innovations

Prior research has defined *technological innovations* as new hardware or software components introduced to expand or improve a product's functionality or change its aesthetic design (Kaplan and Tripsas, 2008; Teece, 1986), resulting in *new product attributes* that provide value to users (Mukherjee and Hoyer, 2001; Piazzai and Wijnberg, 2019). Firms introduce such innovations both during periods of technological change and stability. We contend that during periods of stability, rivalry-based motives for rapid imitation dominate as firms experience lower levels of uncertainty about the likely outcome of their decisions. In such scenarios, firms imitate their rivals' innovations to maintain competitive parity, with the speed of imitation being critical in achieving this goal. Indeed, “when uncertainty is low [...] firms may also be *risk averse*, particularly to loss of market share” (Lieberman and Asaba, 2006, p. 377), deriving from the lack of differentiation advantages with respect to first movers (Lieberman and Montgomery, 1988). Hence, during periods of technological stability, firms may be more inclined to imitate rapidly to prevent lagging behind technology pioneers and early followers.

In contrast, during transitions, firms are confronted with higher levels of uncertainty about the likely outcome of their decisions (Ozalp et al., 2023). In fact, although a technological discontinuity may be perceived as a window of opportunity for some firms (Lee and Malerba, 2017), it often poses challenges to the current dominant design, necessitating firms to *reassess and reallocate their resources and capabilities* in order to leverage the benefits of the newly emerging generation of products (Anderson and Tushman, 1990; Kaplan and Tripsas, 2008). In response to such scenarios, we contend that firms decrease the speed of imitation, waiting until the *uncertainties* associated with the new generation of products have been *sufficiently resolved*. This measured approach can potentially mitigate the risks faced by a given firm, particularly those concerning the appropriateness and effectiveness of adopting newly introduced innovations during these periods of change. Thus, given the heightened uncertainty during transitions, the rivalry-based motives that foster rapid imitation in periods of stability are dampened.

During technological transitions, a firm is instead more likely to have information-based motives for imitation, leading it to search for imitation targets assumed to possess superior market knowledge (Semadeni and Anderson, 2010), as firms prioritize reducing uncertainty rather than focusing solely on maintaining competitive parity. In fact, the window-of-opportunity logic (Lee and Malerba, 2017) suggests that the temporal boundaries of windows opening at the onset of technological transitions are often unclear: what appears to be an opportunity for many may actually be illusory, and some firms may lack the capability to reconfigure their processes and routines in a timely manner. The very volatility that generates opportunities also clouds their recognition and evaluation. As Rosenberg (1998) noted, the economic potential of breakthrough innovations is often only understood *ex post*. Consequently, imitation of rivals' technological innovations during transitions is rarely driven by robust learning or contextual fit but is instead shaped by pattern-matching behaviors in the search for superior information. However, all else being equal, we expect such motives for imitation to slow down the imitation process when firms face high ambiguity regarding which rivals constitute reliable reference points, because of the substantial costs associated with searching for and processing information (Cyert and March, 1963) in an evolving technological

landscape. Authors have noted that information search is often tied to time-consuming and resource-intensive activities (Dierickx and Cool, 1989; Pacheco-de-Almeida, 2010; Pacheco-de-Almeida and Zemsky, 2007), especially when uncertainty is high. Search costs to find a reliable reference target to imitate are particularly high during a transition, as rivals are heterogeneous in the way they try to adapt to the emerging breakthrough innovation that triggered the technological discontinuity. They usually exhibit different approaches to launch product configurations aimed at becoming the new dominant design (Tushman and Anderson, 1986), and this is likely to confound the focal firm about which pioneer possesses more market knowledge and is worth imitating. Thus, we propose:

Hypothesis 1. All else being equal, a firm's speed of imitation of its rivals' technological innovations is lower during periods of technological transition compared to periods of technological stability.

2.4. The role of the imitator's pioneering orientation

Pioneering orientation is a strategic behavior that reflects a firm's inclination to introduce innovative products or technologies (Mueller et al., 2012). Firms with high pioneering orientation “compete heavily on the basis of being first-to-market with new products; and [...] typically precede [...] competitors in bringing new products to market” (Mueller et al., 2012, p. 1530). Such an orientation implies forward-looking technology vision, insightful market research, and innovative culture (Agarwal et al., 2004; Halebian et al., 2012; Lieberman and Montgomery, 1988).

We argue that when a firm possesses a higher pioneering orientation, technological transitions have a diminished impact on slowing down its imitation of rivals' technological innovations compared to firms with a lower pioneering orientation. This is because firms with a strong pioneering orientation often exhibit a *higher tolerance for risk* and a greater propensity to invest in uncertain projects with the aim of gaining early mover advantages (Mueller et al., 2012; Zahra et al., 1995). Thus, we expect that, during transitions, this risk-loving attitude will sustain a high speed of imitation compared to rivals with a lower pioneering orientation. It is in these contexts that firms equipped with a greater pioneering orientation are more inclined to assume the risk of rapidly imitating their rivals' technological innovations than firms with a lower pioneering orientation. Based on this argument, we propose:

Hypothesis 2. The effect of periods of technological transition on slowing down a firm's imitation of its rivals' technological innovations is weaker the higher the firm's pioneering orientation.

2.5. The role of the technology pioneer's market share advantage relative to the focal firm

In this section, we explore how a technology-pioneer-level characteristic, particularly its market share advantage relative to the focal firm, influences the speed of imitation during periods of technological transition. A larger technology pioneer's market share advantage relative to the focal firm indicates that the pioneer is relatively larger than the focal firm, reflecting a greater differential in resource and information endowments (Ferrier et al., 1999). As the market share advantage approaches zero, the two firms are more similar in size—and in resource and information endowments—whereas a market share disadvantage occurs when the focal firm is larger than the pioneer. Building on this, we examine how differences in market share advantages shape speed of imitation decisions. Specifically, we consider two distinct motives for speed of imitation—rivalry-based and information-based—and present two competing hypotheses, each grounded in one of these perspectives.

From a rivalry-based perspective, a larger technology pioneer's market share advantage relative to the focal firm reflects a greater differential in resource endowment between the technology pioneer and the focal firm. We contend that this differential can slow down imitation

because attempting to imitate a rival with a larger market share advantage exposes the focal firm to potentially *dangerous retaliation* from a rival with superior resources, including aggressive competitive actions or defensive responses that the focal firm may lack the resources to counter. For example, authors in the competitive dynamics literature have noted that rivals with a larger resource endowment relative to the focal firm “are more able to implement responses” (Smith et al., 1991, p. 66), and this could deter a firm from imitating their innovations for fear of retaliation (Giachetti and Li Pira, 2022). Larger rivals' propensity to respond aggressively is mainly explained by their need to defend their reputation relative to the smaller firm attacking their competitive position: “The larger the firm, the greater the reputation [...], and thus the greater the pressure to respond” (Chen and Hambrick, 1995, p. 460).

We argue that the focal firm perceives the likelihood of retaliation from pioneers with a larger market share advantage vis-à-vis itself to be particularly high during periods of transition. In these periods, pioneers have already made investments to introduce new technologies amid uncertainty and are therefore motivated to defend the returns on these investments. Focal firms considering imitation are likely to foresee that such commitments increase the incentives of strong pioneers to protect these innovations aggressively, especially against smaller rivals, which lack the competitive weapons to withstand them. As a result, focal firms become more hesitant to imitate rapidly, fearing that early imitation of a powerful rival will trigger retaliation they cannot afford to counter. Rivalry-based motives for rapid imitation are thus weakened. Consistent with this reasoning, research in competitive dynamics emphasizes that in high-velocity contexts, where uncertainty is elevated, “competitive advantages are rapidly created and destroyed,” and “push rivals into accelerating the pace of responses” (Nadkarni et al., 2016, p. 1138). Accordingly, “in fast-changing environments, where competitive advantage is temporary and actions become obsolete very quickly, competitive aggressiveness is even more critical to survival and success than in slow-changing environments” (Nadkarni et al., 2016, p. 1140).

By contrast, during periods of technological stability, pioneers face less uncertainty about the value and effectiveness of their innovations, and the focal firm is likely to perceive that pioneers with a market share advantage feel less pressure to defend such innovations aggressively against imitators. In this regard, competitive dynamics scholars note that, in environments that change slowly, incumbents “enjoy longer temporal windows of opportunities and sustainable advantages from existing competitive actions” (Nadkarni et al., 2016, p. 1138), due to their consolidated resources, which leave rivals with fewer options for differentiation and make incumbents less prone to respond aggressively to direct attacks. This perspective is echoed in the technology innovation literature: Abernathy and Utterback (1978) observe that when industry evolution is increasingly driven by “incremental innovations [this] typically produce[s] a highly specialized system that depends upon economies of scale and mass marketing for success” (p. 41), and that the emergence of a dominant product design “is accompanied by [an] increased emphasis on process innovation” (p. 45). Under such conditions, established rivals can defend their position less through aggressive retaliation and more through accumulated advantages, such as brand reputation, distribution networks, and an installed customer base, which naturally reinforce their competitive position. In our context, once a dominant design is established and the returns to technological innovations become more predictable, pioneers with relatively large market shares vis-à-vis the focal firm can rely on these established competitive advantages rather than on costly retaliation against its rapid imitation. The deterrent effect of a pioneer's market share advantage on the speed of imitation is therefore weaker, and thus, rivalry-based motives for rapid imitation are strengthened. Hence, we propose:

Hypothesis 3a. The effect of periods of technological transition on slowing down a firm's imitation of its rivals' technological innovations is stronger when the technological innovation is introduced by a pioneer with a larger market share advantage relative to the focal firm.

However, from an information-based perspective, we might expect the opposite prediction. Theories of information-based imitation suggest that under high uncertainty and heterogeneous market knowledge among rivals (conditions that create high information asymmetry), firms tend to imitate those perceived to *possess superior market knowledge* (Lieberman and Asaba, 2006). As noted in *Hypothesis 1*, searching for information about imitation targets can be time-consuming, especially during transitions. Consequently, information-based imitation could generally slow down the speed of imitation, as it requires careful examination of the competitive environment and incurs substantial search costs.

Yet, this effect may weaken when the pioneering rival is clearly perceived as possessing superior information. We argue that the greater the technology pioneer's market share advantage relative to the focal firm, the more the focal firm perceives the pioneer as having superior knowledge about the technological innovation potential. In such cases, information-based imitation may accelerate imitation of innovations introduced by a highly visible, market-leading rival. Two mechanisms underpin this moderating effect.

First, *perceived credibility and market acceptance*. A pioneer with a larger relative market share advantage is seen as superior by the focal firm due to its stronger market position and track record (Baum et al., 2000; Bikhchandani et al., 1998). When the market share advantage is substantial, the focal firm perceives the pioneer's innovations as more likely to succeed, especially during uncertain technological transitions. This perception enables the focal firm to reduce search costs by focusing on the most informative technological advances, thereby accelerating imitation. When the relative market share advantage is small, the focal firm may rely on its own knowledge and feel less compelled to imitate the near-equal rival quickly.

Second, *perceived legitimacy through imitation*. Imitating a pioneer with a large relative market share advantage helps the focal firm align with a clearly superior competitor, signaling competent technology adoption to stakeholders and enhancing legitimacy in a high-risk environment (Haunschild and Miner, 1997). When the relative market share advantage is small, the focal firm may already view itself as knowledgeable and credible, so imitating a near-equal (or even inferior) rival offers limited legitimacy benefits and does not strongly accelerate imitation. Thus, we propose:

Hypothesis 3b. The effect of periods of technological transition on slowing down a firm's imitation of its rivals' technological innovations is weaker when the technological innovation is introduced by a pioneer with a larger market share advantage relative to the focal firm.

2.6. The role of technology visibility

For a technological innovation to be imitated by industry rivals, they must first become *aware* of its existence and potential relevance. The diffusion of innovations literature highlights two key factors shaping such awareness: *observability* and *communication channels* (Rogers, 2003). Observability refers to the degree to which the results of an innovation are visible to users; for instance, when the benefits of using a new product can be directly observed in practice. Communication channels capture the means by which information about an innovation is transmitted, such as mass media or interpersonal networks. While both constructs address how awareness and knowledge spread, they do not fully capture the broader salience and prominence of a technology within an industry. Relatedly, competitive dynamics research has emphasized the *visibility of targets* (rivals) and *objects* (strategic actions), and the organizational literature has examined *firm-level media attention*; however, these constructs focus on the visibility of firms or firm actions rather than the visibility of the underlying technological innovations themselves.

Drawing on competitive dynamics research on *object visibility*, which shows that a firm's ability to respond to a competitive stimulus depends

on awareness of objects targeted by rivals (Chen and Miller, 2012; MacMillan et al., 1985), and on research in organizational sociology demonstrating that *information sources* like the media shape perceptions of what is legitimate and desirable behavior in a social system (Pollock and Rindova, 2003), we introduce the construct of *technology visibility*. We define it as the degree to which a technology attracts attention and is recognized by external actors in the organizational field, as evidenced by its presence and discussion across diverse information sources, including newspapers, magazines, academic journals, newswires, and industry blogs.

To clarify its conceptual boundaries, technology visibility is distinct from several related constructs that might otherwise appear overlapping. First, unlike observability, which concerns the visibility of outcomes at the user level, technology visibility reflects the collective prominence of a technology in industry-level discourse. Organizational theorists have defined "prominence" as "the extent to which an organization is widely recognized among stakeholders in its organizational field" (Rindova et al., 2005, p. 1035). In our context, the level of analysis is the technology rather than the organization: a prominent technology is one that is widely noticed and discussed. Second, unlike communication channels, which emphasize the mode of information transfer, technology visibility captures the volume and intensity of attention directed toward a technology, regardless of the channel through which it circulates. Third, unlike target visibility—the salience of the firm introducing an action (e.g., market leaders or highly reputable rivals)—and object visibility, which refers to the visibility of specific competitive actions such as product launches or entry mode strategies, technology visibility shifts the unit of analysis from actors and competitive actions to the technological innovation itself, focusing on how noticeable the specific innovation is independent of who introduces it. Finally, technology visibility is related to but distinct from firm-level media attention: rather than capturing how much attention a firm receives in the media, technology visibility reflects the aggregate volume of attention a technology receives across diverse information sources in the organizational field.

We contend that technology visibility is essential for rapid imitation: firms can only imitate a specific innovation quickly if they are aware of it. Competitive dynamics research suggests that a firm's response speed depends on the visibility of objects targeted by rivals (MacMillan et al., 1985). For example, a new product's visibility during its launch can be amplified through heavy advertising, eliciting swift imitation because widespread attention increases a rival's awareness of a competitive threat. Complementing this, research in the sociology of organizations shows that abundant signals from information sources, such as media outlets, influence collective awareness and recognition of a given object (Pollock and Rindova, 2003). Journalists, scientists, industry experts, bloggers, and other information providers function as institutional intermediaries, forming opinions, disseminating them publicly, and serving as authoritative sources whose attention creates awareness among other stakeholders (Deephouse, 2000; Pollock and Rindova, 2003; Rindova et al., 2007).

Drawing on information-based and rivalry-based theories of imitation, we contend that when technology visibility is high, uncertainty is reduced, and rivalry-based motives for imitation are more likely to prevail. The sheer volume of attention signals relevance and encourages firms to investigate the innovation more actively, accelerating experimentation and imitation. In this sense, visibility reduces informational barriers and provides social cues that lower the perceived risk of imitating a technological innovation. Firms' awareness of the visible, technological innovation makes them more engaged in rapid imitation to preserve competitive parity and avoid falling behind their peers. By contrast, when visibility is low, ambiguity about the nature and relevance of the technology remains high. In such cases, imitation is primarily information-based, and firms take time to gather intelligence on whom to imitate and whether imitation is warranted. In light of these search costs, firms may thus hesitate to imitate quickly, either because

they fail to recognize the innovation or because they cannot assess its value. As a result, imitation tends to be slower and more selective under conditions of low visibility.

During technological transitions, when uncertainty is particularly high, and (all else being equal) information-based motives for imitation dominate, firms must bet on which innovations will become part of the dominant design (Anderson and Tushman, 1990). Competitive advantage accrues to those who correctly anticipate which technology will prevail (Lee and Malerba, 2017; Ozalp et al., 2023). In this context, it is even more challenging for firms to determine whether a poorly visible technological innovation carries high or low risks and opportunities, both in terms of technical compatibility with other product components and in terms of future market acceptance. Thus, the uncertainty of imitating a technological innovation during transitions is compounded by the uncertainty linked to its visibility. While the introduction of a technological innovation may initially grant pioneers and early imitators a temporary advantage, if the technology is poorly visible, uncertainty arises regarding its integration into the next generation of products and its eventual consumer adoption. Consequently, this uncertainty strengthens even further the information-based motives for imitation that we expected to find during periods of transition (Hypothesis 1), resulting in an even slower imitation. By contrast, highly visible innovations (i.e., those widely covered in the media, showcased at trade publications, and discussed in analyst reports and industry forums) are commonly associated with lower perceived uncertainty and are considered less risky to adopt. Therefore, during technological transitions, we anticipate firms will seek competitive parity by more swiftly imitating their rivals' highly visible technologies rather than those that remain obscure. In this sense, technology visibility during technological transitions tends to de-emphasize information-based motives for imitation while strengthening rivalry-based ones, thereby accelerating imitation. Thus, we propose:

Hypothesis 4. The effect of periods of technological transition on slowing down a firm's imitation of its rivals' technological innovations is weaker the higher the technology visibility.

In Fig. 1, we report a graphical representation of the proposed research model.

3. Methods

3.1. Sample and setting

We tested our hypotheses within the context of the mobile phone

industry. The data utilized comprises mobile phone makers that have a global presence and have operated within the 1992–2019 observation period. Throughout this period, we gathered data on 156 distinct mobile-phone-related technological innovations (that is, mobile phone attributes) that were incorporated into 9060 mobile phone models, which were launched by a total of 114 mobile phone makers. The combined market share in terms of units sold for all handset makers included in our sample, on average, constitutes approximately 90%, as derived from our 28-year period.

The mobile phone industry provides a suitable context for testing our hypotheses for three main reasons. First, our extended observation period has provided us with a comprehensive view of the industry life cycle, enabling us to identify two pivotal technological transitions. The first was in the early 1990s, with the introduction of digital cellular networks, or 2G networks. This necessitated a substantial reconfiguration of resources within firms to accommodate a transition from analog phones, capable of providing only phone call capabilities, to digital phones. Later, in 2007, the industry underwent a second significant discontinuity with the advent of a new generation of smartphones, triggered by Apple's iPhone (and its iOS) and Google's Android operating system (OS). Smartphones existed before 2007, but were a small niche, mainly because they ran OSs that were unfriendly to users and targeted at corporate clients. This development heralded advanced OSs and extended the functionality of handsets, thus prompting another radical alteration in how firms produced handsets. These two technological transitions will be discussed in greater detail later in the paper. Second, the mobile phone industry, like other consumer electronics industries, consistently exhibits a rapid pace of technological development, with firms incessantly launching product innovations and seeking to improve upon existing ones (Giachetti et al., 2017). Third, it is key to emphasize the pivotal role of quick imitation in maintaining competitive parity in the mobile phone industry, given its rapid technological evolution. Indeed, the relentless pace of technological progress in the mobile phone industry renders advantages transient in nature (Fine, 1998). Previous studies highlight that mobile phone makers that managed to swiftly imitate their rivals' innovations were able to sustain their performance compared to laggards (Giachetti et al., 2017). In the mobile phone industry, players are "often technology takers" (Klingebiel and Joseph, 2016, p. 1005), meaning that technologies are generally accessible and subject to imitation by all industry players. All these technologies are protected by thousands of patents, but it is in the interest of the patent holders to make these technologies available to all players, often under the payment of a license fee. Nonetheless, as we will explain later, a few non-licensable technologies were excluded. Finally, because firms in our

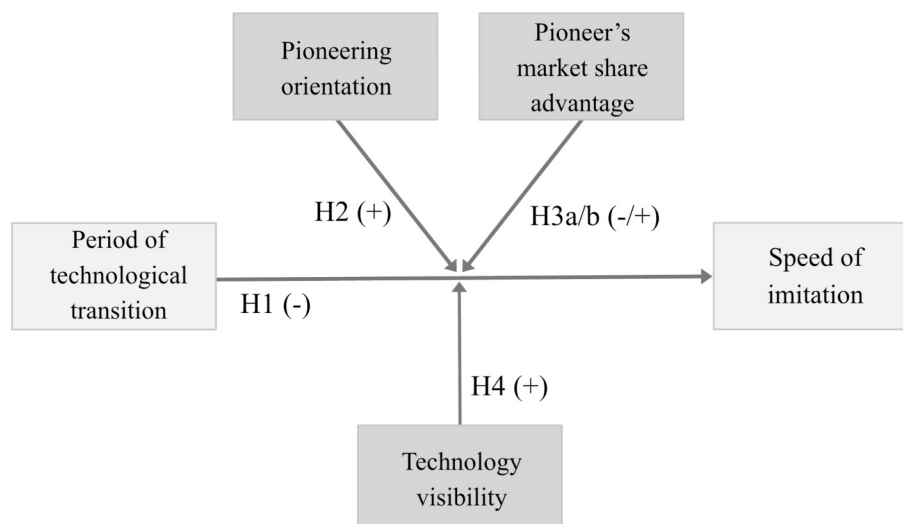


Fig. 1. Research model.

sample can act as pioneers for some technological innovations and imitators for others—and may be larger than the pioneer in certain cases and smaller in others—this role and positional variability generate substantial within-firm variation, thereby strengthening identification and mitigating concerns that our results are driven by fixed innovator–imitator or leader–follower structures.

3.2. Data sources

We used multiple secondary sources to collect data for our analysis. We collected data on handset models and related technologies from specialized interest online catalogs for mobile telephony, primarily from <https://www.gsmarena.com>, a provider of online content about the mobile phone industry that does not belong to or is moderated by any mobile phone maker or telecommunication company. www.gsmarena.com is regarded as a reference source by scholars (e.g., Giachetti and Marchi, 2017), industry experts, and practitioners (e.g., Deloitte., 2016). Mobile phone makers and their product models reported on this website constitute a seemingly representative snapshot of the mobile technology landscape. Next, we integrated and cross-checked this data with information on phone models and related technological innovations from other online catalogs, like <https://mobile.softpedia.com>, <https://www.imei.info/phonedatabase/>, <https://phonesdata.com>, and <https://www.cnet.com>. All these websites provide mobile phone technical specifications and the month of introduction by mobile phone makers. This information allowed for identifying the pioneer of each technology, the imitators, and their imitation timing. A list of the sampled mobile-phone-related technological innovations is presented in Table A1 of Appendix A. It is important to note that mobile phone innovations refer to the built-in technologies, encompassing both hardware and software components pre-installed by the handset makers in their devices. This specifically excludes applications that users can download after purchasing the phone. Also, a few technological innovations, such as CPUs and GPUs, although important, were excluded from our analysis due to incomplete or missing information in the consulted catalogs. Including them would have made the identification of pioneers and the time to imitation less clear and accurate.

Moreover, drawing on Murmann and Frenken (2006), we grouped mobile-phone-related technological innovations based on their “technological system,” which refers to macro categories of technological innovations related to a broad product function. For example, in mobile phones, technologies such as vibrate alert, ringtone composer, downloadable ringtones, polyphonic ringtones, true tones, voice dial, and video calling are related to the making or receiving of a phone call and thus belong to the same technological system, which we named “phone call.” We grouped the 156 technologies into 22 technological systems (see Table A1).

Data on mobile phone makers' global market share in terms of units sold at the year level were used to compute the technology pioneer's relative market share advantage and control for firm size. These data came from Gartner and Euromonitor International. For smaller players, we also relied on industry magazines, newspaper articles, and business information providers. Since most handset makers entered after 1992 and many exited before 2019, this resulted in an unbalanced panel. We relied on ProQuest, a comprehensive digital database indexing published information sources, to construct our measure of technology visibility.

3.3. Measures

3.3.1. Speed of imitation

The unit of analysis in our model is a focal firm's speed of imitation of a given technology previously introduced by a rival, determined by the time, in months, it took for a focal mobile phone maker to adopt that technological innovation in one of its mobile phones. Thus, our database comprises firm-technology-level observations. To capture the speed of imitation, we adopt a measurement approach consistent with prior

studies (e.g., Jonsson and Regnér, 2009). In particular, we first assigned a unique ascending number to each month within our data. Our research spanned from January 1992 (designated as month 1) to December 2019 (designated as month 336). During this time, we monitored the introduction of new technological innovations, and detected the month each of these technologies was first introduced by the pioneer, and the month when they were imitated for the first time by each mobile phone maker. This process was carried out individually for each firm under consideration. Specifically, to assess a firm's speed of imitation, we employed a parametric survival model (StataCorp, 2013), which takes into account (a) the introduction date of each product feature—varying for each feature—corresponding to the month when a pioneering firm first introduced that specific technological innovation (our “ t_0 ”), and (b) the imitation date by the focal firm (our “ t_1 ,” i.e., the month the focal firm experienced the event of imitating). To assess the “failure event,” we added a column to our database, assigning a value of 1 if the focal firm imitated a technological innovation by the end of the observation period, and 0 otherwise. This specification (i.e., failure event = 0) reflects a “right-censoring.”¹

For accuracy, we only considered technologies introduced during the observation period in which the focal firm was operating as a mobile phone maker. This corrected inflated values of speed of imitation for those firms not operating in the industry at the time of the introduction of a given technology. We assumed a firm's month of entry into the industry to be the month in which the firm introduced its first handset, and the month of exit as the last month of the year in which it introduced its latest handset, according to our database. Moreover, we chose not to include proprietary, non-licensable technological innovations in the calculation of imitation speed. The underlying rationale is their protection by legal barriers, making such innovations not imitable. Only three out of 156 product technological innovations fell under this category: Apple's iOS, RIM's BlackBerry OS, and Huawei's nano SIM. Despite this, these three innovations remained in the database to compute other variables, as explained later.

3.3.2. Technological transition

Anderson and Tushman (1990) argued that, following a period of ferment triggered by a technological discontinuity, a dominant design emerges when there is a high degree of convergence among design features across products within an industry. Empirically, a dominant design occurs when at least 50% of firms or products sold in an industry adopt the same product architecture. We build our measure of technological transition in the mobile phone industry by drawing on Anderson and Tushman (1990). Previous studies have identified two main technological shifts in the mobile phone industry (Giachetti and Marchi, 2017). The first occurred in 1992 with the introduction of the first digital cellular networks, commonly known as 2G networks, along with the simultaneous commercial launch of the first digital phones. Digital network connectivity was initially launched in Europe under the name GSM (Global System for Mobile Communications). In the context of mobile phones, “digital technology” refers to the use of digital signals and processing, as opposed to analog signals. Digital phones transform audio signals into digital data, facilitating more precise transmission and reconstruction compared to analog signals. This transition to digital technology in mobile phones played a crucial role in advancing voice

¹ Although we refer to our main specification as a parametric survival model, the Gompertz model estimated via “streg” in Stata is parameterized in proportional-hazards (log relative-hazard) form. Accordingly, coefficients are interpreted as log hazard ratios, analogously to a Cox proportional hazards model: positive (negative) coefficients indicate a higher (lower) hazard of imitation and thus a faster (slower) speed of imitation. In robustness analyses using Weibull and Exponential specifications estimated in accelerated failure-time (AFT) form, coefficient signs should instead be interpreted in terms of time to imitation.

quality and incorporating enhanced features. In fact, the main difference between analog and digital phones lies not only in the manner of signal transmission (analog vs. digital), but also in the significant capability of digital technology to integrate additional features and services into mobile phones. These include text messaging, internet connectivity, multimedia capabilities, and various applications, thereby expanding the functionalities of handsets beyond traditional phone calls. Furthermore, the introduction of the new digital standard brought widespread compatibility across different countries, enabling seamless roaming capabilities. In the early 1990s, it became increasingly evident to mobile phone makers that digital phones presented numerous advantages over analog phones. Consequently, by 1998, digital phones had emerged as the dominant design, accounting for over 50% of global mobile phone sales.

The second significant technological shift occurred in 2007 with the introduction of Apple's iPhone. The iPhone featured a revolutionary proprietary OS named iOS, which (a) introduced a highly intuitive touchscreen interface that was easy to navigate and interact with, and (b) mounted the "App Store," which revolutionized the way users could personalize and enhance their devices by offering a vast array of third-party applications for download. This marked a new era for multi-tasking portable devices. While Apple was the sole provider of its proprietary OS, Google followed suit and introduced Android OS in 2008. Android OS was similar to iOS but offered as an "open source" platform, available for free to mobile phone makers. By 2012, the aggregate market share of Android-based phones exceeded 50%, becoming the dominant design.

To define a period of technological transition, we considered the period between a technological discontinuity and the establishment of the emerging generation of products as the dominant design, marked by exceeding 50% diffusion (Anderson and Tushman, 1990), i.e., when over half of the mobile phones align with such a generation of products. To gauge technological transitions in contrast to periods of stability, we utilized a binary variable that takes a value of 1 for the intervals 1992 to 1997 (analog phones to digital phones transition) and 2007 to 2011 (regular digital phones to smartphones transition), and 0 otherwise. Information regarding the point at which global sales of digital phones surpassed analog phones, as well as the identification of the year when the Android OS became the dominant operating system worldwide, was obtained from *Gartner*. The use of a binary variable to measure technological transitions has also been employed by recent empirical studies on competition dynamics in the telecommunications and console game industries (Garrido et al., 2023; Ozalp et al., 2023). Of the 156 technological innovations, 43 were first introduced during periods of technological transition, and 113 were introduced during periods of stability.

3.3.3. Pioneering orientation

Building on the idea that "a firm's pioneering orientation measures the degree to which it emphasizes pioneering behaviors" (Mueller et al., 2012, p. 1523), the variable *pioneering orientation* (of the imitator) was measured by counting the total number of technological innovations pioneered by the focal firm in the most recent three years, including the current year (Giachetti et al., 2017). For instance, if a firm pioneered a technology for the first time in 2009 and then pioneered two other technologies in 2016, our measure would remain at 0 until 2008. It would then increase to 1 from 2009 to 2011 and then return to 0 from 2012 to 2015. The measure would then increase to 2 from 2016 to 2018 before returning to 0 in 2019.

3.3.4. Pioneer's market share advantage

The technology pioneer's relative market share advantage measures the difference in market share between the technology pioneer and the focal firm in a given year. To construct this variable, we first identified the firm pioneering each technological innovation, along with the corresponding year and month of introduction. Following prior research

(e.g., Ferrier et al., 1999; Giachetti and Li Pira, 2022; Giachetti and Torrisi, 2018), we then collected yearly data on market shares for all firms to calculate the difference between the pioneer's and the focal firm's market share. This measure captures the relative market position of the pioneer versus the focal firm, reflecting differences in resource and information endowments that may influence imitation behavior. Notably, not all technological innovations were introduced by the largest firms: in our dataset, the market leader—defined as the firm with the largest market share (e.g., Ferrier et al., 1999)—was the pioneer in only 29 out of 156 cases.² Our unstandardized variable ranges from -0.351 to 0.351 (i.e., from -35% to 35%), with a mean of 0.066 (6.6%), indicating many instances in which innovations were introduced by firms smaller than the pioneer. The variability of the variable ensures sufficient dispersion to examine how differences in relative market position affect imitation behavior, making it statistically appropriate for inclusion in our analyses.

3.3.5. Technology visibility

We operationalize technology visibility as the extent of coverage a technology receives in published information sources, measured by the yearly count of *ProQuest*-indexed articles citing the technology. *ProQuest* is a comprehensive digital database that indexes a wide range of information sources, including international newspapers, magazines, trade publications, newswires, blogs, and academic sources, making it a rich resource for capturing the widespread discussion of an innovation across different outlets. To retrieve relevant coverage, we constructed queries that combined general keywords related to mobile phones (e.g., "mobile phone," "handset," "cellphone," and "smartphone") with multiple synonyms referring to the specific technology under investigation (for example, "music player," "audio player," and "MP3 player" for the music player functionality). This approach ensured that we captured the diverse terminology that outlets used to describe the same technological innovation, thereby increasing the reliability of our visibility measure. Our variable, calculated as the natural logarithm of one plus the number of articles returned by the *ProQuest* query (a transformation that both avoids taking the log of zero and corrects for skewness), exhibits ample variability: e.g., some technologies received little to no yearly coverage at launch, while others were cited in thousands of outlets, thus offering meaningful variation to examine the role of visibility in shaping imitation dynamics.

We did not distinguish between articles with positive or negative tones because such distinctions are often arbitrary and difficult to standardize. Most articles were largely neutral, neither endorsing nor criticizing a technology, but instead simply describing its features, functionalities, or differences relative to competitors. For instance, a comparative review of smartphones may note the presence of a music player or camera quality without expressing a neat evaluative judgment. By focusing on the sheer volume of coverage rather than its sentiment, our measure captures the collective noticeability and salience of a technology in the field, which is the key driver of awareness, regardless of whether the attention is framed positively or negatively. This methodological choice is consistent with previous studies that measure organizational prominence based on the amount of media coverage, regardless of the article's tone (e.g., Pitsakis et al., 2015; Rindova et al., 2007).

3.3.6. Control variables

In this study, we controlled for firm-level, technology-level, and industry-level factors to rule out alternative explanations for the speed of imitation. At the firm-level, firstly, we included a unique identifier for each mobile phone maker to control for *firm fixed-effects* (Cameron and Trivedi, 2009). Secondly, we measured firm size as the global market

² Over the observation period, Motorola led globally from 1992 to 1997, Nokia from 1998 to 2011, and Samsung from 2012 to 2019.

share of the focal firm in terms of units sold. A larger market share may enable faster imitation due to the accelerated resource mobilization capabilities and more efficient scanning mechanisms for detecting rivals' moves (Gimeno et al., 2005). Thirdly, given that in a few cases within our database, certain firms were majority-owned by a competitor for several years (e.g., Vertu was a subsidiary of Nokia until 2011; Nokia was owned by Microsoft from 2014 to 2016; Motorola was owned by Google from 2012 to 2013 and later by Lenovo from 2014 onward), we investigated whether a firm's speed of imitation is influenced by its parent company when the parent company operates as a rival in the mobile phone industry with its own branded handsets. We thus created a dummy *subsidiary* equal to 1 if the focal firm is a subsidiary of an industry rival, and 0 otherwise. Fourth, we assessed whether a firm's propensity to imitate rapidly is influenced by its prior performance in imitative activities. In particular, this captures a focal firm's *imitation capabilities*. Within the strategic management literature, there is no clear consensus on how to measure a firm's capabilities empirically (e.g., Grant and Verona, 2015; Schilke et al., 2018). Given the data available, we operationalized imitation capabilities as the product between (a) the number of imitations undertaken by the firm in the past three years and (b) the firm's annual market share growth following these imitations. This measure weights the frequency of imitation by the effectiveness of those imitations in generating market gains. A positive market share growth increases the score, rewarding effective imitation; negative market share growth lowers the score, penalizing ineffective imitation; and no imitative activity results in a score of zero regardless of market outcomes. Fifth, we controlled for a firm's *patent litigation involvement*. In fact, although mobile phone makers are predominantly technology takers—equipping their phones with technological innovations patented by others—it often happens that they intentionally, or more commonly, unintentionally infringe on others' patent rights. This is because mobile phones integrate thousands of patented technologies, making entry and operation in this industry comparable to walking through a minefield. The more a phone maker is involved in patent litigation, the more cautious it may become in rapidly adopting innovations introduced by rivals. Drawing on previous studies (Onoz and Giachetti, 2023; Paik and Zhu, 2016), we captured the intensity of a firm's patent litigation involvement with the count of articles from multiple information sources discussing its cases. Since patent litigation cases vary widely in terms of legal expenses, managerial attention, operational disruptions, reputational risks, potential injunctions, and monetary penalties—dimensions not fully reflected in a simple count of cases—we assume that cases attracting greater media attention signal a deeper level of firm involvement. To retrieve articles, we developed *ProQuest* queries combining keywords related to mobile phones, the focal firm's name, patents, and litigation-specific terms (e.g., “infringement,” “lawsuit,” “dispute,” “claim,” “sue”). This procedure was applied at the firm-year level, and our variable of patent litigation involvement is operationalized as the annual count of litigation-related articles for each firm. Furthermore, similarities between rivals (Gimeno et al., 2005), such as shared culture and country of origin (Li and Parboteeah, 2015), could have a substantial impact on determining the speed of imitation. To address this aspect, we developed a measure of *home-country similarity* between the focal firm and the pioneer. Specifically, we introduced a binary variable taking the value of 1 if the focal firm's country of origin matches that of the technological pioneer and 0 otherwise.

At the technology-level, first, we controlled for *technological system fixed-effects*, as innovations within the same macro category may share similarities in terms of the resources needed by rivals to assess their potential and incorporate them into their new models, thus affecting speed of imitation to a similar extent. Second, we controlled for the introduction of a technological innovation resulting in a *novel* or *improved* product attribute for consumers (Mukherjee and Hoyer, 2001; Piazzai and Wijnberg, 2019). A novel product attribute is a brand-new functionality or aesthetic design element in a product that has never been experienced by customers in a category. “When the innovation

pioneers a novel knowledge base, uncertainty is accentuated” (Polidoro and Toh, 2011, p. 374), as firms cannot foresee compatibility with other functionalities or market acceptance. At the same time, such innovations offer strong differentiation advantages to early adopters. By contrast, an improved product attribute refines or enhances a pre-existing functionality or aesthetic element and thus “builds on existing knowledge” (Polidoro and Toh, 2011, p. 374). Improvements offer lower differentiation but less uncertainty, as they rely on established architectures already accepted by the market (Lee et al., 2003). To classify each mobile-phone innovation, we assessed whether it introduced a brand-new functionality or aesthetic element, or an amelioration of an existing one (Mukherjee and Hoyer, 2001; Piazzai and Wijnberg, 2019). Consistent with prior research, “we distinguished between innovations that pioneered novel knowledge and those that built on existing knowledge” (Polidoro and Toh, 2011, p. 378). For example, in the system “phone call,” vibrate alert, ringtone composer, downloadable ringtones, voice dial, and video calling were novel attributes, whereas polyphonic and true ringtones were improvements of monophonic ringtones. In “display type,” the touchscreen was a novel attribute, transforming interaction by replacing physical keyboards. In “Bluetooth,” version 1.0 was novel, while later versions were improvements that enhanced transfer rates and reduced energy consumption. In our sample, 54 innovations were coded as novel attributes and 102 as improvements. During stability periods, 38 novel and 75 improved attributes were introduced; during technological transitions, 16 novel and 27 improved attributes were introduced. The full list is in Table A1. Coding relied on searches across business databases, industry publications, mobile phone makers' websites, annual reports, specialized magazines, and consulting reports. The variable was operationalized as a dummy, equal to 1 when an innovation led to a novel attribute and 0 when it led to an improved attribute.³

At the industry-level, we controlled for two variables. Firstly, we controlled for *industry concentration*, which is often used as a proxy for competition intensity, and measured it using the Herfindahl index, calculated as the sum of the squared market shares of all firms in the industry (e.g., Ferrier et al., 1999). Secondly, we controlled for *sales volatility*, measured as the three-year standard deviation of mobile phone units sold at the global level (Zhou and Wan, 2017). This variable proxied demand uncertainty, as it reflects the variation and unpredictability of consumer demand as the industry evolves over time.

3.4. Analytical technique

To test our hypotheses, we employed a parametric survival model with a Gompertz distribution. This choice is supported by two reasons. Firstly, Gompertz models are well-suited for analyzing time-to-event data in industries characterized by non-monotonic trends and dynamic shifts (StataCorp, 2013). Survival regressions with a Gompertz distribution have been applied in the strategic management literature to analyze time-to-event differences between periods of transition and stability (e.g., Argyres et al., 2015). In the mobile phone industry,

³ This distinction between novel and improved product attributes is conceptually different from the common radical versus incremental innovation dichotomy. The radical/incremental distinction typically emphasizes the degree of departure from existing technological paradigms or the extent of change in underlying knowledge bases. In particular, radical innovations not only depart significantly from existing knowledge but also often render prior knowledge and competencies obsolete. By contrast, our categorization focuses on whether a technological innovation introduces a completely new functionality or aesthetic element for consumers (novel attribute) versus enhancing or refining an existing one (improved attribute). Therefore, in our study, we use the term radical innovation specifically to denote the breakthrough innovations that trigger a technological transition. Importantly, during both periods of transition and periods of stability, firms may introduce innovations that result in either novel or improved product attributes.

marked by rapid innovation cycles and fluctuating market conditions, firms strategically time their imitation of new technologies to gain fast-mover advantages. The Gompertz specification allows the hazard of imitation to vary flexibly over time, capturing environments in which hazard rates may initially increase due to fast-mover advantages but later decelerate if technologies fail to meet expectations or become obsolete.⁴ In this specification, the Gompertz model is parameterized and interpreted in proportional-hazards (log relative-hazard) form, so coefficients reflect effects on the hazard (speed) of imitation.

Second, we evaluated two alternatives to the Gompertz specification. The first involved parametric survival models with alternative distributions, specifically Weibull and Exponential (Argyres et al., 2015), which we estimate as robustness checks and interpret in accelerated failure-time (AFT) form. The Weibull distribution is potentially suitable for examining hazard rates in dynamic industries (Elfenbein and Knott, 2015), while the Exponential distribution assumes a constant hazard rate and may be appropriate when the competitive environment does not induce significant fluctuations in event occurrence over time (Hall and Van Keilegom, 2005). However, log-likelihood, AIC, and BIC measures (Tables 2 and 3) indicate that the Gompertz distribution provides the best overall fit (Akaike, 1974).

We also estimated Cox proportional hazards models (Cox, 1972) as an additional robustness check. Although Cox models impose fewer constraints on the baseline hazard (Box-Steffensmeier and Jones, 2004), proportionality tests rejected the assumption of proportional hazards, suggesting that parametric alternatives are more appropriate for our analysis (Blossfeld et al., 2007).

Survival regressions enable the analysis of the likelihood of imitation, which represents the instantaneous rate (hazard) of imitation at any given time, while accounting for censoring. In our case, right-censoring occurs when a firm exits the market before adopting a specific technology or when the observation period ends before the firm adopts the technology. To derive more realistic inferences on the impact of time-sensitive independent variables on the speed of imitation, we lagged them by one year and applied the robust option to address potential heteroscedasticity.

Finally, standard errors were clustered at the firm level to account for within-firm correlation across multiple technology adoption events. In fact, since each firm appears multiple times in the dataset—once for each technology it could imitate—there may be unobserved factors specific to the firm that affect the timing of imitation across technologies. Clustering by firm corrects for potential non-independence of residuals within firms, thereby providing more conservative and robust inference.

⁴ It is worth noting that Gompertz hazard is strictly monotonic. In the mobile phone industry, we can reasonably assume that the hazard of imitation follows a monotonic pattern—either increasing or decreasing over time—depending on the perceived value, uncertainty, and viability of the technology. This reflects firms' strategic considerations in a highly competitive and fast-paced market. For many technologies, the likelihood of imitation accelerates as uncertainty diminishes, early adopters validate the value of the innovation, and the technology becomes industry standard. In this case, a Gompertz distribution with a positive shape parameter captures this growing pressure to imitate. Alternatively, for less promising technologies, firms may quickly evaluate and decide against imitation, leading to a decreasing hazard over time (Gompertz with negative shape). Once early signals suggest the innovation lacks viability or consumer traction, the window for beneficial imitation closes rapidly. Therefore, while some technologies exhibit accelerating imitation risk, others show fast early declines—both cases conform to monotonic hazard trajectories, making the Gompertz model suitable for capturing either pattern across technologies.

4. Results

4.1. Hypothesis tests

Table 1 reports key descriptive statistics. As the correlation table shows, two correlations among the independent variables presented coefficients above 0.5. These include the correlation between pioneering orientation and market share ($r = 0.644$; $p = 0.000$), and pioneer's market share advantage and market share ($r = -0.505$; $p = 0.000$). However, we did not detect multicollinearity issues, as all variance inflation factors (VIF) scores were below the recommended threshold of 10 (Gujarati, 2003), with the average VIF of Model 6 at 1.67.

Table 2 presents the estimated coefficients from the parametric survival model with Gompertz distribution for the drivers of speed of imitation. We present the results stepwise, starting with Model 1, which includes only control variables. In Model 2, we added all main effects, i. e., technological transition, pioneering orientation, pioneer's market share advantage, and technology visibility. Models 3–5 tested one-by-one the three interaction effects between the technological transition variable and the three moderators on speed of imitation. Finally, Model 6 presents the full model. To mitigate multicollinearity, all variables were standardized prior to the formation of interactions (Aiken et al., 1991).

Regarding the effects of the control variables on the speed of imitation, our analyses indicate that the focal firm's market share, subsidiary status, involvement in patent litigation, home-country similarity, and industry concentration are all statistically insignificant. This suggests that neither firm size nor ownership structure, legal exposure, cultural proximity to the pioneer, or competitive intensity meaningfully influence how rapidly firms imitate technological innovations in this context. By contrast, imitation capabilities exhibit a positive and significant association with imitation speed, indicating that firms with greater accumulated experience and demonstrated effectiveness in prior imitation tend to imitate new innovations more rapidly. Innovations introducing novel product attributes are instead associated with significantly slower imitation, suggesting that firms are less responsive to pioneering features which, although offering strong differentiation in the market, also entail higher uncertainty. Finally, sales volatility is negative and significant, suggesting that higher demand uncertainty slows firms' imitation efforts, likely because fluctuating market conditions make it more difficult for firms to confidently allocate resources to rapid innovation adoption.

Hypothesis 1 posits that speed of imitation is lower during periods of technological transition compared to periods of technological stability. A negative coefficient of the transition variable indicates a decrease in the hazard of imitation and thus a slower speed of imitation during periods of transition. As Model 2 shows, the estimated coefficient of the technological transition variable is negative ($\beta = -0.199$; $p = 0.057$), supporting Hypothesis 1. This effect remains consistent in the full model (Model 6: $\beta = -0.310$; $p = 0.006$). Hypothesis 2 predicts that the role of technological transition periods in reducing a firm's speed of imitation of its rivals' technological innovations is weakened as the firm's pioneering orientation increases. The interaction coefficient is positive ($\beta = 0.092$; $p = 0.004$), supporting Hypothesis 2. Hypotheses 3a and 3b predict that the impact of technological transition periods in decelerating a firm's imitation of its rivals' technological innovations is respectively stronger or weaker the greater the pioneer's market share advantage. The estimated coefficient for the interaction term is negative as predicted in Hypothesis 3a ($\beta = -0.118$; $p = 0.028$), suggesting support for Hypothesis 3a and not for 3b. Hypothesis 4 predicts that the influence of technological transition periods in decelerating a firm's imitation of its rivals' technological innovations is less pronounced the higher the visibility of technological innovations. The estimated coefficient for the interaction is positive ($\beta = 0.068$; $p = 0.062$). Thus, Hypothesis 4 is supported. The plots of the hazard functions of the interaction effects are illustrated in Appendix B, where covariates (i.e., interactions) were set

Table 1
Descriptive statistics and correlations.

Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1. Technological transition	0.322	0.467	0.000	1.000	1										
2. Pioneering orientation	0.594	1.410	0.000	11.000	-0.070	1									
3. Pioneer's market share advantage	0.066	0.118	-0.351	0.351	0.160	-0.359	1								
4. Technology visibility	2.314	1.045	0.000	4.513	-0.078	0.045	1								
5. Market share	0.028	0.061	0.000	0.363	0.059	0.644	-0.505	1							
6. Subsidiary	0.082	0.274	0.000	1.000	-0.008	0.009	-0.093	1							
7. Imitation capabilities	1.169	2.324	-0.345	31.091	0.070	0.184	-0.073	-0.068	1						
8. Patent litigation involvement	191.342	423.569	0.000	5623.000	0.029	0.266	-0.190	0.101	0.250	1					
9. Home-country similarity	0.122	0.327	0.000	1.000	-0.096	-0.076	-0.100	-0.029	-0.052	0.060	1				
10. Novel product attribute	0.244	0.429	0.000	1.000	0.010	0.051	0.011	0.211	0.088	-0.044	0.096	1			
11. Industry concentration	0.131	0.037	0.073	0.244	0.447	0.130	-0.042	-0.134	0.143	-0.053	0.244	-0.134	1		
12. Sales volatility	81,143.757	46,841.634	2867.743	153,865.824	0.053	-0.030	-0.104	0.092	-0.132	0.019	-0.123	0.125	-0.090	1	
															0.098

Notes: N = 3794; Mean, SD, Min, and Max values are based on unstandardized variables.

to their minimum and maximum observed values (StataCorp., 2023).

4.2. Robustness tests

To assess the robustness of our results, we conducted a number of additional tests, with the corresponding models detailed in Table 3. Initially, in line with prior studies, we performed additional analyses using alternative parametric survival model specifications (e.g., Argyres et al., 2015). Specifically, we estimated models with Weibull (Model 7) and Exponential (Model 8) distributions. Moreover, we employed a Cox proportional hazard model (Model 9), as it remains a widely used option for similar types of analyses (e.g., Jonsson and Regnér, 2009). Finally, in Model 10, we removed the market share control from the full model because of its high correlation, as discussed above.

It is important to note that differences in coefficient interpretation across models stem from the metric in which the models are estimated and interpreted, rather than from the choice of distribution per se. The Gompertz specification is estimated and interpreted in proportional-hazards (log relative-hazard) form, analogously to a Cox proportional hazards model, such that positive (negative) coefficients indicate a higher (lower) hazard and thus a faster (slower) speed of imitation. By contrast, the Weibull and Exponential specifications are estimated as accelerated failure-time (AFT) models, in which positive coefficients indicate a longer time to imitation (i.e., slower imitation), implying a lower hazard.

As illustrated in Table 3, the main effect of the technological transition variable is, as expected, positive in the AFT model with a Weibull distribution ($\beta = 0.864$; $p = 0.100$) and with an Exponential distribution ($\beta = 0.393$; $p = 0.001$), while it is negative for the Cox model ($\beta = -0.258$; $p = 0.001$). These results are consistent with Hypothesis 1 across alternative model specifications, as well as in the Gompertz model estimated without the most highly correlated control, specifically with market share removed from the model ($\beta = -0.303$; $p = 0.006$). Similarly, regarding our three interactions (Hypotheses 2–4), results were overall supported; only in a few cases, p -values were slightly above the 0.1 threshold.

4.3. Endogeneity issues

One potential source of endogeneity in our model is reverse causality, in that imitation speed may influence firms' pioneering orientation, rather than pioneering orientation solely driving imitation speed. Because classical instrumental variable (IV) estimation is not directly applicable in survival analysis settings, we adopt a two-stage residual inclusion (2SRI) approach (Rawley et al., 2018) to assess whether firm pioneering orientation is endogenously determined in our model of imitation speed. In the first stage, we use OLS to regress pioneering orientation on industry innovation clockspeed (Fine, 1998; Pacheco-de-Almeida, 2010)—measured as the number of innovations introduced in the industry over the three years preceding the focal technology's introduction—along with all exogenous controls from the main model. This instrument captures the pace of innovation in the firm's environment, while being plausibly exogenous to firm-specific determinants of imitation timing. As shown in Model 11 of Appendix C, in this first stage, our instrument is positive and highly significant ($\beta = 0.050$; $p = 0.000$; $F = 39.05$). We then include the residuals from this first-stage regression in the second-stage parametric survival model (Gompertz distribution). As shown in Model 12, the coefficient on the residual term is not statistically significant ($\beta = 0.009$; $p = 0.961$), while our key regressors maintain their signs and significance levels, suggesting no evidence of endogeneity in the pioneering orientation variable. This indicates that our original model provides consistent estimates, and instrumental variable correction is not required in this case.

We have implemented several other corrections to address potential endogeneity issues. When considering concerns about endogeneity, a crucial point in our findings is that any alternative explanation must

Table 2
Parametric survival model with Gompertz distribution for the drivers of speed of imitation.

	Hypothesis	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant		-3.301 (0.355) [0.000]	-3.226 (0.369) [0.000]	-3.159 (0.369) [0.000]	-3.265 (0.364) [0.000]	-3.226 (0.369) [0.000]	-3.196 (0.369) [0.000]
Main effects							
Technological transition	H1		-0.199 (0.104) [0.057]	-0.296 (0.113) [0.009]	-0.252 (0.106) [0.018]	-0.199 (0.104) [0.057]	-0.310 (0.112) [0.006]
Pioneering orientation			-0.014 (0.042) [0.732]	-0.044 (0.022) [0.042]	0.003 (0.030) [0.925]	-0.014 (0.042) [0.730]	-0.028 (0.022) [0.210]
Pioneer's market share advantage			-0.098 (0.030) [0.001]	-0.097 (0.030) [0.001]	-0.023 (0.037) [0.540]	-0.095 (0.030) [0.002]	-0.046 (0.034) [0.176]
Technology visibility			0.152 (0.020) [0.000]	0.157 (0.020) [0.000]	0.152 (0.021) [0.000]	0.133 (0.026) [0.000]	0.131 (0.025) [0.000]
Interaction effects							
Technological transition × Pioneering orientation	H2			0.118 (0.028) [0.000]			0.092 (0.032) [0.004]
Technological transition × Pioneer's market share advantage	H3				-0.189 (0.055) [0.001]		-0.118 (0.054) [0.028]
Technological transition × Technology visibility	H4					0.051 (0.036) [0.160]	0.068 (0.036) [0.062]
Control variables							
Market share		0.111 (0.125) [0.377]	0.081 (0.127) [0.522]	0.065 (0.128) [0.611]	0.057 (0.130) [0.659]	0.084 (0.127) [0.510]	0.055 (0.131) [0.674]
Subsidiary		0.335 (0.245) [0.170]	0.348 (0.255) [0.173]	0.311 (0.264) [0.239]	0.342 (0.266) [0.198]	0.348 (0.253) [0.170]	0.315 (0.267) [0.239]
Imitation capabilities		0.049 (0.019) [0.009]	0.053 (0.019) [0.005]	0.058 (0.019) [0.002]	0.054 (0.018) [0.003]	0.053 (0.019) [0.005]	0.058 (0.018) [0.002]
Patent litigation involvement		0.059 (0.038) [0.117]	0.066 (0.044) [0.132]	0.059 (0.040) [0.146]	0.064 (0.043) [0.144]	0.066 (0.044) [0.132]	0.058 (0.041) [0.154]
Home-country similarity		0.128 (0.084) [0.128]	0.092 (0.082) [0.262]	0.100 (0.082) [0.219]	0.104 (0.081) [0.200]	0.089 (0.083) [0.283]	0.102 (0.082) [0.213]
Novel product attribute		-0.557 (0.064) [0.000]	-0.619 (0.072) [0.000]	-0.617 (0.071) [0.000]	-0.605 (0.072) [0.000]	-0.613 (0.071) [0.000]	-0.601 (0.071) [0.000]
Industry concentration		-0.003 (0.073) [0.971]	0.078 (0.082) [0.346]	0.090 (0.080) [0.257]	0.081 (0.080) [0.311]	0.071 (0.083) [0.388]	0.082 (0.079) [0.303]
Sales volatility		-0.077 (0.052) [0.142]	-0.124 (0.054) [0.022]	-0.132 (0.053) [0.013]	-0.121 (0.054) [0.025]	-0.124 (0.054) [0.022]	-0.127 (0.053) [0.017]
Firm fixed-effects		Included	Included	Included	Included	Included	Included
Technological system fixed-effects		Included	Included	Included	Included	Included	Included
Number of observations		3794	3794	3794	3794	3794	3794
Log-pseudolikelihood		216.935	243.577	254.031	251.121	244.068	257.180
AIC		-235.871	-323.155	-336.061	-336.242	-324.137	-342.360
BIC		382.005	188.622	200.680	181.775	187.640	194.381

Note: Estimates are based on standardized variables; robust standard errors are reported in parentheses; *p*-values are reported in square brackets.

account for the effects of each moderator across various industry transitions. First, as discussed in previous studies on technological change, technological transitions “are assumed to come from exogenous events” (Kaplan and Tripsas, 2008, p. 796) and are attributed to “stochastic technological breakthroughs” (Anderson and Tushman, 1990, p. 605). In the mobile phone industry, the examined transitions were largely driven by external regulatory or market-wide forces, rather than competitive dynamics among firms. Therefore, consistent with previous studies, we believe that “an empirical setting with multiple generational technological changes over time allows us [...] to reduce concerns about endogeneity” (Ozalp et al., 2023, p. 1294). For example, the transition from analog to digital phones was driven by regulators, which favored

the diffusion of digital cellular networks and the progressive displacement of analog ones. Since this shift was largely driven by national institutions, mobile phone makers had little influence over its timing or direction, reinforcing its exogeneity. Regarding the second discontinuity, Google, with its Android OS—which became the dominant design in the new generation of smartphones—was primarily an OS supplier rather than a handset maker, and had an interest in spreading this OS across the handset makers. Since Google was not competing as a handset maker, its motivations for Android OS adoption were distinct from those of hardware competitors, further underscoring the exogenous nature of this transition.

Second, we incorporate firm and technological system fixed-effects

Table 3
Robustness tests.

		AFT Weibull	AFT Exponential	Cox proportional hazards	Gompertz (proportional hazards) without market share
	Hypothesis	Model 7	Model 8	Model 9	Model 10
Constant		0.252 (3.833) [0.948]	4.101 (0.170) [0.000]		-3.228 (0.368) [0.000]
Main effects					
Technological transition	<i>H1</i>	0.864 (0.526) [0.100]	0.393 (0.121) [0.001]	-0.258 (0.076) [0.001]	-0.303 (0.110) [0.006]
Pioneering orientation		0.061 (0.061) [0.314]	0.033 (0.021) [0.128]	-0.042 (0.021) [0.043]	-0.023 (0.021) [0.274]
Pioneer's market share advantage		0.116 (0.100) [0.245]	0.058 (0.038) [0.126]	-0.058 (0.039) [0.134]	-0.055 (0.033) [0.093]
Technology visibility		-0.313 (0.172) [0.069]	-0.129 (0.027) [0.000]	0.109 (0.034) [0.001]	0.132 (0.025) [0.000]
Interaction effects					
Technological transition × Pioneering orientation	<i>H2</i>	-0.228 (0.157) [0.147]	-0.093 (0.035) [0.009]	0.090 (0.029) [0.002]	0.094 (0.031) [0.003]
Technological transition × Pioneer's market share advantage	<i>H3</i>	0.271 (0.176) [0.125]	0.143 (0.059) [0.016]	-0.114 (0.055) [0.037]	-0.126 (0.057) [0.025]
Technological transition × Technology visibility	<i>H4</i>	-0.156 (0.110) [0.156]	-0.055 (0.040) [0.165]	0.080 (0.051) [0.122]	0.066 (0.036) [0.063]
Control variables					
Market share		-0.120 (0.329) [0.715]	-0.055 (0.113) [0.624]	0.075 (0.047) [0.109]	
Subsidiary		-0.672 (0.862) [0.436]	-0.171 (0.247) [0.488]	0.335 (0.111) [0.002]	0.270 (0.231) [0.241]
Imitation capabilities		-0.161 (0.109) [0.137]	-0.086 (0.023) [0.000]	0.049 (0.012) [0.000]	0.059 (0.018) [0.001]
Patent litigation involvement		-0.132 (0.126) [0.298]	-0.042 (0.035) [0.233]	0.053 (0.021) [0.010]	0.064 (0.039) [0.100]
Home-country similarity		-0.231 (0.211) [0.273]	-0.094 (0.086) [0.273]	0.114 (0.072) [0.116]	0.101 (0.082) [0.216]
Novel product attribute		1.466 (0.690) [0.034]	0.569 (0.081) [0.000]	-0.577 (0.083) [0.000]	-0.596 (0.072) [0.000]
Industry concentration		-0.297 (0.174) [0.088]	-0.202 (0.071) [0.005]	0.023 (0.050) [0.645]	0.086 (0.078) [0.273]
Sales volatility		0.307 (0.204) [0.132]	0.181 (0.059) [0.002]	-0.057 (0.039) [0.148]	-0.133 (0.050) [0.008]
Firm fixed-effects		Included	Included	Included	Included
Technological system fixed-effects		Included	Included	Included	Included
Number of observations		3794	3794	3794	3794
Log-pseudolikelihood		245.209	223.668	-12,501.973	256.461
AIC		-326.419	-241.336	25,287.95	-338.922
BIC		185.358	401.505	26,174.19	204.060

Note: Estimates are based on standardized variables; robust standard errors are reported in parentheses; *p*-values are reported in square brackets.

to isolate time-variant factors from static differences among firms and technological categories. In this way, we control for time-invariant characteristics of firms and technologies that could correlate with both the explanatory variables and the error term, reducing the risk of omitted variable bias (Cameron and Trivedi, 2009), minimizing the confounding effects that could otherwise distort our results.

Third, we employ lagged independent variables to mitigate concerns about reverse causation (Kim et al., 2013). This helps account for the potential influence of the dependent variable on the independent

variables, ensuring a more robust causal inference.

Finally, the inclusion of time-variant controls at both the firm level (e.g., market share, subsidiary, home-country similarity, imitation capabilities) and the industry level (e.g., industry concentration, sales volatility) addresses unobserved heterogeneity that evolves over time, minimizing omitted variable bias and controlling for confounding factors. For instance, the decision to imitate rapidly or slowly could be influenced by unobserved firm capabilities. We mitigate this concern by including multiple proxies—such as market share, age, and imitation

capabilities—capturing different aspects of firm-specific capacity.

4.4. Additional analyses: The role of capabilities

Although our theorizing does not explicitly focus on the role of a firm's capabilities in shaping how it adapts its speed of imitation during periods of technological stability and transition, this nonetheless constitutes an important additional analysis. Capabilities concern how effectively a firm is able to undertake a specific action or navigate a particular challenge—for example, relying on imitation to cope with industry-wide technological changes in our context. On the one hand, the literature on technological transitions (Lawless and Anderson, 1996; Lee and Malerba, 2017) suggests that during such shifts, firms are heterogeneous in how they reconfigure their capabilities to exploit the opportunities created by technological changes. On the other hand, recent contributions have emphasized the need to move beyond purely theoretical accounts and empirically assess the role of firm capabilities in innovation and competition (Grant and Verona, 2015; Schilke et al., 2018).

When theorizing the moderating effect of pioneering orientation, our main argument drew on firms' risk attitudes. A complementary, but distinct, mechanism, however, concerns firms' *innovation capabilities*. Innovation capabilities go beyond a firm's general orientation or propensity to innovate: they refer to the firm's ability to translate innovative efforts into effective outcomes, and involve “technological foresight, perceptive market research, or skillful product or process development” (Lieberman and Montgomery, 1988, p. 49). We expect that these capabilities provide the focal firm (the imitator) with the superior knowledge and routines required to integrate uncertain technological solutions effectively, thereby enabling greater confidence in the firm's ability to imitate rapidly and successfully. For example, firms with strong innovation capabilities tend to allocate resources more efficiently, streamline decision-making processes, and respond promptly to emerging technological opportunities (Pacheco-de-Almeida, 2010). Just as pioneering new technologies entails significant uncertainty, so too does rapid imitation. To imitate swiftly, a firm must be capable of assessing how the imitated technology can be integrated into new product models, ensuring compatibility with existing product components, and maintaining coherence within its broader product line. Allocating resources for rapid imitation is particularly challenging when the firm lacks the capabilities to navigate the uncertainty associated with being an early mover. Thus, we should expect that firms with greater innovation capabilities will be better equipped to sustain rapid imitation during technological transitions, rather than decelerating their imitation activities.

Empirically, measuring capabilities is notoriously difficult, and the literature provides few consolidated measures (Grant and Verona, 2015; Schilke et al., 2018). Using the data available, we operationalized innovation capabilities in a manner similar to our measure of imitation capabilities—specifically, as the product of (a) pioneering orientation (i. e., the number of innovations introduced by the firm in the past three years) and (b) the firm's annual market share growth following these pioneering efforts. This measure captures not only the firm's propensity to innovate but also the extent to which such innovations are translated into market performance. A positive market share growth increases the score, rewarding effective pioneering; negative market share growth lowers the score, penalizing ineffective pioneering; and no pioneering activity results in a score of zero regardless of market outcomes. We then re-estimated our full model by substituting pioneering orientation (and its interaction) with innovation capabilities. As shown in Model 13 of Appendix D, the results reveal that the main effect of innovation capabilities is negative: firms with greater ability to innovate effectively tend to focus on innovation itself rather than on rapid imitation. More importantly, the interaction term is positive and significant: the negative effect of technological transition on speed of imitation is weakened for firms with stronger innovation capabilities. This finding suggests that,

although innovation-capable firms are generally slower to imitate rivals' innovations, their ability to generate value from newly launched technologies enables them to navigate transition-related uncertainty more confidently. As a result, innovation capabilities mitigate the otherwise slowing effect of transitions on imitation speed. In other words, innovation capabilities provide firms with the confidence and knowledge to continue imitating relatively quickly despite environmental uncertainty, because they possess a clearer sense of how to translate such innovations into positive outcomes.

As a complement, we also examined the moderating role of firms' *imitation capabilities*, which in our full model was used as a control. In fact, firms may develop routines and expertise that allow them to imitate more effectively. We then ran an additional model where imitation capabilities were introduced as a moderator of the technological transition–speed of imitation relationship (Model 14, Appendix D). The results show that the main effect of imitation capabilities is positive and significant, indicating that firms with stronger imitation capabilities are generally faster in imitating rivals' innovations. However, the interaction effect is negative and significant: during technological transitions, the positive influence of imitation capabilities on speed of imitation diminishes. Ex post, a plausible explanation is that particularly firms skilled at imitation adopt a more cautious approach in transition periods, recognizing that the uncertain environment makes it harder to translate rapid imitation into performance gains. Thus, despite their expertise, such firms may deliberately reduce their imitation speed in order to avoid costly missteps when technological trajectories are still unsettled. Interestingly, these results are broadly consistent with the arguments made by Pacheco-de-Almeida (2010) and Hawk et al. (2013) regarding “intrinsic speed capabilities,” defined as the ability to execute investment projects faster than competitors. Pacheco-de-Almeida and colleagues hypothesize that firms with intrinsic speed capabilities face lower preemption risks and can therefore afford to wait longer for uncertainty to resolve before committing to new markets. Essentially, they revealed that a firm's optimal timing for when to follow rivals in embarking on innovative activities is contingent on its intrinsic “superior speed capabilities” (Pacheco-de-Almeida, 2010, p. 1506). In our context, when entering an unfamiliar and volatile environment that demands significant upfront investments—such as a technological transition—a firm with strong imitation capabilities may delay imitation until it observes how early movers perform. This provides directional insights and reduces the risk of early missteps. Such firms appear to time their imitation by carefully balancing the value of learning from pioneers against the risk of arriving too late to capture sufficient market share.

Finally, we examined the moderating role of firm *age*, as the technological change literature has long debated its effects on incumbents' versus late entrants' capacity to reconfigure resources and capabilities in response to environmental shifts. Some scholars argue that older, more experienced firms have accumulated greater knowledge and routines, which translate into capabilities that enable them to adapt more effectively to change (Eggers and Park, 2018; König et al., 2021). In contrast, drawing on the windows-of-opportunity logic, others suggest that older firms often exhibit inertia and organizational rigidities, making them slower to adapt during transitions (Lee and Malerba, 2017). Firm age was measured as the natural logarithm of the number of years since a firm's entry into the mobile phone industry. As shown in Model 15 of Appendix D, the moderating effect of age on the technological transition–speed of imitation relationship is statistically insignificant. This finding suggests that firm age does not meaningfully condition the slowing effect of technological transitions on imitation speed in our sample. Given the contrasting theoretical perspectives and the mixed empirical findings in prior work, the role of firm age in shaping technology imitation—as well as technology innovation—dynamics warrants further investigation. Accordingly, as a further step in this line of inquiry, we examine whether, during technological transitions, firms differ in their propensity to innovate—rather than imitate rapidly—and

whether this relationship depends on firm age. Because pioneering orientation is measured as a count of pioneered technologies introduced over a three-year period, we estimate Poisson regression models with firm fixed and random effects. As shown in Models 16 and 17 (Table D2), technological transition has a negative and statistically significant effect on pioneering orientation, indicating that firms are generally less likely to pioneer new technologies during such periods. Firm age also shows a negative main effect (albeit with a p -value of 0.147 in Model 17), suggesting that older firms tend to exhibit lower pioneering orientation. However, the interaction between firm age and technological transition is positive and significant, indicating that the negative effect of technological transition on pioneering orientation weakens as firms age. In other words, while technological transitions generally suppress pioneering activity, this negative effect is attenuated for older firms relative to more stable periods. While this does not necessarily imply superior performance for older firms—given the risk of *incumbent traps*, which often lead established firms to launch innovations closely tied to designs that are about to be displaced (Lee and Malerba, 2017)—the results suggest that technological upheaval can prompt mature firms to increase innovation in response to shifting competitive dynamics. Interestingly, among the control variables, market share has a positive effect on firms' pioneering orientation. This pattern reflects the evolution of the industry: early large incumbents (e.g., Motorola and Nokia) were initially highly innovative but later declined as they aged, whereas younger entrants, such as Apple, Huawei, and Xiaomi, rapidly gained market share and exhibited a high pioneering orientation. This dynamic explains why innovation is positively associated with market share but negatively related to firm age.

5. Discussion

5.1. Implications

The tension between firms rapidly imitating rivals' innovations versus waiting for others to imitate first has garnered significant attention in the strategy and innovation literature (e.g., Ethiraj and Zhu, 2008; Lee et al., 2003; Pacheco-de-Almeida, 2010). While studies have provided empirical evidence on factors influencing a firm's speed of imitation, they often overlook the impact of the changing technological landscape in which firms compete (Anderson and Tushman, 1990; Lawless and Anderson, 1996). This gap is surprising given contrasting views on how firms respond to technological transitions (Eggers and Park, 2018; König et al., 2021). Understanding the factors that drive firms to accelerate or decelerate imitation during periods of technological transition versus stability is an issue that merits thorough investigation.

To address this issue, we integrated information-based and rivalry-based theories of imitation with the literature on technological change. We argued that the speed of imitation is contingent on whether these innovations are introduced during periods of technological stability or transition. Furthermore, in this study, we developed a model in which the relationship between periods of technological transition, as compared to periods of technological stability, and speed of imitation is influenced by imitator-level, target-level, and object-level contingencies. Our results support that firms imitate at a higher speed during periods of technological stability due to decreased technological uncertainty compared to periods of technological transition. Additionally, the speed of imitation-dampening effect of periods of technological transition is weakened if the firm possesses a strong pioneering orientation, the lower the pioneer's market share advantage relative to the focal firm, and the higher the technology visibility.

Our analysis underscores the issue of imitation timing as a strategic decision contingent on multiple factors, including the *level of uncertainty* in the environment, a *firm's strategic orientation* toward fast imitation, the *entity pioneering* a particular move, and the *object* being assessed for quick or slow imitation. Particularly, our first result, which suggests that firms imitate more slowly during periods of technological transition compared to periods of technological stability (Hypothesis 1), extends theories of imitation (Lieberman and Asaba, 2006), highlighting the diminishing speed-fostering role of rivalry-based motives for imitation when technological trajectories in an industry become less predictable. It implies that in the presence of low technological uncertainty, firms imitate each other more rapidly to maintain competitive parity. Conversely, during periods of technological transition, when the risk of making mistakes is higher, firms' motives for imitation are information-based. Firms that imitate in such conditions of high technological uncertainty bear high costs to process information from potential imitation targets, thus slowing down the imitation of rivals' innovations.

Regarding our imitator-level contingency (Hypothesis 2), we underscore the role of a firm's pioneering orientation (Mueller et al., 2012) in accelerating the imitation of rivals' innovations. Prior studies have theorized that firms with a great pioneering orientation are likely to strive to stake out leading positions in an industry (e.g., Halebian et al., 2012). These firms usually experiment internally to anticipate rivals in the introduction of innovations (Zahra, 1996). We extend this literature by integrating the concept of pioneering orientation into the speed of imitation research. In particular, we delved into the role of pioneering orientation as a primary driver of speed of imitation across varying technological contexts. We proposed that, although during periods of technological transition firms may prioritize information-based imitation over rivalry-based imitation, resulting in slower imitation of rivals' innovations, firms with a greater pioneering orientation are less adversely affected in their imitative speed because of their greater risk-taking attitude. Thus, we advance this literature, recognizing that a firm's speed of imitation during transitions depends on its prior experience with pioneering new technologies.

Regarding our target-level contingency (Hypothesis 3), our study differentiated between various types of technology pioneers based on their market share advantage relative to the focal firm. We provided guidelines on which technology pioneers are more likely to be imitated rapidly during periods of technological transitions compared to periods of technological stability. While existing literature has highlighted the market leader's role in driving imitation processes (e.g., Bikhchandani et al., 1998; Giachetti and Lanzolla, 2016; Pacheco-de-Almeida, 2010; Ross and Sharapov, 2015), our study is the first to explore how technology pioneers with varying *relative market share advantages* influence a firm's speed of imitation in the face of technological landscape changes. We drew on two competing perspectives—rivalry-based versus information-based theories of imitation—with the former prevailing empirically: during a technological transition, firms are less likely to rapidly imitate technologies introduced by rivals with a larger market share advantage, because they fear, we argue, that such rivals will aggressively retaliate to safeguard their temporary competitive advantages during times of heightened uncertainty. On the one hand, the competitive dynamics literature has shown that larger rivals possess greater retaliatory power and are more likely to launch aggressive responses to defend their reputation relative to smaller attackers (Chen and Hambrick, 1995; Smith et al., 1991). On the other hand, the technological change literature has emphasized firms' strategies across an industry's technology cycle (Anderson and Tushman, 1990; Lee and Malerba, 2017) but has overlooked the dynamics of imitation speed throughout such cycles. We bridge these two streams of research and

offer a novel contribution by showing how differences in relative market share shape firms' imitation behavior under transitions, thereby advancing our understanding of how competitive asymmetries condition strategic responses during industry evolution.

Regarding our object-level contingency (*Hypothesis 4*), we shed light on the relationship between the technology visibility and the speed at which it is imitated. Drawing on competitive dynamics research on object visibility (Chen and Miller, 2012; MacMillan et al., 1985) and on research in organizational sociology, we theorized that the volume of refracted signals by information sources—to which external actors in the organizational field are exposed—shapes collective awareness and perceptions of a technological innovation. By capturing the volume of attention directed toward a technology, these signals act as social cues that reduce uncertainty and accelerate imitation. First, these findings complement the extant literature on competitive dynamics by extending the focus from firm-level responses to technology-level outcomes, showing how attention to an innovation influences the timing of imitation across the industry. Second, these findings advance sociological research on refracted signals (Pollock and Rindova, 2003) by empirically supporting that these signals do not merely shape general perceptions of legitimacy or desirability, but also concretely affect firms' strategic behavior in rapidly evolving technological contexts. In doing so, we demonstrate that highly visible innovations are imitated more rapidly, particularly during technological transitions, as refracted signals from authoritative information sources enhance awareness, legitimize the innovation, and reduce the perceived risks of rapid imitation. Finally, these findings complement the literature on technology diffusion, underscoring that technology visibility extends beyond user-level observability or mere communication channels (Rogers, 2003), reflecting the broader prominence of an innovation in industry discourse, which systematically informs firms' imitation strategies.

5.2. Limitations and avenues for future research

Our study is not without limitations. First, our analysis is confined to the mobile phone industry. This industry is characterized by short product life cycles, modular technological architectures, and rapid market turnover, features that may not extend to industries such as pharmaceuticals or chemicals. In these industries, innovation processes are typically longer, more cumulative, and subject to stringent regulatory oversight. Pharmaceutical innovation, for example, requires extensive clinical testing, patent-based exclusivity, and compliance with safety and efficacy standards, all of which lengthen development timelines and limit the speed at which rivals can imitate newly introduced products. Similarly, chemical innovations often depend on scale-intensive processes, deep expertise in materials science, and costly production adjustments, making imitation slower, more complex, and more path-dependent. Because the drivers of imitation in such industries are shaped by barriers related to regulation, intellectual property protection, capital intensity, and knowledge cumulateness—rather than by rapid design cycles and competitive parity concerns—the mechanisms influencing the speed of imitation in those contexts may differ markedly from those observed in our setting. Accordingly, the generalizability of our findings is necessarily constrained by these structural differences across industries. Future research could examine whether the patterns we observed also emerge in industries with different structural characteristics.

Second, our analysis did not capture the intentionality behind the varying speed of imitation, which might encompass a myriad of strategic

considerations, managerial cognitive schemas, and resource constraints. The intentionality behind speed of imitation is rarely questioned in imitation research. Thus, by diving deeper into the strategic micro-foundations underpinning a firm's decision to imitate and at what speed, future studies could attempt to improve our knowledge around the notions of choice and deliberation in imitation processes. To this end, future avenues could involve case study analyses with in-depth interviews or the application of cognitive mapping techniques.

A further limitation concerns the absence of R&D spending as a control variable, which is theoretically relevant because firms' R&D investments may influence both their ability and their strategic incentives to imitate technological innovations. Our sample consists mainly of diversified firms whose R&D investments are allocated across multiple product categories, making it impossible to isolate the share directed specifically toward mobile-phone technologies. Consequently, constructing a valid and comparable measure of R&D for our context was not feasible. Future research would benefit from examining whether firms' R&D investment decisions moderate rivalry-based versus information-based motives for rapid imitation.

Finally, our study does not account for the fact that handset makers operate interdependently. They frequently engage in joint ventures and outsource the production of components and phone assembly to third-party entities wielding significant market influence. These partnerships extend both upstream and downstream in the value chain, potentially facilitating the rapid adoption of innovations introduced by their rivals, especially when those rivals are also strategic collaborators. Thus, future research could delve into vertical integration, strategic alliances, and co-competition literature to explore additional factors explaining how firms adjust their speed of imitation throughout the industry's technological evolution.

CRediT authorship contribution statement

Claudio Giachetti: Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Marco Balzano:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. The sampled mobile phone technologies

Table A1
Product technologies introduced in the mobile phone industry (1992–2019).

Technological system	Technological innovation	Month of introduction	Novel / improved attribute
Audio	Voice Recorder	May 1997	Novel
Audio	Loudspeaker	February 1998	Improved
Audio	Music Player	October 2000	Novel
Audio	3.5 mm Jack	April 2005	Improved
Audio	Dual Speaker	June 2014	Improved
Band (network)	GSM Band 1	November 1992	Novel
Band (network)	CDMA (Code Division Multiple Access) Band 1	November 1995	Novel
Band (network)	GSM Band 2	January 1996	Improved
Band (network)	GSM Band 3	January 2000	Improved
Band (network)	GSM Band 4	April 2003	Improved
Band (network)	CDMA Band 2	May 2008	Improved
Band (network)	CDMA Band 3	August 2011	Improved
Band (network)	CDMA Band 4	September 2011	Improved
Battery	Removable battery	September 1994	Novel
Battery	NiMH (Nickel-Metal Hydride) battery	November 1994	Improved
Battery	Li-Ion (Lithium-Ion) battery	May 1996	Improved
Battery	Li-Po (Lithium Polymer) battery	January 1999	Improved
Battery	Wireless Charge	February 2009	Novel
Battery	Quick Charging	December 2013	Improved
Battery	Reverse Charging	January 2014	Novel
Bluetooth	1.0	October 2000	Novel
Bluetooth	1.1	March 2001	Improved
Bluetooth	1.2	March 2004	Improved
Bluetooth	2.0	February 2005	Improved
Bluetooth	A2DP (Advanced Audio Distribution Profile)	February 2005	Improved
Bluetooth	2.1	October 2006	Improved
Bluetooth	EDR (Enhanced Data Rate)	September 2008	Improved
Bluetooth	3.0	April 2010	Improved
Bluetooth	aptX (Adaptive Transform Acoustic Coding)	June 2010	Improved
Bluetooth	4.0	October 2011	Improved
Bluetooth	LE (Low Energy)	October 2011	Improved
Bluetooth	3.1	August 2012	Improved
Bluetooth	4.1	November 2013	Improved
Bluetooth	4.2	August 2015	Improved
Bluetooth	5.0	April 2017	Improved
Bluetooth	5.1	August 2019	Improved
Camera	One front camera	March 2002	Novel
Camera	Videocamera presence	November 2002	Novel
Camera	One selfie camera	February 2003	Novel
Camera	LED Flash	August 2003	Novel
Camera	Autofocus	November 2004	Improved
Camera	Wide function	August 2009	Improved
Camera	Panorama	September 2009	Improved
Camera	HDR (High Dynamic Range)	July 2011	Improved
Camera	OIS (Optical Image Stabilization)	November 2012	Improved
Camera	Depth sensor	March 2014	Improved
Camera	Two front cameras	May 2015	Improved
Camera	Two selfie cameras	October 2015	Improved
Camera	Telephoto lens	December 2015	Improved
Camera	Three front cameras	April 2018	Improved
Camera	Five front cameras	February 2019	Improved
Camera	Four front cameras	March 2019	Improved
Camera	Macro function	June 2019	Improved
Camera pixel	0.1 megapixels	October 2002	Improved
Camera pixel	1 megapixels	February 2004	Improved
Camera pixel	2 megapixels	February 2004	Improved
Camera pixel	5 megapixels	January 2005	Improved
Camera pixel	3 megapixels	February 2005	Improved
Camera pixel	8 megapixels	August 2008	Improved
Camera pixel	12 megapixels	August 2009	Improved
Camera pixel	13 megapixels	July 2011	Improved
Camera pixel	16 megapixels	April 2012	Improved
Camera pixel	32 megapixels	June 2012	Improved
Camera pixel	48 megapixels or more	December 2018	Improved
Card	Card Slot Presence	August 1999	Novel
Card	Micro SD (Secure Digital)	February 2004	Improved
Colors	4096 colors	June 2001	Novel
Colors	256 colors	August 2001	Improved
Colors	64,000 colors	September 2001	Improved
Colors	256,000 colors	February 2003	Improved
Colors	16,000,000 colors	January 2005	Improved

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Table A1 (continued)

Technological system	Technological innovation	Month of introduction	Novel / improved attribute
Connectivity	FM (Frequency Modulation) Radio	February 1998	Novel
Connectivity	Infrared	March 1998	Novel
Connectivity	GPS (Global Positioning System)	August 1999	Novel
Connectivity	Wi-Fi/WLAN (Wireless Fidelity/Wireless Local Area Network)	February 2004	Novel
Connectivity	Wi-Fi DLNA (Digital Living Network Alliance)	September 2008	Improved
Connectivity	Nfc (Near-Field Communication)	April 2009	Novel
Connectivity	Wi-Fi Hotspot	November 2009	Improved
Connectivity	Wi-Fi Direct	November 2010	Improved
Connectivity	Wi-Fi Dual Band	January 2011	Improved
Display resolution	Up to about 6000 pixels	March 1998	Improved
Display resolution	Up to about 150,000 pixels	August 1998	Improved
Display resolution	Up to about 40,000 pixels	September 1998	Improved
Display resolution	Up to about 16,000 pixels	August 1999	Improved
Display resolution	Up to about 10,000 pixels	January 2000	Improved
Display resolution	Up to about 96,000 pixels	January 2000	Improved
Display resolution	Up to about 500,000 pixels	July 2005	Improved
Display resolution	Up to about 1,000,000 pixels	October 2011	Improved
Display resolution	Up to about 2,000,000 pixels	November 2012	Improved
Display resolution	Up to about 4,000,000 pixels	September 2013	Improved
Display resolution	Up to about 3,000,000 pixels	October 2017	Improved
Display type	LCD (Liquid Crystal Display)	August 1998	Novel
Display type	Touchscreen	September 1998	Novel
Display type	TFT (Thin Film Transistor)	June 2001	Improved
Display type	STN (Super Twisted Nematic)	August 2001	Improved
Display type	Protective Glass	January 2003	Novel
Display type	OLED (Organic Light-Emitting Diodes)	February 2004	Improved
Form factor	Clamshell	January 1992	Novel
Form factor	Flip	January 1993	Improved
Form factor	Slide up	July 1996	Improved
Form factor	Swivel	January 2002	Improved
Games	Games	March 1998	Novel
Internet	HTML (HyperText Markup Language)	August 1998	Novel
Internet	WAP (Wireless Application Protocol) 1	June 1999	Novel
Internet	WAP 2	January 2002	Improved
Internet	RSS (Really Simple Syndication) Feed	November 2005	Novel
Memory	eMMC (Embedded MultiMediaCard) type	May 2018	Improved
Memory	UFS (Universal Flash Storage)	April 2019	Improved
Messaging	SMS (Short Message Service)	November 1992	Novel
Messaging	Email (Electronic Mail)	August 1998	Novel
Messaging	EMS (Enhanced Messaging Service)	December 2000	Improved
Messaging	SMS Chat	January 2001	Improved
Messaging	MMS (Multimedia Messaging Service)	November 2001	Improved
Messaging	Instant Messaging	March 2002	Improved
Operating system	Microsoft Windows	November 2000	Novel
Operating system	Symbian	June 2001	Novel
Operating system	Palm OS (Operating System)	August 2002	Novel
Operating system	Blackberry	May 2003	Novel
Operating system	Linux	February 2004	Novel
Operating system	iOS (iPhone Operating System)	January 2007	Novel
Operating system	Android	October 2008	Novel
Operating system	Bada	April 2010	Novel
Operating system	Tizen	May 2012	Novel
Operating system	Firefox	July 2013	Novel
Phone call	Vibrate Alert	January 1996	Novel
Phone call	Ringtone Composer	May 1997	Novel
Phone call	Downloadable Ringtones	March 1998	Novel
Phone call	Voice Dial	October 1998	Novel
Phone call	Polyphonic Ringtones	January 2000	Improved
Phone call	Video Calling	February 2003	Novel
Phone call	True Tones	February 2003	Improved
Sensor	Compass	November 2003	Novel
Sensor	Fingerprint	May 2004	Novel
Sensor	Accelerometer	October 2006	Novel
Sensor	Proximity	October 2006	Novel
Sensor	Gyro (Gyroscope)	November 2010	Novel
Sensor	Barometer	April 2011	Novel
Sensor	Color Spectrum	February 2015	Novel
Sensor	Face ID	October 2017	Novel
Sim	Mini SIM (Subscriber Identity Module)	November 1993	Novel
Sim	Multiple SIM	August 2007	Improved
Sim	Micro SIM	September 2011	Improved
Sim	Nano SIM	September 2012	Improved
Sim	eSIM (Embedded Subscriber Identity Module)	October 2017	Improved
Sim	Nano SD	November 2018	Improved
Speed data transfer	GPRS (General Packet Radio Service)	December 2000	Improved
Speed data transfer	3G/UMTS (3rd Generation/Universal Mobile Telecommunications System)	January 2003	Improved

(continued on next page)

Table A1 (continued)

Technological system	Technological innovation	Month of introduction	Novel / improved attribute
Speed data transfer	EDGE (Enhanced Data rates for GSM Evolution)	August 2003	Improved
Speed data transfer	HSPA (High-Speed Packet Access)	February 2006	Improved
Speed data transfer	4G (4th Generation)	September 2010	Improved
Speed data transfer	5G (5th Generation)	April 2019	Improved
USB	USB (Universal Serial Bus) 1.0 first generation	February 2002	Novel
USB	Micro USB	October 2006	Improved
USB	Reversible Connector	September 2012	Improved
USB	On The Go	December 2014	Improved
USB	Type-C Connector	August 2015	Improved

Notes: A “novel” product attribute is a completely new functionality or design element in a product category, while an “improved” attribute enhances or refines an existing functionality or design element.

Within each technological system, innovations are chronologically ordered by their date of introduction. Furthermore, it is worth noting that in the case of five technological systems—i.e., “colors,” “camera,” “camera pixel,” “Bluetooth,” and “display resolution”—we observed a few instances of an “improved” attribute exhibiting lower performance compared to attributes introduced in a closely preceding period. We investigated these issues by consulting various specialized secondary sources on mobile telephony to better understand the non-monotonic increase in feature performance over time. These cases include a 3-megapixel camera introduced after a 5-megapixel camera, a phone with four front cameras introduced after a phone with five front cameras, a 256-color display introduced after a 4096-color display, Bluetooth 3.1 introduced after Bluetooth 4.0, and a few similar cases for the display resolution technological system. In the case of camera pixels, the two types of cameras were introduced in consecutive months, leading us to assume they were two attempts to improve upon the 2-megapixel camera introduced almost a year earlier. Similarly, in the case of color displays, the two types of color displays were introduced almost simultaneously as different attempts to enhance monochrome displays. However, only the 4096-color display represented a significant departure from monochrome displays and was therefore coded as “novel.” Likewise, in the case of display resolution and Bluetooth, from the sources we consulted, we understood that there was a race among suppliers of these technologies to introduce more performant features over time, but their time to market was different. In the eyes of users, however, these features were perceived as improvements over previous ones. In summary, a technological innovation coded as “improved” was not necessarily better performing than the immediately preceding technological innovation of the same type, but improved with respect to a series of preceding technological innovations. Finally, some product attributes, such as “monophonic ringtones,” are not included in our database, despite being collected. This is because these product attributes were embedded in the design of cellular phones before the beginning of our observation period.

Appendix B. Plots of hazard curves of interaction effects

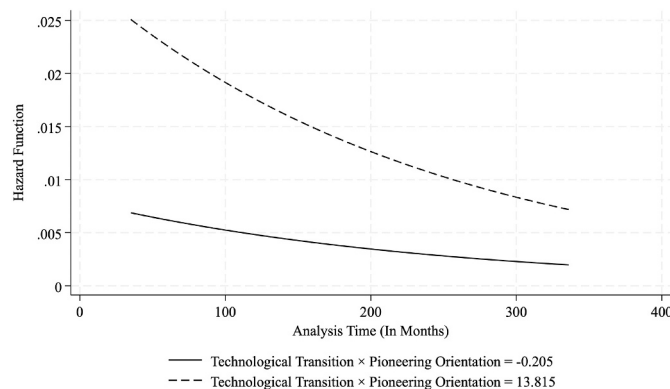


Fig. B1. Gompertz model: Hazard curves of speed of imitation by technological transition × pioneering orientation.

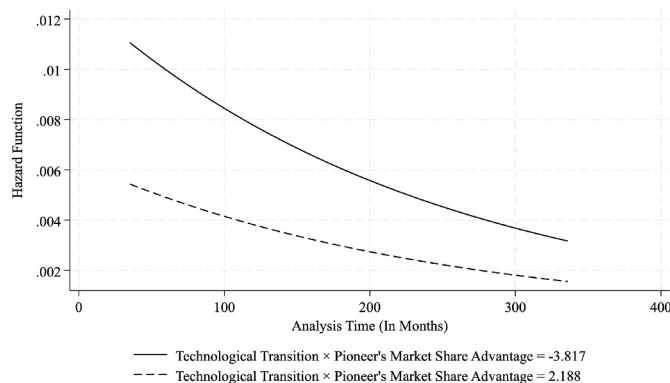


Fig. B2. Gompertz model: Hazard curves of speed of imitation by technological transition × pioneer's market share advantage.

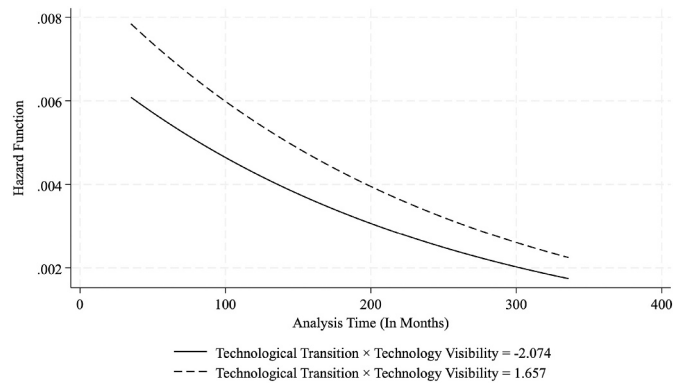


Fig. B3. Gompertz model: Hazard curves of speed of imitation by technological transition × technology visibility.

Appendix C. Endogeneity test

Table C1

Endogeneity tests: 2SRI models.

	Model 11	Model 12
	OLS (dependent variable: Pioneering orientation)	Gompertz (proportional hazards)
Constant	-0.812 (0.262) [0.002]	-3.193 (0.351) [0.000]
Main effects		
Industry innovation clockspeed	0.050 (0.006) [0.000]	
Technological transition	-0.329 (0.081) [0.000]	-0.317 (0.177) [0.072]
Pioneering orientation		-0.037 (0.183) [0.841]
Pioneer's market share advantage	-0.059 (0.026) [0.021]	-0.047 (0.036) [0.196]
Technology visibility	0.003 (0.025) [0.916]	0.131 (0.026) [0.000]
Interaction effects		
Technological transition × Pioneering orientation		0.092 (0.032) [0.004]
Technological transition × Pioneer's market share advantage		-0.119 (0.053) [0.026]
Technological transition × Technology visibility		0.068 (0.036) [0.060]
Control variables		
Market share	0.797 (0.043) [0.000]	0.062 (0.178) [0.727]
Subsidiary	-0.089 (0.112) [0.428]	0.313 (0.278) [0.260]
Imitation capabilities	-0.022 (0.013) [0.082]	0.058 (0.019) [0.003]
Patent litigation involvement	0.133 (0.019) [0.000]	0.060 (0.053) [0.256]
Home-country similarity	0.005 (0.066) [0.938]	0.102 (0.082) [0.216]
Novel product attribute	-0.052 (0.074) [0.483]	-0.602 (0.072) [0.000]
Industry concentration	0.162 (0.038) [0.000]	0.084 (0.094) [0.370]
Sales volatility	-0.069 (0.032) [0.032]	-0.126 (0.062) [0.043]
Residuals		0.009 (0.192) [0.961]
Firm fixed-effects	Included	Included
Technological system fixed-effects	Included	Included
Number of observations	3794	3794
Adjusted R-squared	0.582	
Log-pseudolikelihood		257.182
AIC	12,037.26	-348.365
BIC	12,911.02	169.653

Note: Estimates are based on standardized variables; robust standard errors are reported in parentheses; p-values are reported in square brackets.

Appendix D. Additional analyses: The role of capabilities

Table D1

Additional analysis: Moderating effects of innovation and imitation capabilities and firm age.

	Model 13	Model 14	Model 15
Constant	-3.239 (0.370) [0.000]	-3.455 (0.348) [0.000]	-3.334 (0.248) [0.000]
Main effects			
Technological transition	-0.306 (0.107) [0.004]	0.095 (0.122) [0.438]	-0.194 (0.151) [0.199]
Innovation capabilities	-0.043 (0.013) [0.001]		
Pioneer's market share advantage	-0.044 (0.036) [0.218]	-0.110 (0.031) [0.000]	-0.129 (0.035) [0.000]
Technology visibility	0.124 (0.025) [0.000]	0.158 (0.021) [0.000]	0.103 (0.037) [0.006]

(continued on next page)

Table D1 (continued)

	Model 13	Model 14	Model 15
Imitation capabilities	0.055 (0.018) [0.003]	0.171 (0.044) [0.000]	0.054 (0.017) [0.002]
Firm age			−0.036 (0.084) [0.672]
Interaction effects			
Technological transition × Innovation capabilities	0.066 (0.027) [0.013]		
Technological transition × Pioneer's market share advantage	−0.125 (0.051) [0.014]		
Technological transition × Technology visibility	0.070 (0.036) [0.050]		
Technological transition × Imitation capabilities		−0.159 (0.039) [0.000]	
Technological transition × Firm age			0.143 (0.122) [0.241]
Control variables			
Market share	0.074 (0.133) [0.579]	0.064 (0.114) [0.572]	−0.009 (0.085) [0.918]
Subsidiary	0.298 (0.265) [0.262]	0.385 (0.257) [0.133]	0.066 (0.211) [0.754]
Patent litigation involvement	0.059 (0.043) [0.171]	0.072 (0.043) [0.096]	0.071 (0.052) [0.168]
Home-country similarity	0.102 (0.083) [0.215]	0.095 (0.084) [0.258]	−0.022 (0.155) [0.889]
Novel product attribute	−0.614 (0.072) [0.000]	−0.544 (0.083) [0.000]	−0.546 (0.090) [0.000]
Industry concentration	0.083 (0.079) [0.294]	0.035 (0.078) [0.651]	0.078 (0.103) [0.448]
Sales volatility	−0.119 (0.054) [0.027]	−0.146 (0.055) [0.009]	0.007 (0.080) [0.930]
Firm fixed-effects	Included	Included	Included
Technological system fixed-effects	Included	Included	Included
Number of observations	3794	3794	3794
Log-pseudolikelihood	256.221	271.741	−12,501.973
AIC	−340.442	−335.482	−79.486
BIC	196.299	313.601	231.872

Note: Estimates are based on standardized variables; robust standard errors are reported in parentheses; *p*-values are reported in square brackets.

Table D2

Additional analysis: Poisson regression results for pioneering orientation.

	Model 16 (Fixed effects)	Model 17 (Random effects)
Main effects		
Technological transition	−0.915 (0.102) [0.000]	−0.932 (0.102) [0.000]
Firm age	−0.098 (0.051) [0.056]	−0.075 (0.052) [0.147]
Interaction effects		
Technological transition × Firm age	0.164 (0.089) [0.066]	0.176 (0.089) [0.049]
Control variables		
Pioneer's market share advantage	−0.035 (0.026) [0.178]	−0.035 (0.026) [0.172]
Technology visibility	−0.006 (0.030) [0.838]	−0.008 (0.030) [0.784]
Imitation capabilities	−0.001 (0.012) [0.945]	0.002 (0.011) [0.880]
Market share	0.187 (0.031) [0.000]	0.194 (0.031) [0.000]
Subsidiary	−0.574 (0.159) [0.000]	−0.523 (0.158) [0.001]
Patent litigation involvement	0.046 (0.012) [0.000]	0.048 (0.012) [0.000]
Home-country similarity	0.085 (0.061) [0.162]	0.087 (0.061) [0.152]
Novel product attribute	−0.011 (0.071) [0.879]	0.000 (0.071) [1.000]
Industry concentration	0.254 (0.040) [0.000]	0.269 (0.040) [0.000]
Sales volatility	0.029 (0.035) [0.412]	0.023 (0.035) [0.515]
Technological system fixed-effects	Included	Included
Number of observations	1779	2331
Log-likelihood	−1544.434	−2082.260
Wald χ^2	1068.04	504.27
Prob > χ^2	0.000	0.000

Notes: Estimates are based on standardized variables; standard errors are reported in parentheses; *p*-values are reported in square brackets. All models are estimated on firm-level panel data: Fixed and random effects are specified at the firm level. The Poisson fixed-effects model uses fewer observations than the random-effects model because the fixed-effects estimator drops firms that have no within-firm variation in the dependent variable, i.e., always the same count over time.

Data availability

Although the data used in this study are confidential due to provider restrictions, the manuscript presents a description of the database and a sample of the data in [Appendix A](#).

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