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How does technology catch-up experience affect innovation performance of latecomer firms?: Evidence from the Korea pharmaceutical industry

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ABSTRACT

Drawing on the technological learning model of latecomer firms (LCFs) and the literature on catch-up, this paper examines how accumulated internal R&D investment, foreign technology in-licensing experience, and creative imitation experience independently and interactively affect innovation by LCFs. We showed that LCFs' accumulated internal R&D investment and creative imitation experience have a positive impact on their innovation, respectively. However, LCFs' creative imitation experience weakens the positive relationship between accumulated internal R&D investment and innovation, implying the paradoxical effect of LCFs' creative imitation strategy on their innovation. Using the unique panel dataset on drugs developed by Korean pharmaceutical firms between 1999 and 2019, we find evidence that generally supports our hypotheses.

KEYWORDS

Creative imitation; innovation; latecomer firms (LCFs); technological catch-up; technology licensing

Introduction

The impact of imitation strategies on firm performance has long been of scholarly interest (Ethiraj & Zhu, 2008; Giachetti et al., 2017; Lieberman & Asaba, 2006; Posen et al., 2013; Posen et al., 2020; Posen & Martignoni, 2018; Shenkar, 2010). Specifically, for many latecomer firms (LCFs) from emerging economies, imitating the success formula verified by incumbent firms is indispensable to survive fierce competition and ultimately to catch up with incumbents with strong innovation capabilities (Chang et al., 2020; Kim, 1997; Luo et al., 2011). Existing literature proposes that the process of technological catch-up follows a sequential evolutionary path: LCFs first build an initial knowledge base through duplicative imitation of mature technologies developed by industry leaders; next, they gradually accumulate capabilities required for innovation through creative imitation of existing technologies or products; finally, they become innovation leaders (Kale & Little, 2007; Kim, 1997; Li & Kozhikode, 2008; Luo et al., 2011). Yet, where capabilities required for innovation largely differ from those for technological catch-up, LCFs that have excelled in the latter might find it difficult to pursue innovation. While a few case studies support this theory of a sequential catch-up process of LCFs (e.g. Kale & Little, 2007; Luo et al., 2011; Zhang et al., 2021), empirical evidence on the factors contributing to their successful catch-up is still very limited.

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To fill this research gap, we investigate the effects on innovation of various actions of LCFs during the imitation stages. In LCFs advancing to the creative imitation stage, numerous internal R&D activities are conducted and in-licensing of standardised, foreign, and latest technologies occurs (Kale & Little, 2007; Kim, 1999). Kim (1999) argues that activities conducted for the purposes of creative imitation, including investment in large-scale internal R&D projects and learning from those, in-licensing of up-to-date technologies originated by foreign firms, joint R&D activities with foreign industry leaders, and hiring foreign engineers, all help LCFs develop capabilities necessary for innovation. By contrast, Wu et al. (2019) report that excessive engagement in technology imitation hinders transformation of LCFs from imitators to innovators capable of radical innovation. Based on the technological learning model of LCFs proposed by Kim (1997, 1999), we seek empirical evidence on the impact of accumulated internal R&D investment and technology imitation activities, such as foreign technology in-licensing and creative imitation experience, on innovation performances of LCFs.

To test our hypotheses, we construct a unique panel dataset consisting of drug development projects undertaken by 66 listed Korean pharmaceutical firms, considered typical LCFs, from 1999 to 2019. We examine the independent impact of accumulated internal R&D investment, foreign technology in-licensing, and creative imitation experience on innovation outcomes of these LCFs as well as the effects of the interaction of explanatory factors. The Korea pharmaceutical industry provides an ideal setting for this study, because many firms have ample experiences of duplicative and creative imitation for a few decades, with some recently starting to harvest from their innovation-based products. The results of the analysis show a nuanced impact of creative imitation and technology in-licensing on innovation of LCFs, implying that the sequential evolutionary path suggested by Kim (1997) may not fully capture the technological catch-up process of these firms in the real world (Luo et al., 2011).

The remainder of the paper is structured as follows. In the theory and hypotheses section, we discuss related literature and propose testable hypotheses. The empirical setting and methods section explains the research design and describes the dataset used for our empirical analysis. The results of our empirical analysis are discussed in the next section. The discussion and conclusion section brings this paper to a close.

Theory and hypotheses

Technological catch-up process of LCFs and the importance of internal R&D

As Mathews (2002, p. 471) stated, 'latecomer firms start not from the powerful position of an IBM, but from the resource-meager position of isolated firms seeking some connection with the technological and business mainstream'. Many LCFs enter markets where incumbents have already set the rules of the game. Because LCFs often lack strategic assets such as technology or global market access upon market entry, they initially imitate industry leaders' knowledge and technologies (Mathews, 2002, 2006, 2017). Over time, some LCFs that have accumulated innovation capabilities attempt to catch up with incumbents, threatening their positions as global market leaders or innovators in the industry (Miao et al., 2018; Ray et al., 2017). This gradual catch-up process involves numerous growth strategies, especially in firms from emerging economies such as India,

China and ASEAN countries, or newly-industrialised countries such as Korea, Taiwan, Brazil and Mexico (e.g. Chung & Lee, 2015; Figueiredo, 2007; Lee & Yoon, 2015; Malerba & Lee, 2021; Park & Ji, 2020). These strategies usually involve technology imitation, the purpose of which is to foster innovation (Forbes & Wield, 2006; Kim, 1997; Ulhøi, 2012).

Kim (1997) suggests that LCFs follow a sequential evolutionary path, as follows: they initially survive through duplicative imitation, after which they advance to creative imitation, and finally, they move on to innovation. Duplicative imitation refers to the development of copies of original products, in the forms of straightforward knock-offs or clones, based on the reverse engineering of mature technologies whose patents or copyrights have expired (Kim, 1997; Raustiala & Sprigman, 2012; Schnaars, 2002). At the creative imitation stage, however, firms do not blindly imitate original products or technologies of incumbents, attempting to creatively reorganise and recombine existing knowledges (Kim, 1997; Wang et al., 2023). Creative imitation, thus, often accompanies with the acquisition and exploitation of knowledge sourced from outside, mainly through technology in-licensing. During the creative imitation stage, LCFs obtain essential information about original technologies, learn the operating principles of products, and internalise effective organisational routines, all of which prepare them for innovation (Li & Kozhikode, 2008; Wu et al., 2019).

Creative imitation requires LCFs to actively engage in internal R&D activities to figure out how to recombine the acquired knowledge to meet the new needs of customers or to enter new markets (Kim, 1997; Lee & Zhou, 2012; Posen & Martignoni, 2018; Shenkar, 2010; Wang et al., 2023). Recent literature on the catch-up of LCFs reports that the impact of technology imitation strategies on technological catch-up is complicated and nuanced. The extent to which technological imitation leads to innovation depends on the intensity of competition (Moreira et al., 2020; Sikimic et al., 2016). Wu et al. (2019) claim that excessive imitation of pre-existing technology prevents firms from pursuing radical innovation. To make a successful transition from imitators to genuine innovators, LCFs must be capable of independent, long-term, large-scale R&D investment, which comes with a high risk of failure (Kim, 1999). While engaging in internal R&D activities, LCFs can acquire both tangible strategic assets such as R&D staff, R&D equipment, and financial resources as well as intangible ones such as tacit knowledge, innovation capabilities, and organisational routines, all of which help motivate and manage innovation. These strategic assets are critical for LCFs to overcome uncertainty led by trial and error and to cope with inevitable modifications that frequently arise during the process of new technology or product development (Li & Kozhikode, 2008).

Internal R&D investment is also important in building absorptive capacity, defined as the ability of a firm to acquire, assimilate, transform and exploit external knowledge (Cohen & Levinthal, 1990; Zahra & George, 2002). While LCFs may increase their absorptive capacity through imitation at the early stage of catch-up, the genuine ability to absorb up-to-date technologies and transform them into valuable products cannot be developed without a significant amount of internal R&D activity (Chang et al., 2020; Kim, 1997; Sohn et al., 2009). Therefore, as a baseline hypothesis, we posit that:

> Hypothesis 1. Accumulated internal R&D investment of latecomer firms has a positive relationship with innovation performance in those firms.

Impacts of technology in-licensing and creative imitation on innovation of LCFs

Acquiring diverse knowledge developed outside the firm is important to enhance innovation outcomes at the firm level. It is often not easy for LCFs to acquire new knowledge necessary for innovation solely through internal R&D, because, in the technological frontiers, the changes in technological paradigms occur fast and the scope of knowledge to be acquired also changes frequently with the acceleration of technological convergence (Enkel et al., 2009). Thus, LCFs need to acquire up-to-date knowledge and explore a variety of technology alternatives through technology sourcing to reduce uncertainty and to mitigate the risk of failure associated with internal knowledge creation (Laursen & Salter, 2006; Levitt, 1966; Wu et al., 2019). Technology in-licensing is an effective strategy for acquisition and imitation of external knowledge. Because in-licensing agreements allow LCFs to use knowledge and/or technologies invented by other organisations legitimately (Arora & Fosfuri, 2003), they can complement internal R&D activities with the in-licensing of existing knowledge (Bianchi & Lejarraga, 2016; Bianchi et al., 2014; Sikimic et al., 2016; Veugelers & Cassiman, 1999).

For LCFs emerging from developing economies, specifically, in-licensing of knowledge developed in foreign markets is important to complement internal R&D (Kim, 1999). LCFs from emerging or newly industrialised economies are less likely to benefit from knowledge spillover or the 'peer effect' compared to incumbent firms located in regions with strong industrial, technological and innovative capabilities (Hobday, 1998; Lee et al., 1988; Malerba & Lee, 2021). In-licensing of knowledge and technologies developed by foreign innovators can serve as an important strategic channel through which LCFs access cutting-edge knowledge required for innovation (Guo et al., 2013; Kim, 1999). By licensing in technologies produced in innovative regions or industrial clusters abroad, LCFs acquire the new knowledge that cannot be sourced from the domestic market nor easily generated through internal R&D in a timely and cost-effective manner (Arora & Fosfuri, 2003; Asheim & Isaksen, 2002; Kim, 1999). Li-Ying and Wang (2015) show that Chinese firms that license foreign technologies outperform local counterparts that license domestically-produced technologies in terms of innovation outcomes. Based on this finding, we hypothesise that:

> Hypothesis 2. In-licensing of technologies from foreign firms has a positive impact on innovation performance in latecomer firms.

Likewise, LCFs build the capabilities necessary for innovation through creative imitation experiences, as these attempts help LCFs learn how to utilise or combine knowledge to bring new products to market (Kim, 1998; Luo et al., 2011). Li and Kozhikode (2008) suggest that LCFs learn from emulation at the creative imitation stage. To add creative features and functions to products using the existing set of knowledge, LCFs must understand the underlying principles of what they imitate, taking considerable time and effort to understand how to re-organise internally and externally sourced ideas to improve the existing products (Li & Kozhikode, 2008). Unlike duplicative imitation, therefore, LCFs that promote creative imitation gradually acquire the capabilities necessary for creating new knowledge through emulation-based learning. At the same time, LCFs encounter risks and failures when creating new value by using various set of knowledge in creative ways. Organisational routines accumulated during the creative imitation stage become

important assets when the LCFs proceed to pursue innovation thereafter. Accordingly, we hypothesise that:

> Hypothesis 3. Creative imitation in latecomer firms has a positive relationship with innovation performance in those firms.

Moderating effect of in-licensing and creative imitation on the relationship between internal R&D and innovation of LCFs

Meanwhile, numerous scholarly works report a complementary relationship between technology in-licensing and internal R&D in fostering innovation (e.g. Cassiman & Veugelers, 2006; Ceccagnoli et al., 2014; Laursen et al., 2010; Laursen & Salter, 2006; Veugelers & Cassiman, 1999). Novel ideas can be developed when firms effectively combine licensed technologies with independently produced ones through internal R&D (Fleming & Sorenson, 2004; Higgins & Rodriguez, 2006; Kim, 1997; Tsai & Wang, 2008). In other words, merely tapping into externally-produced knowledge does not guarantee that firms are capable of innovation. Technology in-licensing is only advantageous when LCFs possess sufficient internal capacity to develop and manage tacit knowledge (Lyles & Salk, 1996; Nonaka & Takeuchi, 1995).

An issue may arise when LCFs are too accustomed to exploit outsourced knowledge so that they fail to acquire organisational routines and capabilities required to conduct innovation. Since innovation involves the complicated set of information that is not perfectly codifiable, using a canned package of codified knowledge through technology in-licensing is not enough for LCFs to obtain the comprehensive set of components required to develop a new technology (Chung & Lee, 2015; Liefner et al., 2019). For example, LCFs that have been used to license in technologies develop organisational routines optimised to capture value by quickly recombining the existing set of knowledge (Levinthal & March, 1993; Levitt & March, 1988). When R&D staff does not understand how to use a licensed technology, the internal R&D teams can always turn to the technology licensor rather than attempting to figure out the questions by themselves (Lowe & Taylor, 1998, 1999). Moreover, because the use of in-licensed technology is subject to a variety of legal restrictions and, thus, might come with the risks of legal disputes, R&D staff of LCFs would not be able to enjoy full autonomy in determining how to use it (Walter, 2012). In other words, while in-licensing can be considered an easy and quick alternative to internal experimentation in the short term, too much dependence on the outsourcing might obstruct LCFs to internalise trials and errors which is essential to develop innovation capabilities.

As LCFs allocate R&D resources predominantly to interpret licensed knowledge and apply it to incrementally improve existing products, the firms become avoiding considerable risks to produce original knowledge autonomously (Levitt & March, 1988). This situation could lead to organisational inertia whereby LCFs prefer to keep cherry-picking market opportunities originated by others rather than making creative attempts to produce unique knowledge by their own (Wu et al., 2019). Yet, the devotion to dynamic learning and the development of absorptive capacity is critical for the technological catch-up of LCFs (Kim, 1997, 1999). It implies that, if LCFs would opt for technology in-licensing even after they have accumulated enough experience with internal R&D, the persistence in knowledge outsourcing might undermine R&D productivity,

measured by innovation outcomes produced per the unit input in internal R&D, in the long term (Atuahene-Gima & Patterson, 1993; Enkel et al., 2009; Lowe & Taylor, 1998; Walter, 2012). We hypothesise the moderating impact of technology in-licensing on the impact of internal R&D on innovation performance of LCFs as follows:

> Hypothesis 4. The positive relationship between accumulated internal R&D investment and innovation performance in latecomer firms is weakened as their foreign technology in-licensing experience increases.

Finally, we examine how the creative imitation experience of LCFs moderates the relationship between internal R&D efforts and their innovation performance. Creative imitation, as opposed to duplicative imitation, provides LCFs the chance to simulate knowledge creation and accumulate necessary capabilities. However, creative imitation starkly differs from innovation. As previously discussed, creative imitation refers to the imitation of original products or technologies with some reorganised components or additional modifications (Kim, 1997; Wang et al., 2023). While this process somewhat involves creativity, the changes made by creative imitation are closer to the incremental improvement of existing knowledge rather than to the creation of new, unexplored knowledge. Given that a firm's R&D capacity is a scarce resource, the more internal R&D resources are allocated to creative imitation, the fewer resources remain to be allocated toward innovation (Chang et al., 2020).

During the technology catch-up process, LCFs face a trade-off between creative imitation and innovation when allocating internal R&D resources. On one hand, they could decide to stick with the creative imitation strategy and earn a modest amount of rent; in such situations, LCFs may gain a thin and unsustainable competitive edge over fast followers on a similar evolutionary path. On the other hand, they could boldly pioneer unexplored knowledge domains in pursuit of pre-emptive advantages, gaining market leadership as innovative incumbents did before them. Due to high attrition rates and risk, however, it is not easy for LCFs to invest significantly and persistently in innovation. Kim (1999) argues that LCFs seeking innovation must be able to tolerate frequent failure in the innovation process. By contrast, a disproportionate share of learning experience during the creative imitation process is likely to be relatively safe and incremental.

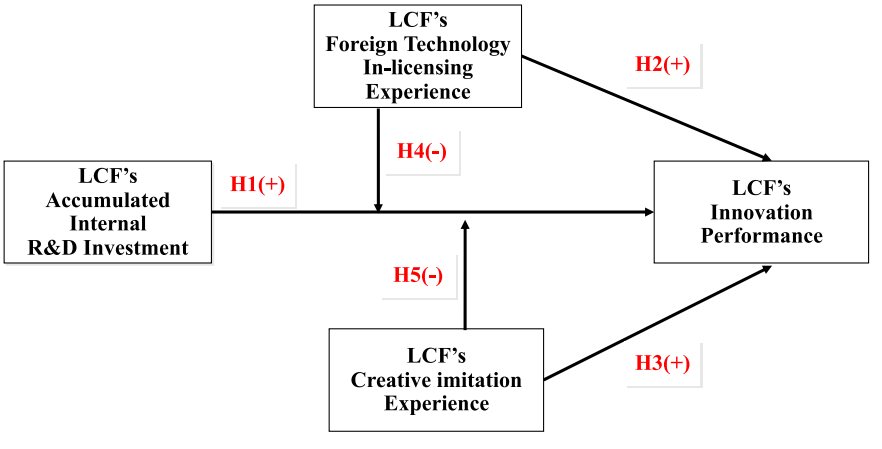

Figure 1. Research model.

Over time, the 'learning-by-doing' mechanism strengthens LCFs' ability to engage in creative imitation. Knowing that creative imitation will bring success, internal R&D teams may prefer to allocate R&D resources toward creative imitation rather than taking risks to pursue innovation, unless they are strongly encouraged by a few motivated leaders (Kim, 1997, 1998, 1999). Thus, we present our last testable hypothesis (Figure 1):

> Hypothesis 5. The positive relationship between accumulated internal R&D investment and innovation performance in latecomer firms is weakened as their creative imitation experience increases.

Empirical setting and methods

Empirical context and data

In the pharmaceutical industry, original drugs, incrementally-modified drugs and generics correspond to innovation, creative imitation and duplicative imitation, respectively (Kale & Little, 2007). Original drugs are new medicines based on a new chemical entity with a new structure (Kale & Little, 2007). Original drugs are developed through discovery, pre-clinical research and clinical studies; a patent guarantees associated intellectual property rights for a certain period of time. Incrementally-modified drugs (often known as 'me-too' drugs) are medicines that have similar compounds and efficacy to original drugs, but the properties and types of the latter have been changed to create an effective product (Ha et al., 2011). Generic drugs are medicines created to be the same as already marketed original drugs in terms of dosage form, safety, strength, route of administration, quality, performance characteristics and intended use (Kale & Little, 2007).

We conducted empirical analyses within the context of the Korean pharmaceutical industry. In the 1960s and 1970s, Korean pharmaceutical firms entered the pharmaceutical industry by imitating already existing technology. Korean pharmaceutical firms reverse-engineered or in-licensed original drugs invented by industry leaders of advanced countries and regions such as the US, Japan, and the EU to manufacture and sell generic drugs in the Korean domestic market. Since the 1990s, some Korean pharmaceutical firms have developed incrementally-modified drugs and original drugs based on their own capabilities. The industry provides an ideal setting for our study for following reasons. First, many Korean pharmaceuticals have had ample experience of duplicative and creative imitation for more than 5 decades. Second, it allows to observe the creative imitation and innovation performances simultaneously. As the pharmaceuticals positioned at the late stage of technological catch-up attempt to make the transition to become innovators, the increasing number of firms have succeeded in winning the marketing approvals of independently developed drugs.

We tested our hypotheses by constructing a panel dataset of 66 Korean pharmaceutical firms for a period of 21 years (1999–2019), firms listed on the Korea Stock Exchange as of December 31, 2020. Information on licensing contracts of and product development in Korean pharmaceutical firms was collected using the TS-2000 (a reputable web-based database of Korean firms' business information managed by the Korea Listed Companies Association), Korea Pharmaceutical Industry R&D White

Papers published by the Korea Drug Research Association, Korea Pharmaceutical Company Directory Books published by the Korea Health Industry Development Institute, Korea Pharmaceutical Data books published by the Korea Pharmaceutical and Bio-Pharma Manufacturers Association, company websites and press releases. Financial and other business information of sample firms was collected from DART (a reputable web-based database of Korean companies' business and financial information managed by the Financial Supervisory Service of the Korean government) and KIND (a reliable web-based database of Korean companies' disclosed information managed by the Korea Stock Exchange).

On the Korea Stock Exchange, 148 listed firms were coded as belonging to the pharmaceutical manufacturing industry during the study period. We categorised these 148 listed companies as general pharmaceutical companies, animal pharmaceuticals specialists, raw material specialists, medical device specialists and therapy specialists. To secure information from sample firms suitable for our research, we selected only general pharmaceutical companies. Due to data availability issues, information for only 66 sample firms was used for hypothesis testing.

Variables

Dependent variable. To observe innovation performance in LCFs at the firm level, we calculated the number of new original drugs developed by a focal firm in a given year. Admittedly, it is not common that LCFs successfully get original drugs approved. Still, we measure the innovation performance with the successful development of original drugs, instead of the antecedents of innovation such as the patent application or the new project entry, because we aim to understand how imitation and exploitation experiences of LCFs ultimately affect their performances as genuine innovators.

Independent variable. We measured the extent of accumulated internal R&D investment in LCFs by calculating the natural logarithm of their total R&D expenditure in the 5-year window before a given observation year. In the pharmaceutical industry, long-term R&D investments must occur for LCFs to succeed in developing incrementally-modified drugs or new original drugs (Kale & Little, 2007). According to the 2019 Korea Pharmaceutical Industry R&D White Paper, on average, 5∼10 years of R&D activities are required for Korean pharmaceutical companies to develop one original drug (the dependent variable). To measure LCFs' foreign technology in-licensing experience, we calculated the total number of publicly-disclosed international in-licensing contracts signed by a focal firm within the 5-year window before a given observation year. We used 5-year windows following the approach of Sikimic et al. (2016), which assumes that recent in-licensing experience is more relevant to firms' innovative activities than is experience from the distant past. We measured LCFs' creative imitation experience by calculating the total number of incrementally-modified drugs developed by a focal firm within the 5-year window before a given observation year.

Control variables. We controlled for several firm-level factors that may impact innovation outcomes in LCFs. We controlled for international joint R&D experience, which may significantly confound the effects of accumulated internal R&D investment, foreign technology in-licensing experience and creative imitation experience on innovation. International joint R&D experience was measured by determining the number of cases

in which LCFs had conducted joint research or development projects for R&D purposes with external overseas organisations such as foreign pharmaceutical companies, bio-ventures, specialised research institutes or universities within the 5-year window before a given observation year. To take into account different patenting strategies, we also controlled for the number of patents filed by a focal firm within the 5-year window before a given observation year (Wu et al., 2019). Additionally, firm size was controlled by determining the total revenue of a focal firm in a given observation year (using a natural logarithm form). To measure firm age, we subtracted the year of establishment of a focal firm from the focal observation year. Since LCFs with more financial slack resources can initiate more projects, albeit with a higher risk of failure, we controlled for slack resources, measured as the logarithm of the ratio of total current liabilities to total current assets in a given observation year. Firms with better performance can also allocate more financial resources to innovation activities. We therefore controlled for firm performance, measured by returns on assets – the ratio of total income divided by total assets in a given observation year (Wu et al., 2019). Lastly, we accounted for year-specific unobserved heterogeneity by including year dummies in the regression models.

Methods

As our dependent variable is a count variable, which has a positive integer value, we can employ a panel Poisson or negative binomial regression model to test our hypotheses (Wooldridge, 2013). As the results of the likelihood ratio test in all models (Model 1 to Model 8) show that the dependent variable of this study is not over-dispersed, the results are reported based on a panel Poisson regression model (Wooldridge, 2013). To take into account time-lag effects, all explanatory variables were lagged by 1 year.

Results

Main results

Table 1 presents the descriptive statistics associated with the variables and shows the correlations between them. The correlation matrix indicates no troubling collinearity among the variables, except for that between firm size and accumulated internal R&D investment. To ensure that the results of this study were not affected by multicollinearity, we calculated the variance inflation factors (VIFs) associated with the model covariates. VIFs of firm size and accumulated internal R&D investment were 4.88 and 4.82, respectively, and all other VIFs were below 3, suggesting that there is no significant bias in the estimated models resulting from a multicollinearity problem.

Table 2 presents the results of the Poisson regression analyses from Model 1 to Model 8. Model 1 is the base model, which shows the effects of control variables only. In Models 2, 3 and 4, we added accumulated internal R&D investment, foreign technology in-licensing experience and creative imitation experience, respectively. Model 5 includes all three independent variables. In Models 6 and 7, we added the interaction term between accumulated internal R&D investment and foreign technology in-licensing and that between accumulated internal R&D investment and creative imitation, respectively. Model 8, the

Table 1. Descriptive statistics and correlation matrix.

Variables	Innovation performance	Accumulated internal R&D investment	Foreign technology in-licensing experience	Creative imitation experience	International joint R&D experience	Number of patents filed	Firm size (Log scale)	Firm age	Slack resources	Firm performance
Innovation performance	1.000									
Accumulated internal R&D investment	0.220***	1.000								
Foreign technology in-licensing experience	0.162***	0.321***	1.000							
Creative imitation experience	0.071	0.406***	0.131***	1.000						
International joint R&D experience	0.216***	0.419***	0.121**	0.189***	1.000					
Number of patents filed	0.160***	0.656***	0.159***	0.411***	0.656***	1.000				
Firm size (Log scale)	0.238***	0.858***	0.391***	0.330***	0.344***	0.562***	1.000			
Firm age	0.158***	0.371***	0.180***	−0.021	0.048	0.103**	0.452***	1.000		
Slack resources	−0.134***	−0.0898*	−0.045	0.019	−0.0904*	−0.131***	−0.208***	−0.204***	1.000	
Firm performance	0.013	0.185***	0.069	0.024	0.031	0.0821*	0.214***	0.031	0.165***	1.000
Mean	0.073	9.618	0.516	0.368	0.230	16.954	11.461	46.586	5.512	0.034
SD	0.307	1.560	0.949	0.966	0.813	23.998	1.022	19.276	0.639	0.151
Min	0.000	4.954	0.000	0.000	0.000	0.000	7.493	1.000	3.638	−2.039
Max	3.000	13.282	6.000	9.000	8.000	180.000	14.087	119.000	8.127	2.842

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 2. Results from the Poisson model.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Innovation performance							
Accumulated internal R&D investment		1.150***			1.159***	1.230***	1.043**	1.123**
		(2.760)			(2.660)	(2.830)	(2.380)	(2.470)
Foreign technology in-licensing experience			−0.0193		−0.12	0.554		0.289
			(−0.15)		(−0.86)	(0.360)		(0.190)
Creative imitation experience				0.222*	0.159		4.113***	4.087***
				(1.690)	(1.150)		(2.710)	(2.700)
Accumulated internal R&D investment X Foreign technology in-licensing experience						−0.06		−0.0373
						(−0.43)		(−0.27)
Accumulated internal R&D investment X Creative imitation experience							−0.339**	−0.336**
							(−2.52)	(−2.50)
International joint R&D experience	0.486***	0.393***	0.489***	0.524***	0.448***	0.398***	0.389***	0.402***
	(3.390)	(2.770)	(3.380)	(3.740)	(3.090)	(2.750)	(2.750)	(2.790)
Number of patents filed	−0.0160**	−0.0313***	−0.0164**	−0.0197***	−0.0367***	−0.0341***	−0.0259***	−0.0294***
	(−2.17)	(−3.39)	(−2.09)	(−2.62)	(−3.53)	(−3.30)	(−2.77)	(−2.80)
Firm size (Log scale)	1.037***	−0.0912	1.058***	1.006***	−0.00626	−0.00826	0.0427	0.119
	(4.900)	(−0.21)	(4.170)	(4.730)	(−0.01)	(−0.02)	(0.090)	(0.260)
Firm age	0.0162*	0.0111	0.0162*	0.0202**	0.0145	0.0113	0.0119	0.0124
	(1.920)	(1.220)	(1.920)	(2.300)	(1.530)	(1.250)	(1.190)	(1.250)
Slack resources	−0.780***	−0.945***	−0.782***	−0.806***	−0.994***	−0.977***	−1.066***	−1.098***
	(−2.60)	(−3.04)	(−2.60)	(−2.67)	(−3.15)	(−3.10)	(−3.23)	(−3.30)
Firm performance	−0.0853	−0.293	−0.0921	0.0385	−0.229	−0.378	−0.411	−0.494
	(−0.08)	(−0.22)	(−0.09)	(0.040)	(−0.18)	(−0.29)	(−0.29)	(−0.34)
Constant	−10.59***	−6.727**	−10.79***	−10.24***	−7.512**	−8.195**	−6.885**	−8.239**
	(−3.63)	(−2.14)	(−3.35)	(−3.46)	(−2.18)	(−2.28)	(−2.06)	(−2.19)
Year dummy	Included	Included	Included	Included	Included	Included	Included	Included
Wald Chi-squared	88.98	86.88	88.56	88.27	82.88	83.09	90.2	86.63
N	732	717	732	732	717	717	717	717

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

full model of this study, included all explanatory variables. The explanatory power of Model 1 increased significantly with the addition of the main independent variables.

In Hypothesis 1, we predicted a positive relationship between accumulated internal R&D investment and innovation in a given LCF. Across all models, the coefficients of accumulated internal R&D investment are consistently positive and significant ($p < 0.01$), suggesting that accumulated internal R&D investment is essential for LCFs to develop innovation. This result supports Hypothesis 1. Hypothesis 2 proposed a positive relationship between foreign technology in-licensing experience and innovation in a given LCF. While the coefficients have positive values, no coefficients of foreign technology in-licensing experience are statistically significant in any models. Thus, Hypothesis 2 is not statistically supported. Hypothesis 3 proposed a positive relationship between creative imitation experience and innovation in a given LCF. The coefficients of creative imitation experience are statistically significant across all models except Model 5, generally supporting Hypothesis 3. One possible interpretation of the loss of the statistical significance in Model 5 is that the explanatory powers of the internal R&D investment and creative imitation on innovation performance overlap so that the inclusion of the former variable overrides the impact of creative imitation.

The interaction terms of accumulated internal R&D investment and foreign technology in-licensing experience in Models 6 and 8 are not statistically significant. Although the coefficients have negative values, we cannot reject the null hypothesis against Hypothesis 4. The interaction terms of accumulated internal R&D investment and creative imitation experience in Models 7 and 8 are significant with a negative sign ($p < 0.01$), supporting Hypothesis 5. Figure 2 visualises the moderating effect of creative imitation

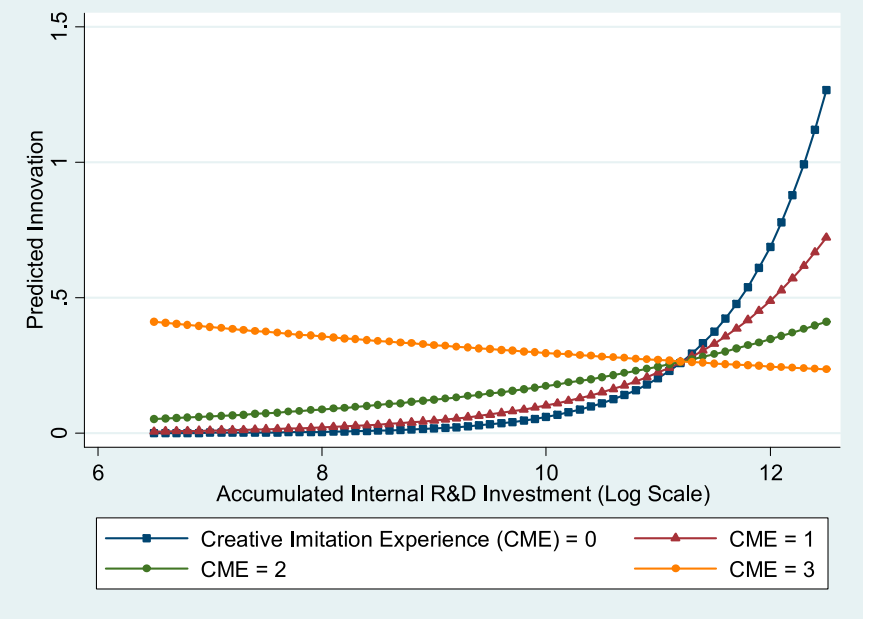

Figure 2. Moderating effect of LCFs' creative imitation experience.

experience on innovation in LCFs, which implies that LCFs' creative imitation experience weakens the positive effect of their accumulated internal R&D investment on innovation.

Taken together, while our results are consistent with the predicted outcomes of the creative imitation on innovation performance, we didn't find corresponding effects of the foreign technology in-licensing. There might exist a few explanations. First, LCFs may decide to license in technologies for multiple reasons. While a patent has strictly and narrowly defined claims, a licensee may learn useful know-how or otherwise uncodified knowledge as it uses the patented technology. If a firm exploited the outsourced technology to initially make the gradual improvement of existing products and, then, to use as reference when developing an original drug, merely counting in-licensing records would not fully separate the impact of in-licensing on catch-up from that on innovation. Second, the types of licensed technologies may differ. LCFs at the early stages of the catch-up might choose to license in a set of technologies that are suitable for duplicative imitation or creative imitation, while those seeking innovation might choose different set of technologies necessary to develop original technologies. For example, the former group of LCFs might disproportionately license patent-protected new chemical entities in order to manufacture drugs with the core ingredients, whereas LCFs that develop original drugs might license in method-related patents to optimise the dose, to reduce side effects, or to increase the yield rate during mass-production.

Robustness checks

To verify that the results were not artefacts of the statistical specification, we present the findings from different regression models for count data. First, as the likelihood ratio test indicated no inter-panel heterogeneity in any model, we introduced the GEE (Generalised Estimating Equation) population-averaged model into the analysis (Wooldridge, 2013) in Model 1 of Table 3. Model 2 reports the analysis results with the negative binomial regression model. Also, in Model 3 and Model 4, we add the results of analyses with zero-inflated Poisson and negative binomial regression models, respectively. Because it is not common that LCFs successfully get original drugs approved, too many zeros in the dependent variable might distort the anlayses of usual Possion and negative binomial regressions. The zero-inflated models assume that the observation of zero comes from two sources: the failure during the development and no participation in innovation. We run the zero-inflated regressions, assuming that LCFs without enough slack resources can't afford to develop original drugs. Across all four models, the results of hypothesis testing are consistent with the results of the main analytical model in this study based on the Poisson model with fixed effects.

Discussion and conclusion

LCFs technologically catch up with industry leaders by imitating their technologies and conducting internal R&D (Chang et al., 2020; Sohn et al., 2009; Song & Lee, 2014). However, most LCFs struggle to expand their internal R&D activities because they lack internal resources and capabilities and are vulnerable to the risk of investment failure. Moreover, as the technological gap between industry leaders and LCFs

Table 3. Robustness checks (full models).

	(1) GEE PA	(2) Negative binomial	(3) Zero-inflated Poisson	(4) Zero-inflated negative binomial
Accumulated internal R&D investment	1.159***	1.122**	1.121**	1.120**
	(2.740)	(2.470)	(2.350)	(2.350)
Foreign technology in-licensing experience	0.187	0.288	0.4	0.4
	(0.130)	(0.190)	(0.250)	(0.250)
Creative imitation experience	3.810***	4.089***	3.348**	3.348**
	(2.930)	(2.700)	(2.270)	(2.270)
Accumulated internal R&D investment X Foreign technology in-licensing experience	−0.0291	−0.0371	−0.0452	−0.0452
	(−0.22)	(−0.27)	(−0.31)	(−0.31)
Accumulated internal R&D investment X Creative imitation experience	−0.306***	−0.336**	−0.276**	−0.276**
	(−2.69)	(−2.51)	(−2.11)	(−2.11)
International joint R&D experience	0.389***	0.402***	0.431***	0.431***
	(2.930)	(2.790)	(2.650)	(2.650)
Number of patents filed	−0.0302***	−0.0294***	−0.0295***	−0.0295***
	(−3.10)	(−2.80)	(−2.68)	(−2.68)
Firm size (Log scale)	0.125	0.119	0.115	0.115
	(0.290)	(0.260)	(0.230)	(0.230)
Firm age	0.0104	0.0125	0.0157	0.0157
	(1.150)	(1.260)	(1.580)	(1.580)
Slack resources	−1.096***	−1.099***		
	(−3.50)	(−3.31)		
Firm performance	−0.488	−0.495	−1.118	−1.118
	(−0.33)	(−0.34)	(−0.65)	(−0.65)
Constant	−8.517**	0.704	−13.77***	−13.77***
	(−2.40)	(0.020)	(−4.00)	(−4.00)
Year dummy	Included	Included	Included	Included
Wald Chi-squared	103.8	86.86	88.37	87.76
N	717	717	717	717

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

narrows, industry leaders become increasingly reluctant to transfer their innovative technologies to LCFs (Li-Ying & Wang, 2015). As industry leaders continue to strive for innovation, LCFs are likely to lag behind and fall into a continuous catch-up trap (Zhang et al., 2021).

In this empirical study, we investigated the effects of accumulated internal R&D investment and technology imitation experience on innovation in LCFs to identify optimal technology learning strategies, increase innovation potential and escape from the catch-up trap. The results show that accumulated internal R&D investment and creative imitation experience have a positive effect on innovation in LCFs. However, as their creative imitation experience increases, the positive impact of accumulated internal R&D investment on innovation is weakened. This is because a creative imitative strategy can decentralise internal resources that should be focused on creating innovation, thereby weakening the incentives of internal R&D staff to pursue innovation. In addition, foreign technology licensing experience neither significantly affects innovation nor significantly moderates the relationship between accumulated internal R&D investment and innovation in LCFs.

This study contributes to the literature on innovation and catch-up strategy in the following ways. First, we ensured statistical accuracy by testing a series of generalisable hypotheses about explanatory factors of innovation in LCFs identified in case studies in the existing literature. Second, we described the paradoxical effects of creative imitation experience on innovation in LCFs, gaining a deeper understanding of why innovation is difficult in LCFs even when R&D investment is intense and on par with creative imitation efforts. Excessive creative imitation can be an obstacle for firms within the imitator group to move to the innovator group (Caves & Porter, 1977; Lee, 2003) though creative imitation may contribute to increased diversity within an industry (e.g. Posen et al., 2013; Posen & Martignoni, 2018). Third, there is a complex relationship between foreign technology in-licensing experience and innovation in LCFs, making clear causal analysis difficult. This indicates that despite management scholars' arguments that technology in-licensing can complement or substitute for internal R&D activities in the innovation process, LCFs must invest considerable amounts in internal R&D in order to succeed in their innovative efforts and not indiscriminately rely on foreign technology in-licensing.

This study has several practical implications for managers of LCFs and R&D staff as follows. Creative imitation strategies are attractive strategic options for LCFs because they enable stable revenue generation in the short term and help LCFs build flexible routines for innovation in the long run. However, since continued creative imitation can cause internal R&D staff to neglect risk-taking and intensive efforts toward innovation, managers of LCFs should implement creative imitation strategies selectively. In addition, according to agency theory, managers have an incentive to engage in external technology imitation (e.g. technology in-licensing) with less investment risk rather than investing in internal R&D at very high risk and uncertainty in order to preserve their positions and wages (e.g. Balkin et al., 2000; Baysinger et al., 1991; Coff, 2003). Managers of LCFs are therefore more likely to prefer technology imitation over internal R&D. The results of this study implicitly suggest that LCFs should invest in internal R&D by solving their potential agency problem with regard to technological learning strategies.

This study has several limitations that should be resolved in future studies. First, we found no significant results in this study on the impact of foreign technology in-licensing experience on innovation in LCFs. It calls for better understanding on how LCFs use the outsourced knowledge and what kind of technologies LCFs license-in across different stages of the technological catch-up. Also, in addition to in-licensing of foreign technology, LCFs in the late stage of catch-up may source external knowledge through international joint R&D, hiring engineers and foreign direct investment (e.g. Almeida et al., 2002; Mathews, 2017; Nicholson & Salaber, 2013; Sohn et al., 2009; Sun et al., 2012). Because foreign technology in-licensing may influence innovation in LCFs through interactions with these other knowledge sourcing modes and tacit knowledge transfer, follow-up research on this issue may be necessary. Second, one country was the empirical context for our research. It would be empirically and theoretically meaningful to expand the context of this research to other countries such as India, in which the catch-up process has been successful in the pharmaceutical industry (Kale & Little, 2007; Ray & Ray, 2021). Third, types of innovation were not distinguished in this study. Existing literature on innovation suggests that the optimal learning strategy for a firm may differ depending on the type of innovation it pursues. For example, Wu

et al. (2019) show that technology imitation and internal R&D investment have different impacts on incremental and radical innovation. Laursen and Salter (2006) argue that while it is beneficial for firms to have a wide range of knowledge in various fields for the purposes of incremental innovation, in-depth knowledge in a specific field is better for radical innovation. Therefore, future research could classify the types of innovation in LCFs to identify optimal technology learning strategies for each type. Lastly, by measuring innovation performance with the successful commercialisation of original drugs, this study doesn't measure how the catch-up experiences of LCFs change their intention for innovation, for example, by filing patents or expanding the search domains to technologies at the scientific frontier. To comprehensively understand the catch-up process of LCFs, it would be as important to understand whether and when LCFs initiate the efforts as to examine their innovation outcomes.

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