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Differentiated knowledge bases and catch-up in creative industries – A case of the online game industry in China

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ABSTRACT

Catch-up phenomena have been studied intensively in many manufacturing industries, but they have not been well explored in creative industries. Moreover, the internal heterogeneity of different segments within a specific industry has also largely been overlooked in the catch-up literature. This paper fills these gaps by analyzing the catch-up of a creative industry—the online game industry in China— and by extending the "windows of opportunity" framework with due account to the differentiated knowledge bases underpinning the value chain of the games industry. The findings show that the differentiated knowledge bases underlying this specific creative industry are combinatorial, and such combinations of different knowledge bases have led to distinct firm strategies in the different segments of game production (i.e. game design and content creation, programming, artistic creation, marketing) and catch-up outcomes (path skipping, following and creating). The introduction of the differentiated knowledge bases approach helps to provide a more nuanced understanding of catch-up in many industries where added-value are based on cultural tastes and symbolic knowledge, and thus leads to better policy implications for latecomers.

1. Introduction

Catch-up phenomena have been well examined from various perspectives in many countries and regions. Several emerging economies have successfully managed to improve their positions in global economic rankings (e.g., South Korea, Singapore, and China). In addition to the country-level catch-up, a larger amount of research has explored the catch-up phenomena in various industries, such as steel (Lee and Ki, 2017), automobile (Lee et al., 2009), information technology (IT) and telecommunication (Mu and Lee, 2005; Lee et al., 2012), clean technologies (e.g., Yap and Truffer, 2019; Binz et al.,2020), and recently artificial intelligence (Yu et al., 2022). Based on the catch-up stories in various industries in different countries, Lee and Malerba (2017) proposed an analytical framework of "windows of opportunity" to capture the mechanisms by which latecomers could climb the ladder of the global value chain. These studies have not only provided an in-depth understanding of the geographical shift of global production centers but also produced insightful implications for the development of latecomers.

Nonetheless, existing research has generated little knowledge on the catch-up processes in creative industries (Ström and Ernkvist, 2014). Breaking the stereotype that creative sectors are mainly dominated by industrialized countries (Sternberg, 2017), recent studies have provided some initial evidence of successful catch-up in creative industries in certain emerging countries (Lorenzen and Mudambi, 2012; Jones et al., 2015; Shim, 2008). However, these studies have not fully analyzed how latecomers manage to catch up in creative industries, which are seemingly the most difficult to catch up due to the tacit nature of symbolic knowledge needed in creative and cultural goods (Asheim and Coenen, 2005). Although there have been some studies studying creative industries from the perspective of global production networks or global value chains (Chalaby, 2016; Cohendet et al., 2018; Zhu et al., 2021), they barely reveal how latecomers succeed in catch-up in these industries. Since creative industries are becoming one of the growth engines of the new economy (Flew and Cunningham, 2013; James et al., 2006), especially those for-profit/ commercial ones, like fashion, film

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production, music, contemporary digital advertising, online content creation, investigating the catch-up of emerging economies in these industries is of increasing academic and practical relevance.

Moreover, existing catch-up studies tend to neglect the *internal heterogeneity* within a specific industry. This is problematic considering the increasing complexity of the production of many products nowadays. It could lead to too simplified generalizations if we study catch-up phenomena without decomposing the constituting segments of a specific industry. In other words, the generic, pan-industry analysis of the catch-up phenomenon fails to capture the differences of catch-up in different segments which are characterized by different knowledge bases. Therefore, intra-industry decomposition is necessary for understanding the overall catch-up phenomenon of a specific industry, as practitioners and policymakers can be informed about the different levels of catch-up in different segments, and hence more targeted strategies could be developed to solve the bottlenecks in certain segments. Another rationale to focus on intra-industry features is the increasingly complex knowledge bases underpinning different constituting segments. Previous research has argued that latecomers are more readily to catch up in industries characterized by a codified knowledge base rather than those characterized by a tacit one (e.g. Lee et al., 2009). These observations, however, overlook the complex and combinatorial knowledge bases that modern industries rely upon (Tsang and Tschang, 2012; Asheim et al., 2017; Grillitsch et al., 2018; Manniche et al., 2017).

Against this backdrop, this paper aims to fill these gaps by looking into the intra-industry knowledge bases of a creative industry—online game industry, in which China has become one of the leading players in terms of market share and the number of leading firms (Kim and Kang, 2021). Although the online game industry is similar to the IT industry in the sense that both industries are highly dependent on information technologies, it has a strong creative nature–the design of gameplay and system, creation of storylines, and artistic work all require intensive creative inputs (Gong and Xin, 2019). Moreover, the marketing strategies based on deep knowledge of local culture have also contributed much to the catch-up of Chinese firms (Tsang and Tschang, 2012; Chew, 2019; Kim and Kang, 2021). Building upon the "window of opportunity" framework (Lee and Malerba, 2017), this paper reveals how the combined responses in intra-industry segments with differentiated knowledge bases lead to the catch-up of creative industries in emerging countries. In doing so, we challenge the conventional approaches to characterize an industry with only one dominant knowledge feature (e.g., explicit vs. tacit) and contribute to the catch-up literature with a more in-depth and nuanced understanding of the impact of intra-industry knowledge bases and actor responses. It also generates policy implications for latecomers that they may not have to target catch-up of a whole industry with unified policy tools at first, but can start with more specific tools to support certain segments according to their knowledge bases, which could be more cost-effective.

The paper is organized as follows: in Section 2, the research on catch-up phenomena is critically examined. Special attention is paid to the "windows of opportunity" framework and knowledge bases that constitute different industrial sectors, upon which an analytical framework for this paper is elaborated. Section 3 introduces the online game industry in a catch-up context and our research design. Section 4 analyzes the windows of opportunity in the online game industry and the catch-up of Chinese game firms. The knowledge bases of the constituting segments of the online game production and marketing as well as the strategies taken by firms to catch up in these segments are presented in Section 5. Section 6 discusses the findings and Section 7 concludes.

2. Theoretical background and framework

2.1. Catch-up and windows of opportunity

The catch-up of latecomers has attracted the interest of scholars for decades (e.g., Johnson, 1982; Lee and Lim, 2001; Lee and Malerba, 2017). The most common catch-up trajectories have been labelled as path-following, path-skipping and path-creating (Lee and Lim, 2001). Path-following means that latecomers go along the same path taken by the forerunners with a shorter period of time. In the path-skipping scenario, latecomers follow the existing path but skip some stages. Latecomers can also develop their own path of technological development, hence, creating new technological paths.

Based on the early work on catch-up and on sectoral systems of innovation, Lee and Malerba (2017) proposed the "three windows of opportunity" framework, unravelling how some latecomers successfully caught up in the emergence of certain technological, demand and institutional windows. A technological window emerges when both latecomers and incumbents have the opportunity to leverage a newly introduced technology. The competencies required for the new technology may differ greatly from the ones established in incumbent leaders, providing an opportunity for latecomers to catch up quickly. A demand or market window opens when the leaders in the field do not pay enough attention to a new demand due to its relatively small size (niche market). If the new demand grows rapidly, it may provide opportunities for late entrants to catch up, as shown in the case of Chinese firms in automobile, mobile phones and telecommunication (e.g. Lee et al., 2009). Lastly, an institutional window may emerge as governments create an asymmetric environment in which foreign firms are placed at disadvantageous positions in terms of domestic market competition. Institutional windows have been prominent in high-tech industries in Korea and Taiwan (Lee and Lim, 2001; Wang, 2007), creative industries in Korea (Shim, 2008) and telecommunications in China (Lee et al., 2012).

According to Lee and Malerba (2017), the combination of the opening of windows and the responses of latecomers vis-à-vis their incumbent counterparts determines changes in industrial leadership and catch-up. The success of a latecomer in tapping those windows depends on the technological capabilities accumulated as well as on the readiness of supportive policies. In increasingly complex businesses, many latecomer companies may tend to adopt the strategy of simple rules, i.e. a few straightforward, hard-and-fast rules that define direction without confining it (Eisenhardt and Sull, 2001) to capture high pay-off opportunities in dynamic environments. This strategy allows companies to focus their limited resources on a few key strategic processes.

2.2. Knowledge bases and analytical framework

Though the "windows of opportunity" framework has been proven successful in explaining catch-up phenomena in several sectors in East Asia (Lee and Ki, 2017; Shin, 2017), thus far, it has paid little attention to the intra-industry differences of the investigated industries. The differentiated constituting segments of the industry, as well as the knowledge bases underpinning these segments, have not been considered. For a long time, the distinction between codified and tacit knowledge has been the dominant approach in differentiating a product's or a sector's knowledge base. Codified knowledge can be stored and transmitted to others through certain moveable media, while tacit knowledge is often learned by doing, using and interacting (DUI) and thus difficult to be transferred by means of words or other symbols. Whereas codified knowledge is more readily to travel across geographical distance, tacit knowledge is usually sticky to particular geographical contexts (Gertler, 2003). Consequently, it is less difficult for latecomers to catch up in sectors largely characterized by a codified knowledge base (e.g. PV and mobile phone) than those by a tacit one (e.g. wind turbine and watchmaking) (e.g. Lee et al. 2009; Hwang and Choung, 2014; Binz et al., 2020).

However, the dichotomy between codified and tacit knowledge has been criticized as being too simplistic to capture the dynamics of knowledge creation, learning, and innovation, which are becoming increasingly complex in the knowledge economy (Asheim et al., 2017). Addressing this gap, economic geographers have proposed the

differentiated knowledge bases (DKB) model (e.g. Boschma, 2018; Manniche et al., 2017; Asheim et al., 2017; Grillitsch et al., 2018). This model differentiates three knowledge bases including analytical (science-based), synthetic (engineering-based) and symbolic (arts-based) knowledge (Table 1). Analytical knowledge stems from abstract and universal scientific laws and theoretical understandings of natural or social systems. Synthetic knowledge is the novel way to combine and apply existing knowledge to solve practical and specific human problems. Symbolic knowledge rests on the creative process in project teams and is mostly concerned with creating socio-cultural meanings, desires, images, and symbols. Its generation needs human creativity to combine interpretation, cultural knowledge, and social values, implying a strong context-specific nature.

The DKB model has been a useful approach to identify the industrial dynamics over space (Boschma, 2018; Grillitsch et al., 2017). In general, studies have found that industries characterized by an analytical knowledge base are more footloose over space while those by a synthetic or symbolic knowledge base are more spatially sticky due to their high tacit content (e.g. Liu, 2013; Davids and Frenken, 2018). However, a simplified categorization of industry based on the dominant knowledge base, e.g., bioscience as an analytical knowledge-based industry, and food industry as a synthetic knowledge-based industry, is problematic as it risks overlooking the different knowledge bases in a sector's subsystems, development stages, or segments along the value chain (Grillitsch et al., 2018; Davids and Frenken, 2018). In this context, recent research has pointed out that the knowledge bases underpinning a certain industry might be combinatorial in nature, and are subject to change as the industry develops (Asheim et al., 2017). Understanding such combinatorial knowledge bases is particularly important for studying catch-up processes in modern complex technologies/industries, as the overall catch-up of such industries usually depends on the catch-up experiences observed in the differentiated constituting segments of the focal industry.

Furthermore, paying more attention to symbolic knowledge has been argued to be important for understanding modern knowledge dynamics (Martin and Moodysson, 2011), as it is increasingly contributing to the added value of many modern products and goods, both in manufacturing and creative industries (e.g., luxury cars, watches, cultural goods, fashion goods, etc.). The symbolic knowledge base is particularly valuable when it comes to creating uniqueness in products by product differentiation. Therefore, in order to better articulate the catch-up phenomena in those industries whose added value mainly come from symbolic knowledge (e.g., creative industries, high-end individualized manufacturing, and entertainment), a more nuanced differentiation of the different knowledge bases by DKB should be applied.

Based upon above reflections, we extend the "windows of opportunity" framework by giving due account to the intra-industry characteristics of the focal industry under investigation (Fig. 1). This new framework is developed due to the following rationales. First of all, the "window of opportunity" framework highlights the importance of industry landscape changes, under which latecomers take actions to seize the opportunities and transform/reconfigure their capacities. The capacities of latecomers in responding to the opportunities are highly conditioned by the knowledge base of the focal industry. Previous research tends to characterize an industry with one dominant knowledge base, which fails to acknowledge and explain that catch-up is not simultaneously happening within the value chain of an industry. Instead, catch-up usually starts from certain parts of the industry with less tacit knowledge bases and then, if successful, to the higher added-value parts with more complex knowledge requirements. This justifies why we need to look into the different segments of an industry and examine how their knowledge characteristics affect actors' response capabilities and catch-up outcomes. Second, "actor strategies and responses" sits in the middle connecting the windows of opportunity and the DKB of constituting segments. Following the "window of opportunity" framework, the new framework also acknowledges that it is the direct interactions between windows and actor responses that lead to specific catch-up outcomes. However, the new framework highlights that the DKB of different segments condition the actors' actions and capabilities in responding to the windows, and hence affect their catch-up outcomes.

Therefore, the three windows in this framework are seen as external settings that have general influence over the entire industry and the interactions between the three windows become a key issue of investigation. Instead of treating the focal industry as a whole, we decompose the constituting segments of the industry, examining differentiated knowledge bases and catch-up outcomes of the constituting segments. Based on the DKB of the different segments, as well as the perceived windows of opportunities, the strategies taken by relevant actors can be analyzed in a nuanced way. By doing so, we disentangle the catch-up of an industry into several closely related but distinct catch-up phenomena within the boundary of the industry.

Table 1
Differentiated knowledge bases: a typology.

	Analytical (science based)	Synthetic (engineering based)	Symbolic (arts based)
Rationale for knowledge creation	Developing new knowledge about natural systems by applying scientific laws; *know why*	Applying or combining existing knowledge in new ways; *know how*	Creating meaning, desire, aesthetic, qualities, affect, intangibles, symbols, images; *know who*
Development and use of knowledge	Scientific knowledge, models, deductive	Problem solving, custom production, inductive	Creative process
Actors involved	Collaboration within and between research units	Interactive learning with customers and suppliers	Experimentation in studios, project teams
Knowledge types	Strong codified knowledge content, highly abstract, universal	Partially codified, strong tacit component, more context specific	Importance of interpretation, creativity, cultural knowledge, sign values; implies strong context specificity
Importance of spatial proximity	Meaning relatively constant between places	Meaning varies substantially between places	Meaning highly variable between place, class and gender
Outcome	Drug development	Mechanical engineering	Cultural production, design, brands

Source: Asheim, Boschma, & Cooke, 2011, p.898.

3. Case study and research design

3.1. Online game as a for-profit creative industry

While the definitions of creative industries vary significantly in the literature (for an overview see Gong and Hassink, 2019), a contrast between the non-profit versus for-profit creative industries seems relevant to this paper. According to O'Connor (2015), the former is closer to the definition of cultural industries, and they are often organized around the *culturalization* of the economy and/ or the society. In this sense, the symbolic meanings of socioeconomic activities are highlighted. In contrast, for-profit creative industries are organized around the *economization* of the culture, meaning that entrepreneurs and firms purposely utilize cultural elements as economic resources for product creation (O'Connor, 2015). The online game industry is a typical for-profit creative industry that relies on both advanced information technologies and fashionable artistic styles (Tschang, 2007). Similar creative industries in this respect are film production, music production, fashion

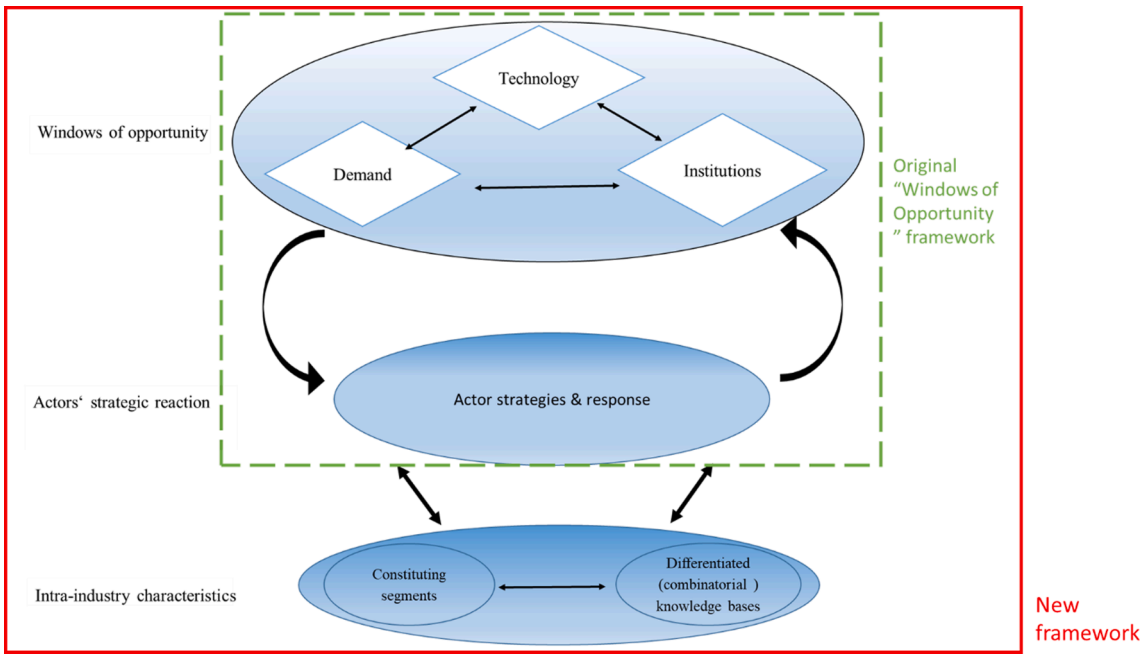


Fig. 1. An analytical framework for capturing catch-up phenomena within an industry.

design, online content creation, advertising, etc. Companies in such for-profit creative industries must compete with other offerings in the market to make profits. Therefore, they are subject to the market logics normally observed in other commodity markets. On the other hand, such industries are also different from pure manufacturing industries and their offerings where cost is one of the most important consumer considerations. For companies that produce for-profit creative products, their added value derives primarily from the symbolic knowledge that such products embody. It is such a unique combination of cultural elements and market logic that makes the for-profit creative industries interesting to investigate from a catch-up perspective.

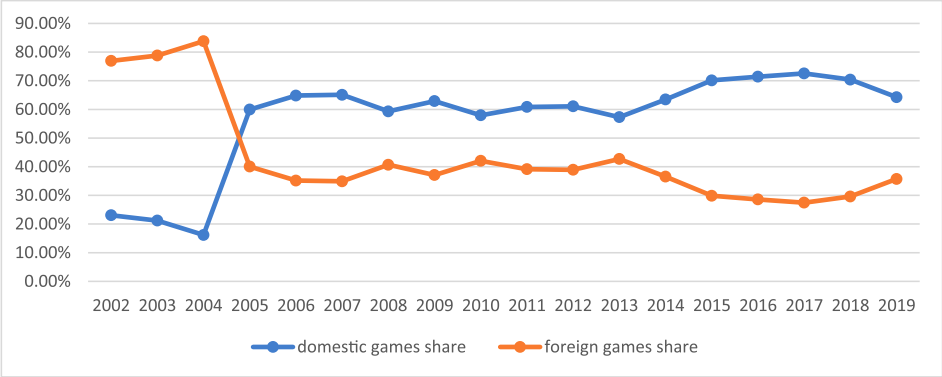
In producing a creative game, several "communities of specialists" are involved in the production processes: game designers, programmers, graphic artists, marketing and operational staff, etc. (Gong and Xin, 2019). All these communities, based on different knowledge bases (Plum and Hassink, 2014), are working on different parts of game production. Whereas game programming relies more on analytical (and sometimes synthetic) knowledge, the work of game design has a more synthetic nature, and artistic creation is much more dependent on symbolic knowledge. In addition to game production, market-oriented innovation and efficient interaction with players, including game promotion, marketing, distribution, and service, is another key factor contributing to the commercial success of online games (Ström and Ernkvist, 2014; Chew, 2019; Zhu et al., 2021; Kim and Kang, 2021). Given the diverse knowledge bases these communities rest upon, we decompose the industry into different segments, i.e., design and content creation, programming, artistic creation, and product marketing (Gong and Xin, 2019). The overall catch-up narrative of the online game industry is thus divided into several catch-up narratives in these four respective segments.

The formation of the Chinese video game market can be traced back to the early 1980s (Chew, 2019). However, a commercially successful online games industry only started in the early 2000s. During the last two decades, the industry has gone through a rapid development process with foreign and domestic games experiencing different growth rates over time. Fig. 2 shows the market shares of domestically- and foreign-developed games in China since 2002. Indigenous companies started to catch up with foreign firms, particularly Korean firms in 2005 when Chinese-developed games held a market share of 60 per cent. Globally, China had surpassed the US to become the leading country in terms of generated game revenues since 2015 (Newzoo, 2015). The importance of domestic markets in emerging economies for their catch-up has been well elaborated in the previous literature (see Lee et al., 2009, and Lema et al., 2020 for China; Guennif, and Ramani 2012, for India; for a general overview, see Malerba and Nelson 2011), this paper will focus on how Chinese domestic companies have managed to capture their domestic market, leading to a general catching-up process in the global market.

3.2. Methods

In general, the catch-up literature measures catch-up or industry leadership either by the relative share of global market or manufacturing volume, or technological capabilities (Lee and Malerba, 2017). The former can be easily observed through market or manufacturing data, while the latter is more difficult to measure and usually needs qualitative analysis from expert interviews and industry reports. To explore the catch-up process of Chinese indigenous firms in the online game industry as thoroughly as possible, we adopt a qualitative mixed method. This paper is mainly based on interview data acquired from in total of 55 interviews as well as many secondary data from various sources. The fieldwork lasted from July 2016 to April 2019. By talking to people working in the industry who have participated in and witnessed the catch-up process, we can zoom in to the different technological catch-up phenomena within the constituting segments of game production. In the beginning, ten expert interviews, lasting between one to two hours, were conducted with experienced industrial practitioners. After that, 45 in-depth semi-structured field interviews were conducted with different stakeholders including top company managers, senior executives, industrial governing authorities, scholars, etc. (Table 2). Issues covered in the interviews include (1) the knowledge bases and main tasks of the different segments of game production; (2) Identification of windows of opportunity over time; (3) Assessment on the degree of catch-up in different segments; and (4) Concrete catch-up strategies applied in different segments. All interviews were digitally recorded, transcribed and triangulated.

In addition, secondary data were collected from a wide range of sources including game media reports, gaming industry surveys, news, commentaries, and official websites of ministries in charge of regulating



Sources: CGIGC, CNNIC

Fig. 2. Market share of domestically and foreign-developed games in China. Sources: CGIGC, CNNIC.

Table 2
Basic information on interviewees.

Interview groups	No. of interviewees
Experts with > 10 years experience (EX)	10
Founders/managers of game companies (industry representatives) (IR)	31
• Layer design and content creation	7
Programming	9
• Artistic design	7
Marketing	8
Directors of intermediary organizations (IO)	5
Government officials (GO)	5
Scholars (SC)	4
Total	55

the industry in China (e.g. MOC, GAPP, MIT). This part of data is valuable as it provides additional information that can be triangulated with interviewees' statements on the developmental history as well as the catch-up process of the online game industry in China.

4. Windows of opportunity for the catch-up of the Chinese online game industry

Generally, the catch-up of the Chinese online game industry can be divided into three stages— the period dominated by foreign online PC games (before 2005), the rapid catch-up period (2005–2009), and the home market position maintenance and export period (2010-). This session examines the windows that mattered for different stages of catch-up.

4.1. Market/ demand window

The market window played a key role throughout the whole catch-up process. In the beginning, a huge, unexploited and underserved mass of potential gamers was one of the most prominent characteristics of the gaming market in China (Ernkvist and Ström, 2008). As gamers were less demanding and less experienced, early indigenous firms could survive and even seek a big fortune by publishing mediocre foreign games (Chew, 2019). The huge domestic demand has opened up a window of opportunity for early Chinese game companies whose overall innovation capabilities were rather weak (SC3).

During the period of rapid catch-up, the capital and technologies accumulated in the early stage facilitated the development of indigenous games. In this period, most of the Chinese-made games had a very strong copycat feature, because the in-house innovation capabilities of indigenous companies were still very poor. However, *"even such imitated games could still find a foothold in the huge (domestic) market because players were not demanding back then"* (IR10). Thanks to the demand from the large and low-end market, many domestic companies could not only survive by imitating popular games but also gradually developed their original R&D and technological capabilities (Kim and Kang, 2021).

When it comes to the third period, the shift of a large number of players from PC games to web browsers and mobile games has also contributed to the development of domestically produced online games on these two platforms (SC1, IO2, IR3, 14). The development of mobile games was due to people's increasing need for fragmented-time[1] entertainment (EX2, IR19). Overall, *"the huge and diverse Chinese domestic market was one of the most significant factors that have contributed to the whole catch-up process in China's online game industry"* (SC1).

4.2. Technological window

In the online game industry, technological windows were mainly discovered in its hardware technologies, i.e. the platforms (IR5). Online games are mainly based on three platforms—the PC end, web browser, and mobile devices. The shift of gaming platforms can be related to the catch-up phenomenon in the industry to a large extent. In the PC game era, for instance, "…*Chinese companies acted mainly as technological followers of game developers from other countries"* (EX3). However, this changed with the arrival of the web browser platform. As an industry representative stated:

While foreign game developers at that time gradually moved to developing 3D games, many Chinese game developers originated from the previous ISP industry such as37Games, 4399, etc.…mostly based in Guangdong, equipped with 2D game technology and talent, have clung to 2D games. (IR5)

The web platform thus provided a technological window of opportunity for Chinese developers to develop games that suited web browsers. While this platform was overlooked by the then-leading foreign firms, web gaming expanded steadily in China before 2015 (iResearch, 2016). In recent years, the most popular platform for online gaming shifted to mobile devices. In this period, Chinese firms were not only able to achieve a dominant position in the domestic market but also started to export more products to foreign countries (IR11). The knowledge and technology accumulation during the early periods have contributed to the competitive advantages of Chinese mobile games (SC1, GO2). Nowadays an increasing number of Chinese companies can produce decent games with enhanced graphics, combined genres and new narrative strategies that fit mobile devices.

[1] describes how people use their digital devices during free moments across the day.

4.3. Institutional window

Both formal and informal institutions affected the catch-up of the Chinese online game industry. Since its early days, digital games have been labelled as "electronic heroin" by Chinese media as youth internet/game addiction was always a severe problem in parents' and educators' view (Gong and Hassink, 2019). Tragedies such as youngsters' abnormal deaths in internet cafés, suicide, and junior delinquency were frequently reported (EX3, 6, GO1). Such a strong negative perception of digital games has resulted in a series of strong actions against the development of the industry by the central government. The main concern of the industry at this period was to reduce the negative impact of the internet and online games on youngsters. Strictly following the central government, a minimum of three permits issued by three different ministries was required (Ernkvist and Ström, 2008; Liu, 2013). Various stringent measures taken by the state also resulted in several self-claimed negative influence on the creativity and efficiency of game developers (IR5, IO1).

Nevertheless, after the first period of development, the online game industry had grown into a billion-RMB business. Meanwhile, public attitude toward online games has gradually changed because "*an increasing number of families could afford laptops or desktop computers at home and children could play games under the surveillance of their parents*" (EX3). The media started to report more positively on the huge economic potential of the industry and less on its negative social impact in the rapid catch-up phase (GO3). Impressed by the huge economic potential of the industry, governments at various levels also started to take a more positive attitude toward the booming industry (Zhu et al., 2021). They began to support the industry in various ways, labelled under the umbrella of "techno-nationalism" (Ernkvist and Ström, 2008), and more recently "neo-techno-nationalism" policies (Jiang and Fung, 2017). Such policies can be further divided into three types (EX4): restricting import (setting yearly quota for imported games), encouraging domestic development (preserving the domestic market for Chinese players), and supporting export (funding boutique games targeting foreign markets) (see Gong and Hassink, 2019). Taken together, these policies have opened the institutional window of opportunity for Chinese firms in the sense that "*a protected business environment has been created in which foreign firms are put in a disadvantageous position in the market*" (EX4).

4.4. Interactions between the windows

It is noticeable that the market window opened before the other two windows. The shift of market demand, for example, from PC to web and mobile games, has strongly affected the technological development of the mainstream gaming platforms in China over time. On the other hand, the opening of the market window also provided the opportunity for the institutional window to open, as it was only after the enormous market potential of the gaming industry was recognized by governments and society that more favorable institutional conditions were created (GO3). The improvement in the technological capabilities of domestic companies and the various institutional support provided by governments, on the other hand, have in turn played a positive role in expanding the share of Chinese games in both the domestic and global markets.

In terms of the mutual influence between the technological and institutional window, the relationship is more implicit. Although the state has implemented various techno-nationalism, or neo-techno-nationalism policies with the hope to create Chinese-made game engines (e.g., in the 863 High-tech Plan, 2003), their effects were limited, as Chinese game companies still continued to use game engines from industrialized countries because of cost-efficiency considerations.

5. Catch-up in game production capabilities: differentiated knowledge bases and firm strategies

In addition to market catch-up, Chinese game companies have also achieved some degrees of catch-up in their game development capabilities. Although Chinese companies were growing quickly in innovation capabilities, the strategies taken to build capabilities in the three segments of game production (i.e. design and content creation, programming, and artistic creation) and marketing showed different features (Table 3). Following Lee and Lim (2001), we differentiate three outcomes of catch-up in these segments, namely, path-following, path-skipping, and path-creating.

5.1. Catching up in game design and content creation capabilities

Game design, or game planning, is the process of designing the content and rules of a game. Game design mainly includes system design, story design, and level design. Working with producers, system design deals with the general concepts and rules and numerical analysis of a game to keep its system balance. Story designers build story contexts and tasks. They often cooperate with level designers to set e.g. the process, in-game difficulty, content, and forms of game levels (Gong and Xin, 2019). Good game design creates attractive goals, content, and incentives to stimulate players' passion for the game. To achieve this, game designers must have a deep understanding of potential players' tastes, purchasing behavior and cultural preference. It thus entails interactive learning processes with players and has a strong tacit and context-specific dimension. Therefore, it is characterized by both synthetic and symbolic knowledge bases.

In terms of catch-up outcome, Chinese game designers have not succeeded in capturing the design style of the forerunners (emphasizing creativity, playability, visual aesthetics, etc.), but have developed a different approach to game design (emphasizing commercialization and in-game purchase while maintaining a certain degree of creativity and playability). In this context, the strategy of simple rules was observed in Chinese companies' catch-up trajectories. As observed by Eisenhardt and Sull (2001), when the business landscape was very complex, companies usually need to simplify their strategies and develop a few simple rules to guide them through the chaos. This was in line with what we observed in the Chinese game design catch-up process.

The early Chinese game market was strongly dominated by imported games.…As a result, a simple rule to concentrate most of their strategic resources on the popular Chinese cultures has been the main strategy adopted by Chinese game designers to differentiate themselves from the forerunners. (IR5)

Thanks to their knowledge of Chinese popular culture and customer preferences, Chinese firms were able to create game content and storylines well received by Chinese players. Several designers mentioned that although the jobs of designers in Chinese and Western game studios looked similar from the description, their focus differed much (IR17, 23).

In Western games, the integrity of the game, the game experience, and playability are strongly emphasized in development; … while in Chinese games, due to pressure from employers and investors, the commercial side is emphasized more. (IR17)

This difference, according to several interviewees, was mainly due to the different consumption modes of Chinese and Western players (IR5, 16). While Western gamers were more willing to pay for the attractive storylines, good experience, and enjoyable gameplay of a creative game, most Chinese players were less willing to pay for these elements in the early years. Alternatively,

…many of the players in China preferred to purchase advanced in-game items (Kejin in Chinese) to beat rivals harder, and achieved in-game success through spending money. (IR5)

Based on the local knowledge of Chinese gamers' consumption preferences, domestic game studios grasped this opportunity by providing "*free-to-play, pay-to-win*" kind of games to the market (IR16). The success of this model in the market fundamentally influenced the approach to game design in China. After years of development, Chinese companies gained a lot of experience with this approach, and many

Table 3
Knowledge bases and Chinese firms' catch-up in different segments.

Segments	Knowledge bases	Firm strategies	Outcome
Design and content creation	Synthetic +++ Symbolic +++	Developing free-to-play and in-game purchase business model (alternative creation) ; Incorporating local culture or popular IPs in story design	Path-creating: Failed in grasping the forerunners' way of designing; but have developed a different approach to game design; taking advantage of Chinese popular online culture
Programming	Analytical +++ synthetic ++	Accessing open-source; Attracting programming talents; Modularization; Detailed division of labour;Technology purchase (e.g. engine)	Path-skipping: Catch-up in programming by building upon the experience of the global epistemic communities; Capable of producing high-quality games jointly or independently; But most firms still rely on foreign-developed game engines
Artistic creation	Symbolic +++ Synthetic ++	Learning from foreign incumbents as their OEMs or subcontractors; Detailed division of work; Attracting artists from animation and design.	Path-following: Getting closer to the global creative frontier, but still lagging behind global leaders in terms of originality and creativity
Marketing and commercialization	Symbolic +++ Synthetic +	Combing online and offline promotion; Leveraging the wide distribution channel in Net café. Close interaction with players; Targeted marketing based on deep local knowledge	Path-creating: Successful in outperforming foreign competitors in the domestic market

foreign companies adopted it and even established subsidiaries in China because Chinese designers had more experience in game design about online free-to-play games[2] (Jou, 2012).

In terms of game content, Chinese firms also adopted the strategy of simple rules (based on a deep understanding of local cultures, habits, consumption modes, etc.) to respond to the increasingly complex business environment. A senior IP manager of *Shanda Games* stated:

If one reviews all the popular games in the history of the Chinese online games industry, he/she might find that most of them were based on popular or well-known cultures. …in order to win safely in the market, large companies are basically doing two things with regards to IPs and content creation—they either buy popular IPs from other cultural and creative sectors, such as movies, online literature, animations, and novels; or they reuse their own old IPs created at single PC or online PC games age. (IR7)

5.2. Development in game programming capabilities

Game programming refers to the use of computer programming languages such as C++ and Java in producing video games. It requires substantial knowledge in programming languages and software engineering (Gong and Xin, 2019). From a perspective of knowledge source, most of this knowledge is codified and formalized and thus can be exchanged and learned from international open-source communities. Hence, programming knowledge has a high analytical nature, allowing developers to interact and collaborate at a far distance. While such analytical knowledge is important for the work of all programmers, for game engine programmers, who design the core component of an editable computer game system, they also need to synthesize work in areas such as modelling, lighting effects, animation, and physical system and are therefore dependent on synthetic knowledge (IR2, 6).

In terms of the outcome of catch-up, Chinese firms have managed to take a path-skipping catch-up in this segment. Several aspects of programming of the Chinese online game industry have reached the same level of sophistication as big foreign studios.

Nowadays, developing decent games is no longer a challenge for Chinese companies. … Particularly big studios such as Tencent, NetEase, Kingsoft, Perfect World, Shanda, etc., they are capable of making high-quality games due to their sufficient pools of in-house talent as well as financial resources. (IR20)

Given the overall analytical knowledge base in this segment, Chinese firms developed corresponding strategies to get access to and make use of international frontier knowledge to improve their programming capacities. First, game programmers in China largely relied on the open-source code developed by the global epistemic communities or websites such as GitHub. Therefore, it was relatively easier for Chinese companies to catch up in programming capabilities. Secondly, they attracted a large number of creative talents trained in computer sciences (IR2). When online games became popular in China, many talented programmers, and high-potential graduates from top universities, were attracted into the industry and thus contributed to the improvement of the programming capabilities of the industry (IR6). Thirdly, programming tasks were divided into detailed modules, so that each programmer can specialize in a few tasks and learn the skills needed for his/her work within a short period of time, which is referred to as "modular production" by interviewees (IR4, 12, 14).

Although all these factors have contributed to a strong improvement in the overall programming capability of Chinese game studios, in respect of game engines, most Chinese game developers were still using Western (particularly American) game engines instead of developing their own (SC4, IR1,16).

Technically, many Chinese game studios were able to develop a game engine, however, very few companies chose to do so because developing an engine often takes time and costs money, which was a major concern for the gaming business that runs on a "time is money" logic. (IR2)

Alternatively, most companies in China chose to use (or buy) the game engines available on the market.

5.3. Catching up in artistic creation capabilities

While programing is necessary for a game's functions, artistic creation is needed for the appearance of a game. In this segment, there are three main activities, original painting, 3D (scenes and characters), and others (e.g. movement, special effect, and user interface) (Gong and Xin, 2019). Original painting decides the style of game appearance and thus needs more artistic knowledge and individual creativity. 3D modelers design the details of scenes and characters, requiring a combination of both artistic skill and technical skill. Other activities like movement design need more technical experience. Nonetheless, even for a specific special effect (e.g. explosion), imagination is the key input to make the outcome not only physically logical but also artistically appealing. Judging from the number of employees involved, 3D modelling is the most dominant activity in this segment, since scenes and characters are the most needed elements in a game. Therefore, the knowledge base of this segment is mainly symbolic with some synthetic features.

This high symbolic content has rendered it difficult for Chinese firms

[2] The free-to-play business model originated in Korea.

to skip development stages. Nonetheless, according to the perceptions of the interviewed practitioners, Chinese companies have become increasingly closer to international leaders in those creative tasks.

We are not that lagging behind the world leaders in designing, and we are able to create a decent visual design for a game as long as there is already a similar game on the market…. But we are still not able to develop our own artistic style, because it really takes a lot of time to be artistically sophisticated, and paradoxically, saving time is the most important issue that concerns a Chinese game company. (IR13)

Even so, many interviewees were confident that they would be able to create novel and original artistic work someday as long as the value of creativity is more appreciated, and additional time is devoted to their work (IR21).

Similar to game programming, Chinese companies have also developed effective strategies for building up their artistic capabilities. First, many artists benefited from their previous experience of working as OEMs for foreign incumbents (IR13, 21). Particularly in the early 2000s, many foreign big studios (e.g. Ubisoft, Electronic Arts, etc.) outsourced their artistic work to Chinese companies for cost reasons (Tecent Institute of Games, 2016; Ystv.cn, 2016). During this period, many Chinese game artists were involved in the production of high-level big titles from abroad, and could thus accumulate original knowledge on artistic design and creation. As Chinese indigenous firms developed some capabilities to produce their own games, those artists who had been trained in OEMs of foreign games started to transfer this knowledge to the rest of the game artist community and thus contributed to an overall improvement in game artistic design capabilities (IR13).

Secondly, game companies made increasingly detailed divisions of labor within art teams (IR21). Instead of allowing a certain number of artists to work longer on a project, managers usually hired more artists to work specifically on different parts of art creation, so that a new game could be produced as quickly as possible. While detailed labor division improved the efficiency of artistic creation, some artists also complained that such a model was detrimental to creativity because more collaboration and negotiation rather than originality was required for artists (IR28). Third, many companies offered good and stable salaries to keep the best artistic workers. Although artistic professions are usually freelance and have an uncertain income, the strong growth of the online game industry has created many stable jobs with relatively high salaries for artists. As a result, many artists moved from animation and design to this booming creative industry (IR12).

5.4. Marketing online games in China: strategies and considerations

In addition to various degrees of catch-up in game production (illustrated from Sections 5.1–5.3), the marketing segment of the online games also featured prominently for the overall success of the Chinese game industry. Game marketing team in a company usually includes an operating group (e.g. arranging online and offline marketing activities), a business group (linking distribution channels), and a customer service group (e.g. answering customers' feedback). In accordance with Davids and Frenken (2018), the marketing process in the online game industry entails substantial symbolic knowledge. Producers need effective communication with existing and prospective users about new products' useful properties and unique experiences. All these would be impossible without being deeply enmeshed into the gamer community, knowing customers' preferences, as well as understanding the local consumption cultures. An online game is not a one-off good that is finished after development. Rather, it is constantly refined and expanded after its launch (Ström and Ernkvist, 2014). Hence, games are highly dependent on the operational service capabilities of companies, particularly after they are launched in the market.

In this respect, Chinese game companies have developed strong capabilities to strategically manage these services and have been successful in outperforming foreign competitors in marketing games in the domestic market, leading to a path-creating catch-up trajectory.

Started as publishers of foreign (in particular, Korean) games in the Chinese market, many domestic game firms accumulated rich experience in operating online games in China (Jiang and Fung, 2017). Similar to the observation of Chew (2019), many interviewees attributed the success of *Legend of MIR II* in China to the excellent operational strategies taken by its Chinese publisher—Shanda (IO1, IR5,11, 20). There were two complementing aspects in Shanda's marketing strategies: marketing games through online channels and adopting labor-intensive person-to-person promotion campaigns that targeted Internet café users (IR7). These marketing strategies have been broadly adopted by large Chinese game publishers in promoting their products later on (IR9).

In addition to game studios publishing foreign games, some commercially successful companies, such as NetEase, Kingsoft, etc., relied on a combination of marketing and game content localization strategies to attract gamers. Localized and targeted marketing turned out to be a prominent factor contributing to the success of most online games in the market.

The operational service capability of Chinese online game companies to

…analyze data, maintain and update servers, prevent cheating and private servers, rapidly respond to market feedback, organize online- and offline- events…had the effect of increasing the overall competitiveness of Chinese game companies. (IR7)

In addition to these strategies, a successful operation also depended on the management of the community to attract new players and increase the retention of existing players. Online game companies, therefore, needed to maintain a high level of customer service and provide constant support in relation to payments, technical issues, and complaints. Game publishers needed to deliver a community service and a sense of belonging to players to keep them from switching to competing games. Consequently, games were updated regularly with new content, features, and services in the form of game expansion packs, virtual events, and new game items in accordance with users' requirements.

6. Discussion

As Fig. 3 summarizes, this paper maps the interaction between windows of opportunity, intra-industry characteristics, and actor responses in the catch-up of China's online game industry. First of all, similar to many catch-up stories, the opening of windows of opportunity constitutes a pivotal and favourable selection environment for the catch-up of latecomer game firms in China. However, whereas many catch-up studies highlight the change of technological trajectory as the most important window for latecomers (Hwang and Choung, 2014), our case has shown that a large and growing domestic market is the key to catch-up of Chinese online game firms. To a large extent, it is the fast growth of the game market that paves the way for the improvement of domestic technological capacities and the change of institutional environment, which in turn provide positive feedback to the market growth. Therefore, while many small market economies (e.g., South Korea, Taiwan, and Singapore) mainly rely on export-oriented strategy for technological catch-up, other emerging countries with large domestic markets (e.g., China, India, Brazil, etc.) can utilise their huge market to achieve a different pathway (Kim and Kang, 2021). This is not unique in to online game industry but is also frequently observed in industries such as automobiles, mobile phones, renewable energies, and artificial intelligence (Mu and Lee, 2005; Binz et al., 2020; Yu et al., 2022). Taking this advantage, firms in these countries can leverage the changes in technological paradigm and domestic institutional protection to outperform their foreign counterparts. Importantly, as showed in many other industries and in other countries, supportive institution arrangements at home often enable domestic firms in latecomer contexts to improve their technological and cultural capacities (e.g., Rajadhyaksha (2003) in India's movie industry; Parc (2017) on Korean cultural industries, Yoshimatsu (2005) on Japan and Korea's gaming industry). In specific to

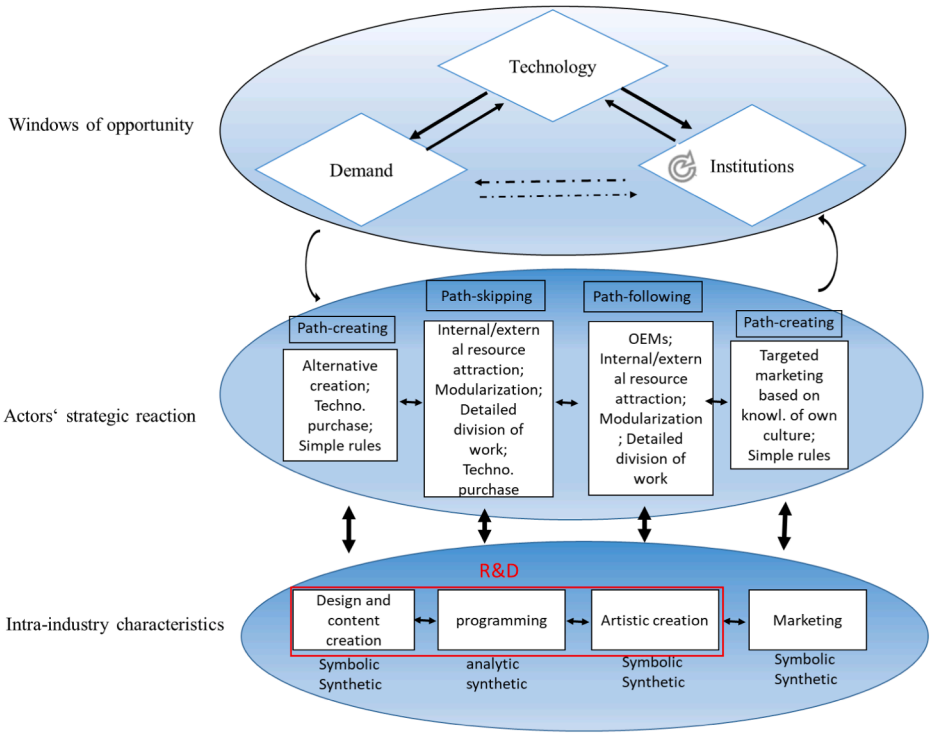


Fig. 3. Mechanisms of catch-up in the Chinese online games industry.

China's game industry, such a protective institutional environment seems to help China to avoid following the failed "market for technology" pathway as shown in the automobile industry (Mu and Lee, 2005). Nonetheless, this is not without side effects. As Zhu et al., (2021) argue, current institutional arrangements and market rules have resulted in a polarized industry structure where some giant publishers and distributors dominate the industry while small developers are marginalized with little profit and incentives for technological development. This could be detrimental to China's future position in the global value chain.

Secondly, instead of viewing the online game industry as a unitary industry characterized by an explicit knowledge base (Kim and Kang, 2021), we acknowledge the complex bases of the industry and examine whether and how differentiated knowledge bases affect actor responses and catch-up performance in different constituting segments. Scholars have increasingly realized the added value to differentiate the complex innovation vs. valuation models within certain industries or sectors (Binz and Truffer, 2017), but so far, not many studies have focused on how the differentiated knowledge bases underpinning different segments of the value chain may provide different opportunities for latecomers' catch-up. In practice, it is more often that a country only catch-up in certain parts of an industry rather than in the whole value chain. By decomposing the online game industry into main segments, we are able to see the constraints and opportunities of latecomers in these segments and, therefore, generate more cost-effective policy measures to target segments with the most catch-up potentials. As our case exemplifies, these constraints and opportunities are deeply shaped by the knowledge bases of the different segments of an industry. We argue that the dichotomy of codified and tacit knowledge is too simple, especially when it comes to the creative industries where symbolic knowledge has a major role to play. Even in the individual constituting segments, we find that the knowledge bases of game production are usually a mix of at least two types of knowledge, with different levels of codifiability. Such combinatorial knowledge bases have conditioned actor responses and hence the catch-up outcomes in the different segments (i.e. path skipping, following and creating). Therefore, in order to better understand the catch-up phenomena in those industries whose added values mainly come from symbolic knowledge (e.g. creative industries, cultural goods, high-end individualized manufacturing such as luxury cars and watches), a more nuanced differentiation of knowledge bases by DKB can be very beneficial.

Thirdly, given the windows of opportunity and differentiated knowledge bases in game production, Chinese game firms have responded in strategic ways to catch up with incumbent leaders. In catching up in their programming and artistic creation capabilities, most firms in China adopted strategies that have been frequently used in traditional manufacturing industries such as modularization, detailed division of labor, purchase of core technology, and attraction of creative workers. Besides, the increasingly available open-source codes and artistic materials on the Internet also made the catch-up of Chinese companies easier in such segments. The catch-up process in game design and content creation, however, is more complex. While Chinese firms failed to learn the forerunners' way of game design, they have developed a different approach to game design with regard to the payment model–the "free-to-play" model (alternative creation). Chinese game developers have developed such an alternative game design, primarily based on the strategy of simple rules. Such simple rules are based on a deep understanding of the local culture, tastes and preferences of the targeted consumers. In industries where symbolic knowledge and cultural elements are a very important part of value creation, such simple rules are extremely effective in differentiating the products of latecomers from the established, more mature offerings of global incumbents because they strike a chord with consumers (in terms of deep cultural understanding and appreciation). As a result, strategies of buying popular Internet IPs, or reusing their previous well-known IPs, have become the primary way in creating storylines and content to meet the interest of their target customers. In addition, the catch-up of Chinese online game firms is also the result of their ability to turn their operational service skills and knowledge of the local market into a competitive advantage (Ström and Ernkvist, 2014). Targeted marketing based on a deep knowledge of the local market, consumer culture and customer tastes turned out to be an indispensable ingredient of the success of most online games in China.

Overall, the symbolic knowledge base underlying the various segments of game production, and the combinatorial nature of the knowledge bases for game production and marketing, have left Chinese game developers an ample room to adopt different strategies, and hence led to different catch-up outcomes in different segments. In comparison to the conventional catch-up strategies observed in mass-production manufacturing sectors, latecomers in those sectors whose added value relies strongly upon symbolic knowledge base might have the opportunity to leapfrog and/or even develop completely different market tastes and thus technological paths by adopting the strategy of simple rules based on a deep understanding of their own cultures.

7. Conclusions

Expanding the windows of opportunity framework developed by Lee and Malerba (2017), this paper pays attention to how the knowledge base underlying different segments influence intra-industry characteristics and firm strategies in response to catch-up windows. Overall, this paper makes novel contributions to the catch-up literature. First of all, by disentangling the constituting segments of game production, and examining the differentiated combinatorial knowledge bases underpinning the different production segments, we subdivided the catch-up of an industry into several closely related but distinct catch-up phenomena within the boundary of the industry. Second, although the DKB approach has been argued to be important to explain industrial dynamics in space, it is rarely applied in catch-up studies. In this paper, we display that the DKB underpinning all segments of game production was combinatorial in nature. Depending on the combinations of DKB, the strategies that were efficient to catch up in different segments also tended to differ strongly. While the strategies adopted to catch up in segments characterized by analytical and synthetic knowledge bases (e.g. programming) were similar to those observed in traditional manufacturing sectors; the strategies taken to improve game design and content creation, as well as marketing capabilities, which relied on symbolic and synthetic knowledge, were of a different nature. What is unique in these segments, however, is that the strategy of simple rules based on deep knowledge of local culture and customer tastes has been adopted in nearly all of these segments to differentiate their products from those provided by foreign rivals.

Therefore, we believe that the introduction of the DKB approach to catch-up literature will not only enable us to explore in detail the catch-up processes in many of the modern technologies and industries that are characterized by combinatorial knowledge bases; it will also contribute to the decomposition of complex catch-up phenomena of an industry into several smaller catch-up stories within the complex industry, and thus lead to better policy implications for latecomers. In catching up in symbolic-knowledge-based industries, once latecomers have grasped the relevant knowledge (e.g. analytical and/or synthetic knowledge) through conventional catch-up strategies, the more tacit symbolic knowledge based on their social and cultural assets may stand out as a point of differentiation in the highly competitive consumer market. In this paper, the differentiation of knowledge bases in different segments is based on qualitative judgement of industry experts. Future research could contribute in the methods to differentiate knowledge bases with more quantitative and standardized approaches. Such methods will help to facilitate comparisons among industries and lead to more generalized implications.

CRediT authorship contribution statement

Huiwen Gong: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Zhen Yu:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Robert Hassink:** Writing – review & editing, Supervision.

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.

Data availability

Data will be made available on request.

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