Asia Pac J Manag (2018) 35:639–669
https://doi.org/10.1007/s10490-018-9566-z

REVIEWS

Technological catch-up by east Asian firms: Trends, issues, and future research agenda

Yuzhe Miao[1] · **Jaeyong Song**[2] · **Keun Lee**[3] · **Chuyue Jin**[4]

Published online: 3 April 2018

Abstract This paper reviews extant research on technological catch-up of East Asian firms, which has recently emerged as an important issue. We review 76 articles on technological catch-up in the East Asian context published in 17 journals over 23 years (1995–2017), covering the academic disciplines of strategic management, international business, entrepreneurship, technology and innovation management, and economics. Based on a systematic analysis of this literature, we develop an overarching framework to this topic. We then identify the major gaps in the literature and suggest areas for future research on technological catch-up of Asian firms.

Keywords Technological catch-up · Latecomer · Incumbent · East Asia · Leapfrogging · Innovation · Imitation · Laggard

This paper is supported by the Institute of Management Research and the Center for Global Business and Research at Seoul National University.

✉ Jaeyong Song
jsong@snu.ac.kr

Yuzhe Miao
yzmiao@skku.edu

Keun Lee
kenneth@snu.ac.kr

Chuyue Jin
chuyuej@hotmail.com

[1] Sungkyunkwan University, Jongno-Gu, Seoul 110-745, South Korea

[2] Graduate School of Business, Seoul National University, Shillim Dong, Seoul 151-916, South Korea

[3] Department of Economics, Seoul National University, Shillim Dong, Seoul 151-916, South Korea

[4] Graduate School of Business, Seoul National University, Shillim Dong, Seoul 151-916, South Korea

In most technology-intensive industries, American, European, and Japanese firms are the leaders. Given their high technological capabilities, firms from these countries have been recognized as global technology incumbents for many years. Firms in emerging Asian economies are behind these leading firms in most technological fields. However, in recent decades, major firms in Asian economies such as those in South Korea, Taiwan, and China have rapidly enhanced their own technological capabilities, catching-up with or even leapfrogging over incumbents from advanced countries in certain technological fields and industries.

As powerful proof of this shift, we have only to look at patent records from the US Patent and Trademark Office (USPTO). Patent records show a distinct trend since the end of the 1970s, at which time Asian economies had been granted very few patents However, the number of patents has increased exponentially in three East Asian countries since the late 1980s in Korea and Taiwan and since the turn of the twenty-first century in the case of China (see Fig. 1). Over time, some Asian companies (e.g., Samsung, LG, and Hyundai-Kia Motors in Korea, MediaTek and AUO in Taiwan, and Huawei in China) have shown that under certain conditions, technological laggards can overcome disadvantages and use latecomer-specific advantages to catch-up with incumbent, first-mover firms in developed countries.

As technological catch-up of Asian laggards has become more and more prevalent, extensive economic research has been conducted on the factors influencing catch-up at the country and industry levels (e.g., Hu & Mathews, 2005; Lee & Lim, 2001; Park & Lee, 2006). At the same time, strategic management and international business scholars have studied how Asian technological laggard firms have successfully competed with incumbents in advanced countries at the firm level (Cho, Kim, & Rhee, 1998; Fan, 2006; Lee & Lim, 2001; Li & Kozhikode, 2008; Mathews, 2002; Mathews & Cho, 1999; Park & Lee, 2006). Many studies have devoted attention to emerging companies from Asian countries because the rapidly developed technological capabilities of these national champions have enabled them to close the technological gap with incumbent leaders in advanced and industrialized economies. For example, Samsung Electronics of South Korea captured 24.8% of the global smartphone market in 2015 compared to 17.5% of the market occupied by Apple. The company has emerged as a leader in the global electronics

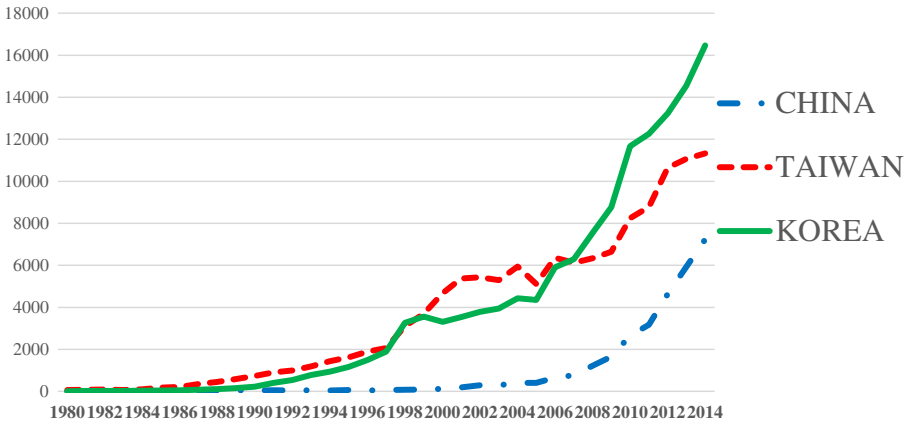

Fig. 1 Patents granted by the USPTO from 1963 to 2014 (China, Korea, Taiwan)

industry, outperforming Japanese companies such as Sony (Khanna, Song, & Lee, 2011; Song, Lee, & Khanna, 2016). Most recently, Huawei of China emerged as a leader in the telecommunications equipment industry, surpassing Ericsson and Cisco Systems in sales. The incredible success of these Asian companies in terms of technological catch-up has gained attention from practitioners and academics all over the world.

However, it is difficult to generalize findings based on these studies. Existing literature employed various theories ranging from Schumpeterian economics to the resource-based view, from a learning perspective to an institutional view. These studies also used various methodologies including case studies, empirical analyses, and simulations to examine technological catch-up at different levels of analysis.

Most extant studies lack comprehensive frameworks and systematic and rigorous analyses. As a result, our understanding of why some previous laggards manage to catch-up successfully while others fail to do so is still limited. Thus, we believe it is timely to review extant studies of technological catch-up critically and offer a comprehensive framework by synthesizing various conceptual and empirical approaches. This review also provides practical implications for policy makers in emerging countries. In this paper, we initially review extant research on technological catch-up of Asian firms. In the process of searching for relevant papers, we discovered that most research has been focused on East Asian economies, especially Korea, Taiwan, and China. This is understandable given that firms from these countries are catching-up quickly with firms in developed countries. Therefore, we include studies representative of technological catch-up in the East Asian context (especially Korea, China, and Taiwan) in this study.

We analyze studies on technological catch-up of Asian firms in terms of theory, data, and methodology. We found a lack of systematic theoretical background in existing literature, especially studies in the area of management. We also found that most firm-level studies used case analysis, which makes it difficult for authors to generalize findings to other contexts. Recently, however, researchers began to use patent data to examine technological catch-up. We therefore identified key factors or boundary conditions that influence successful catch-up based on findings of these existing studies.

After an extensive review of the extant literature, we provided an integrated framework in order to link these extant studies and synthesize their findings. We classified the antecedents of technological catch-up in existing studies into different categories in terms of external and internal factors. We also identified and discussed major issues for each category. We then pinpointed various research gaps for each issue and suggested agendas for future research. We called for future research that can examine technological catch-up in multi-disciplinary studies using several methods, using the contingency viewpoint to examine how different factors interact with each other to influence technological catch-up in different contexts.

Scope and method of literature review

Defining technological catch-up

The concept of catch-up has a long history, including the famous work of Gerschenkron (1962). It was popularized first among development economists when Abramovitz's

(1986) influential article ("Catching up, forging ahead, and falling behind") was published. Nowadays, economic scholars tend to define catch-up as a narrowing of the gap in productivity and income between a leading country and a lagging country (Fagerberg & Godinho, 2005). It has also been described as a process by which a late-developing country narrows the income gap ("economic catch-up") and increases its technological capability ("technological catch-up") vis-à-vis a leading country (Odagiri, Goto, Sunami, & Nelson, 2010). These studies suggest that catch-up may be measured using several indicators such as income, productivity, and technological capability according to the purpose of the research (Lee, 2013). Our primary focus is on the technological aspects of catch-up, defined as substantial improvement of technological capabilities by firms from technologically lagging countries in their process of closing the gap with incumbents in advanced countries, thereby approaching the global technological frontier. In some cases, the process is still ongoing as latecomers are gaining ground vis-à-vis incumbents or leaders; however, cases do exist of already finished or completed catch-up, which is equivalent to convergence or overtaking. In this review paper, we take a broad and flexible approach considering both the consequences and ongoing process of technological catch-up. For example, we include articles that investigate not only cases of aborted catch-up, but also cases of leapfrogging, the latter of which can be considered as one variant of catch-up strategy, possibly leading to different outcomes. We believe this broad definition of technological catch-up facilitates understanding of this research topic.

In this study, we also investigate the linkage between timing of economic and technological catch-up and market catch-up, hypothesizing that technological catch-up may precede or lead to market catch-up (Lee & Lim, 2001). In the past, many stories of catch-up in Asia were about low-cost-based catch-up in terms of market shares rather than technological capability-based catch-up. However, more recently, Asian catch-up has involved firms equipped with advanced technologies allowing them to overtake industry forerunners.

Researchers have studied technological catch-up in two distinct but related disciplines: management (at the firm level) and economics (at the country or industry level). We first review studies from different disciplines, showing trends in theoretical background, the nature of the used data, and the chosen research methodologies. Then, we discuss the main findings in the literature, identifying key factors or boundary conditions that affect more or less successful catch-up, trying to answer the question of why some firms are able to close the technological gap with incumbent leaders or even overtake global leaders, while other laggard firms are not. This review of studies from diverse theoretical perspectives on catch-up at both the macro and micro levels will help researchers in management understand the phenomenon of technological catch-up of East Asian laggard firms more comprehensively.

Research methods

We employed a series of scientific research methods for a systematic literature review (Gaur & Kumar, 2018). First, to set the stage for this review of the literature, we selected major journals in the fields of economics and management, where catch-up is of greatest interest. To ensure complete coverage of technological catch-up literature across different scholarly fields, we examined

78 journals ranked as above level three in the ABS journal lists from seven areas: general management, innovation, international business and area studies, organization studies, strategy, entrepreneurship and small business management, and economics. We report the specific journals we searched in Table 1.

We searched for articles using keywords based on the definition of catch-up and related topics. Because technological catch-up is defined as substantial improvement of technological capabilities by firms from technologically lagging countries in the process of closing the gap with incumbents in advanced countries, thereby approaching the global technological frontier, we selected the following keywords to search articles: catch(ing)-up, laggard, latecomer, follower, first (second) mover, leapfrogging, springboard, technological upgrading, learning, knowledge transfer, knowledge sourcing, and imitation. We also used keywords related to geography in East Asia and Asia. We first identified articles with these words appearing in the title, abstract, or subject terms in the EBSCOhost, JSTOR, Wiley-Blackwell, ProQuest, ScienceDirect, and SAGE Journals Online databases. This searching process initially generated 642 articles. However, among these articles, many were not associated with technological catch-up. Therefore, we narrowed our search further, reading only those articles whose topics were closely associated with technological catch-up in the Asian context, excluding those unrelated to this topic. The publication years of these articles ranged from 1995 to 2017. This search process generated 76 articles in total. The following analysis is mainly based on these 76 articles.

Results of literature review

Overall trends

Figure 2 shows the distribution of the selected publications by year. From the figure, we noted that the number of articles on this topic increased continually since the 1990s, especially after 2010. The distribution of these articles is highly skewed across journals. Table 2 lists where and when the 76 articles were published. Table 3 summarizes the research disciplines in which the articles were published. Most of these articles were published in the areas of economics and management of innovation. Specifically, about 43.24% of these studies were published in economics journals, 40.79% in innovation journals, 9.21% in international business studies journals, 2.61% in organization studies journals, 2.61% in strategy journals, and 1.32% in general management journals. This suggests that catch-up-related research is still needed in other disciplinary areas such as international business, organizational strategy, and others.

We found that most of the articles focus on the East Asian context, especially Korea, Taiwan, and China. Technological catch-up studies focusing on these three East Asian countries account for more than 81% of the selected articles in our literature review (see Table 7). This is understandable given the dramatic economic growth in these countries. Thus, in the review process, we focus on the East Asian context, especially Korea, Taiwan, and China. In the following section, we analyze the articles in terms of theoretical background, research methodology, and main findings.

Table 1 Journals searched for relevant articles

General management	Innovation	International business and area studies	Organization studies	Strategy	Entrepreneurship and small business management	Economics
Academy of Management Journal	Journal of Product Innovation Management	Journal of International Business Studies	Organization Science	Strategic Management Journal	Entrepreneurship: Theory and Practice	American Economic Review
Academy of Management Review	Research Policy	Journal of World Business	Organization Studies	Global Strategy Journal	Journal of Business Venturing	Journal of Political Economy
Administrative Science Quarterly	R&D Management	Asia Pacific Journal of Management		Long Range Planning	Strategic Entrepreneurship Journal	Quarterly Journal of Economics
Journal of Management	Technovation	International Business Review		Strategic Organization	Entrepreneurship and Regional Development	Review of Economic Studies
British Journal of Management		Journal of International Management			Family Business Review	Economic Journal
Journal of Management Studies		Management and Organization Review			International Small Business	Journal International Economic Review
Academy of Management Perspectives		Management International Review			Journal of Small Business Management	Journal of Economic Literature
California Management Review					Small Business Economics	Journal of Economic Perspectives
European Management Review						Journal of Economic Theory
Harvard Business Review						Journal of International Economics
International Journal of Management Reviews						Journal of the European Economic Association
Journal of Business Research						RAND Journal of Economics
Journal of Management Inquiry						American Economic Journal: Applied Economics
MIT Sloan Management Review						American Economic Journal: Economic Policy
						Annual Review of Economics
						Brookings Papers on Economic Activity
						Cambridge Journal of Economics
						Canadian Journal of Economics
						Development and Change
						Economic Development and Cultural Change
						Economic Inquiry
						Economic Policy
						Economic Theory
						Economica
						Economics Letters
						European Economic Review

Table 1 (continued)

General management	Innovation	International business and area studies	Organization studies	Strategy	Entrepreneurship and small business management	Economics
						IMF Economic Review (formerly IMF Staff Papers with ISSN 1020–7635) International Journal of Industrial Organization Journal of Comparative Economics Journal of Development Economics Journal of Economic Behavior and Organization Journal of Economic Dynamics and Control Journal of Economic Growth Journal of Industrial Economics Oxford Economics Papers Review of Economic Dynamics Scandinavian Journal of Economics World Bank Economic Review

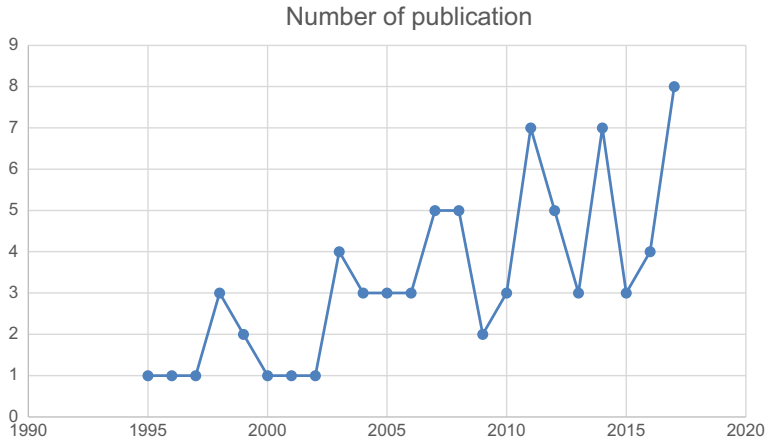

Fig. 2 Overall trends by year of publication

Theoretical background

Table 4 shows the theoretical foundations of the articles included in this study. Given that a substantial number of studies (58%, 44 articles) did not specify the theories employed, we suggest that future researchers should attempt to strengthen the theoretical foundations in this research field. Among studies in which theories were specified, most studies (13% of all articles that we reviewed) adopted theories of learning, absorptive capacity, and technological capability. About 11.8% of studies were written based on Schumpeterian economics, including the neo-Schumpeterian economic view (3.95%), the sectoral innovation system perspective (5.26%), and the global system view (2.63%). About 5.3% of articles used evolutionary theory as the main theoretical foundation. Other theories included the timing of entry and the latecomer advantage perspective (3.95%) and the resource- or knowledge-based view (3.95%). Finally, a few studies used cluster theory, the theory of agglomeration economies, or institutional theory, which we classified as a miscellaneous category (3.95%) in this paper.

From this review of the theoretical background of these articles, we found that the theoretical contribution of existing studies regarding technological catch-up is still weak especially in the area of management compared to that of economics, where the theories of catch-up are relatively well developed. A substantial number of management studies lacked a clear theoretical background; therefore, their theoretical contributions are uncertain. Thus, it is important for future researchers to develop a systematic theory of technological catch-up.

Research method

Research methodologies

We also identified the major research methodologies used in each study and classified them into four categories: qualitative, quantitative, simulation, and conceptual. Some researchers used multiple research methodologies. For instance, a few articles used case analysis, but supplemented with a simple data analysis. In such cases, we identified the

Table 2 Articles reviewed in this study

No.	Title	Year	Author	Journal name
1	East Asian latecomer firms: Learning the technology of electronics	1995	Hobday, M.	World Development
2	Internationalization and competitive catch-up processes: Case study evidence on Chinese multinational enterprises	1996	Young, S., Huang, C.-H., & McDermott, M.	Management International Review
3	The dynamics of Samsung's technological learning in semiconductors	1997	Kim, L.	California Management Review
4	Catching-up, crisis and industrial upgrading: Evolutionary aspects of technological learning in Korea's electronics industry	1998	Ernst, D.	Asia Pacific Journal of Management
5	Latecomer strategies: Evidence from the semiconductor industry in Japan and Korea	1998	Cho, D., Kim, D., & Rhee, D. K.	Organization Science
6	Crisis construction and organizational learning: Capability building in catching-up at Hyundai Motor	1998	Kim, L.	Organization Science
7	Building technological capability for industrialization: Analytical frameworks and Korea's experience	1999	Kim, L.	Industrial and Corporate Change
8	Combinative capabilities and organizational learning in latecomer firms: The Case of the Korean Sem	1999	Mathews, J. A., & Cho, D.-S.	Journal of World Business
9	Transition of latecomer firms from technology users to technology generators: Korean semiconductor firms	2000	Choung, J.-Y., Hwang, H.-R., Choi, J.-H., & Rim, M.-H.	World Development
10	Technological regimes, catching-up and leapfrogging: Findings from the Korean industries	2001	Lee, K., & Lim, C.	Research Policy
11	Competitive advantages of the latecomer firm: A resource-based account of industrial catch-up strategies	2002	Matthews, J. A.	Asia Pacific Journal of Management
12	Innovation, technological regimes and organizational selection in industry	2003	Kim, C.-W., & Lee, K.	Industrial and Corporate Change

Table 2 (continued)

No.	Title	Year	Author	Journal name
	evolution: A "history friendly model" of the DRAM industry			
13	Cross-over, thresholds, and interactions between science and technology: Lessons for less-developed countries	2003	Bernardes, A. T., & Albuquerque, E.	Research Policy
14	Integration model of technology internalization modes and learning strategy: Globally late starter Samsung's successful practices in South Korea	2003	Gil, Y., Bong, S., & Lee, J.	Technovation
15	The developmental path of networking capability of catch-up players in Korea's semiconductor industry	2003	Cho, H.-D., & Lee, J.-K.	R&D Management
16	Catching up or standing still?: National innovative productivity among 'follower' countries, 1978–1999	2004	Furman, J. L., & Hayes, R.	Research Policy
17	Approaching the innovation frontier in Korea: the transition phase to leadership	2004	Hobday, M., Rush, H., & Bessant, J.	Research Policy
18	Technological learning in China's colour TV (CTV) industry	2004	Xie, W.	Technovation
19	National innovative capacity in East Asia	2005	Hu, M.-C., & Mathews, J. A.	Research Policy
20	Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China	2005	Mu, Q., & Lee, K.	Research Policy
21	The transformation of competitive advantage in East Asia: An analysis of technological and trade specialization	2005	Uchida, Y., & Cook, P.	World Development
22	Linking the technological regime to the technological catch-up: Analyzing Korea and Taiwan using the US patent data	2006	Park, K.-H., & Lee, K.	Industrial and Corporate Change
23	Entry and competitive dynamics in the mobile telecommunications market	2006	He, Z.-L., Lim, K., & Wong, P.-K.	Research Policy
24		2006	Fan, P.	Technovation

Table 2 (continued)

No.	Title	Year	Author	Journal name
	Catching up through developing innovation capability: Evidence from China's telecom-equipment industry			
25	Public research institutions and economic catch-up	2007	Mazzoleni, R., & Nelson, R. R.	Research Policy
26	Enhancing the role of universities in building national innovative capacity in Asia: The case of Taiwan	2007	Mathews, J. A., & Hu, M. C.	World Development
27	Biotechnology and nanotechnology: Science-based enabling technologies as windows of opportunity for LDCs?	2007	Niosi, J., & Reid, S. E.	World Development
28	Counterfeit, imitation, reverse engineering and learning: Reflections from Chinese manufacturing firms	2007	Minagawa, T., Trott, P., & Hoecht, A.	R&D Management
29	From technological catch-up to innovation-based economic growth: South Korea and Taiwan compared	2007	Wang, J.-H.	Journal of Development Studies
30	Knowledge management and innovation strategy: The challenge for latecomers in emerging economies	2008	Li, J., & Kozhikode, R. K.	Asia Pacific Journal of Management
31	Catching up and academic institutions: A comparative study of past national experiences	2008	Mazzoleni, R.	Journal of Development Studies
32	Breakthrough? China's and India's transition from production to innovation	2008	Altenburg, T., Schmitz, H., & Stamm, A.	World Development
33	Innovation in product architecture—A study of the Chinese automobile industry	2008	Wang, H.	Asia Pacific Journal of Management
34	The more interactive, the more innovative? A case study of South Korean cellular phone manufacturers	2008	Hu, J.-L., & Hsu, Y.-H.	Technovation
35	Can Taiwan's second movers upgrade via branding?	2009	Chu, W.-w.	Research Policy

Table 2 (continued)

No.	Title	Year	Author	Journal name
36	Learning through informal local and global linkages: The case of Taiwan's machine tool industry	2009	Chen, L.-C.	Research Policy
37	Sectoral systems of innovation and productivity catch-up: determinants of the productivity gap between Korean and Japanese firms	2010	Jung, M., & Lee, K.	Industrial and Corporate Change
38	A hidden cost of strategic alliances under Schumpeterian dynamics	2010	Lee, J., Park, S. H., Ryu, Y., & Baik, Y.-S.	Research Policy
39	National model of technological catching up and innovation: Comparing patents of Taiwan and South Korea	2010	Wang, J. H., & Tsai, C.-j.	Journal of Development Studies
40	International standardization strategies of latecomers: The cases of Korean TPEG, T-DMB, and Binary CDMA	2011	Choung, J.-Y., Ji, I., & Hameed, T.	World Development
41	The role of foreign technology and indigenous innovation in the emerging economies: Technological change and catching-up	2011	Fu, X., Pietrobelli, C., & Soete, L.	World Development
42	Local "test bed" market demand in the transition to leadership: The case of the Korean mobile handset industry	2011	Whang, Y.-k., & Hobday, M.	World Development
43	Learning and catching up in different sectoral systems: Evidence from six industries	2011	Malerba, F., & Nelson, R.	Industrial and Corporate Change
44	Indigenous and foreign innovation efforts and drivers of technological upgrading: Evidence from China	2011	Fu, X., & Gong, Y.	World Development
45	Dynamic competition in technological investments: An empirical examination of the LCD panel industry	2011	Lee, J., Kim, B.-C., & Lim, Y.-M.	International Journal of Industrial Organization
46	Innovation, catch-up, and leadership in science-based industries	2012	Almudi, I., Fatas-Villafranca, F., & Izquierdo, L. R.	Industrial and Corporate Change
47	Knowledge flows in the solar photovoltaic industry: Insights from patenting by Taiwan, Korea, and China	2012	Wu, C.-Y., & Mathews, J. A.	Research Policy

Table 2 (continued)

No.	Title	Year	Author	Journal name
48	In search of an innovative state: The development of the biopharmaceutical industry in Taiwan, South Korea and China	2012	Wang, J. H., Chen, T.-Y., & Tsai, C.J.	Development and Change
49	Technological innovation capabilities in the thin film transistor-liquid crystal display industries of Japan, Korea, and Taiwan	2012	Hu, M.-C.	Research Policy
50	EMNE catch-up strategies in the wind turbine industry: Is there a trade-off between output and innovation capabilities?	2012	Awate, S., Larsen, M. M., & Mudambi, R.	Global Strategy Journal
51	How a latecomer succeeded in a complex product system industry: Three case studies in the Korean telecommunication systems.	2013	Park, T.-Y.	Industrial and Corporate Change
52	Why not greater catch-up by Chinese firms? The impact of IPR, corporate governance and technology intensity on late-comer strategies	2013	Xiao, Y., Tylecote, A., & Liu, J.	Research Policy
53	Knowledge patterns and sources of leadership: Mapping the semiconductor miniaturization trajectory	2013	Epicoco, M.	Research Policy
54	Indigenous innovation vs. *teng-long huan-niao*: Policy conflicts in the development of China's flat panel industry	2014	Chen, T.-J., & Ku, Y.-H.	Industrial and Corporate Change
55	A latecomer's strategy to promote a technology standard: The case of Datang and TD-SCDMA	2014	Gao, X.	Research Policy
56	Transitions of innovation activities in latecomer countries: An exploratory case study of South Korea	2014	Choung, J.-Y., Hwang, H.-R., & Song, W.	World Development
57	Cultural proximity and local firms' catch up with multinational enterprises	2014	Wang, J., Liu, X., Wei, Y., & Wang, C.	World Development
58	The effect of R&D novelty and openness decision on firms' catch-up performance:	2014	Wang, F., Chen, J., Wang, Y., Ning, L., & Vanhaverbeke, W.	Technovation

Table 2 (continued)

No.	Title	Year	Author	Journal name
	Empirical evidence from China			
59	The role of technological catch up and domestic market growth in the genesis of emerging country based multinationals	2014	Buckley, P. J., & Hashai, N.	Research Policy
60	The co-evolution of technology and institutions in the catch-up process: The case of the semiconductor industry in Korea and Taiwan	2014	Hwang, H.-R., & Choung, J-Y.	Journal of Development Studies
61	Compact organizational space and technological catch-up: Comparison of China's three leading automotive groups	2015	Nam, K.-M.	Research Policy
62	How absorptive capacity is formed in a latecomer economy: Different roles of foreign patent and know-how licensing in Korea	2015	Chung, M. Y., & Lee, K.	World Development
63	Technology and external conditions at play: A study of learning-by-licensing practices in China	2015	Wang, Y., Zhou, Z., Ning, L., & Chen, J.	Technovation
64	A history-friendly model of the successive changes in industrial leadership and the catch-up by latecomers	2017	Landini, F., Lee, K., & Malerba, F.	Research Policy
65	Successive changes in leadership in the worldwide mobile phone industry: The role of windows of opportunity and firms' competitive action	2017	Giachetti, C., & Marchi, G.	Research Policy
66	Is co-invention expediting technological catch up? A study of collaboration between emerging country firms and EU inventors	2016	Giuliani, E., Martinelli, A., & Rabellotti, R.	World Development
67	Evolution and coevolution: Dynamic knowledge capability building for catching-up in emerging economies	2016	Dong, X., Yu, Y., & Zhang, N.	Management and Organization Review

Table 2 (continued)

No.	Title	Year	Author	Journal name
68	Rise of latecomers and catch-up cycles in the world steel industry	2017	Lee, K., & Ki, J.-h.	Research Policy
69	Dynamic catch-up strategy, capability expansion and changing windows of opportunity in the memory industry	2017	Shin, J.-S.	Research Policy
70	Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems	2017	Lee, K., & Malerba, F.	Research Policy
71	Innovation and recurring shifts in industrial leadership: Three phases of change and persistence in the camera industry	2017	Kang, H., & Song, J.	Research Policy
72	Catch-up via agglomeration: A study of township clusters	2017	Jia, L., Li, S., Tallman, S., & Zheng, Y.	Global Strategy Journal
73	Toward technology-sensitive catching-up policies: Insights from renewable energy in China	2017	Binz, C., Gosens, J., Hansen, T., & Hansen, U. E.	World Development
74	Inside the virtuous circle between productivity, profitability, investment and corporate growth: An anatomy of Chinese industrialization	2017	Yu, X., Dosi, G., Grazzi, M., & Lei, J.	Research Policy

primary research method for the purposes of classification. Those that used case analysis as the major methodology were defined as qualitative studies, while those in which an empirical data analysis was conducted were defined as quantitative studies. In a few studies, simulation was the major research method. We also found a few studies that provided conceptual research frameworks. Table 5 summarizes the research methodologies: qualitative case studies (27.63%), quantitative empirical research (63.16%), simulation (5.26%), and conceptual papers (3.95%).The large volume of early literature on firm-level catch-up is impressive. Many studies take the form of in-depth case studies of Asian firms that have achieved successful catch-up (e.g., Cho et al., 1998; Fan, 2006; Kim, 1998; Mathews, 2006) or theoretical papers that propose conceptual frameworks of latecomer strategies (e.g., Kim, 1999; Li & Kozhikode, 2008; Mathews, 2002). A representative paper is Mathews (2002) published in APJM.

Table 3 Research disciplines of reviewed articles

Research disciplines	Number of articles	Percentage
Economics	33	43.42%
Innovation	31	40.79%
International business and area studies	7	9.21%
Organization studies	2	2.63%
Strategy	2	2.63%
General management	1	1.32%

Mathews (2002) synthesized the findings of extant studies and proposed a conceptual framework of catch-up by latecomer firms from the resource-based viewpoint. Mathews' seminal piece sparked a number of studies on latecomer firms, especially those based in China. In sum, firm-level studies of catch-up started with a series of case studies.

Based on our examination of these case studies, we observed that some scholars, such as Mathews (2002) and Li and Kozhikode (2008), proposed conceptual models for latecomer firms' catch-up. After the publication of these conceptual works, an increase was evident in firm-level studies of catch-up using diverse methodologies, ranging from case studies of wider scope to quantitative studies and, more recently, patent data analyses. Recently, catch-up studies using patent data have become more prominent. In addition, most technological catch-up studies conducted at the country or industry levels used quantitative methods with patent data. However, few studies used the simulation method. Despite the difficulties of conducting an empirical analysis due to paucity of data, we encourage future firm-level research on catch-up using simulations.

Data and measurement

Most empirical studies included in this review utilized patent data. Among the articles, 32.9% of them (25 studies) were based on patent analysis, which

Table 4 Theoretical background of the reviewed articles

Theoretical background/orientation	Number of times used	Percentage
None or not specified	44	57.89%
Absorptive capacity or capability	10	13.16%
Schumpeterian economics	9	11.84%
Evolutionary economics	4	5.26%
Timing of entry and latecomer advantage perspective	3	3.95%
Resource (knowledge)-based view	3	3.95%
Miscellaneous	3	3.95%

Table 5 Methodology of reviewed articles

Methodology	Number of articles	Percentage
Qualitative	48	63.16%
Quantitative	21	27.63%
Simulation	4	5.26%
Conceptual	3	3.95%

seems to be an important trend in studies examining catch-up or the relationship between catch-up and performance. Studies using patent data to examine catch-up mainly utilized the USPTO database. Not surprisingly, most studies using patent data focused on firms in high-tech industries. We report the distribution of these studies by industry and country in Tables 6 and 7. In terms of industry, the semiconductor industry, the telecommunications industry, the automobile industry, and the electronics industry accounted for 10.47%, 10.4%, 9.3%, and 3.49% of the firms in these studies, respectively. Most of these articles focused on three East Asian countries: Korea (36.59%), China (29.03%), and Taiwan (16.13%) (Table 7).

One of the recent trends in firm-level quantitative studies is the use of patent citation data. A major theme in this stream of studies is the comparison between latecomer firms, which attempt to catch-up, and incumbent firms as their targets. For instance, Lee (2013) made a large-scale comparison of the technological characteristics of latecomer firms with those in an advanced economy. He found that Korean firms were inferior to US firms in many respects, such as the number of patents and their quality, originality, and diversity (i.e., the scope of patenting was more diverse in US firms). In addition, the self-citation ratio was high in US firms. However, Korean firms tended to have patents with shorter cycle times compared to those of US firms. Given that firm growth was significantly related to the investment ratio in Korean firms, Lee (2013) suggested that latecomer firms should pursue growth by borrowing and investing more while specializing in short-cycle technology-based sectors. Among the empirical studies examined herein, most (80%) used patent data to measure catch-up. Technological catch-up was mostly measured as the number of patents. Other studies, such as Park and Lee (2006), measured catch-up using the patent growth rate and total productivity. Although patent stock may reflect technological capabilities of firms, we suggest that the patent growth rate better and more accurately captures the concept of catch-up. We encourage authors of future studies to operationalize technological catch-up using comparative and dynamic measures.

The next section presents an integrated framework of technological catch-up, based on a more detailed review of key findings in the literature.

A comprehensive framework of technological catch-up

Witnessing the rapid economic growth achieved by newly industrialized economies such as those in South Korea and Taiwan and, more recently, China, economists have

Table 6 Industry distribution of reviewed articles

Industry	Number of times	Percentage
Not specified	25	29.07%
Semiconductor	9	10.47%
Telecommunication	9	10.47%
Automobile	8	9.30%
Manufacturing	4	4.65%
Electronics	3	3.49%
Automotive	2	2.33%
Biotechnology	2	2.33%
Camera	2	2.33%
D-RAM	2	2.33%
Memory	2	2.33%
Steel	2	2.33%
Wind industry	2	2.33%
Apparel	1	1.16%
CTV industry	1	1.16%
Flat panel	1	1.16%
High-tech	1	1.16%
ICT	1	1.16%
IT	1	1.16%
LCD panel	1	1.16%
Machine tool	1	1.16%
Wine	1	1.16%
Renewable energy	1	1.16%
Science-based industries	1	1.16%
Solar photovoltaic	1	1.16%
TFT-LCD	1	1.16%
Solar TV, CoPS	1	1.16%

studied how these Asian countries successfully caught up with leading countries in technology-intensive industries. Scholars have attempted to solve the puzzle of why

Table 7 Country distribution of reviewed articles

Country	Number of times	Percentage
Korea	34	36.56%
China	27	29.03%
Taiwan	15	16.13%
India	4	4.30%
Brazil	2	2.15%
Not specified	11	11.83%

some companies were successful in technological catch-up with developed countries, while others were not.

Based on the literature review herein, we present a comprehensive framework of the antecedents for technological catch-up, which includes both external and internal factors (Fig. 3). Because this paper aims to give implications from the point of view of firms, we identify external factors as those that examine environmental effects on catch-up, which include industry- and country-level factors. We identify internal factors as those of firm-level factors. Then, in the next section (Future research agenda), we discuss the gaps in existing literature and a possible future research agenda.

External factors influencing technological catch-up

External environmental factors as antecedents of technological catch-up can be classified into those related to the (1) institutional environment and those related to the (2) technology regime.

Institutional environment Among the reviewed articles, several studies investigated the influence of institutional conditions, national innovation capability, and science and public institutions on successful catch-up as well as the role of government policy in shaping such institutional factors. Most of these studies were conducted at the country level. They recognize that while firms in different countries that achieve successful catch-up may share some common features, there are also substantial variations in the institutional conditions in which they operate. For example, by analyzing USPTO patent data granted to firms in 16 different countries, Hu and Mathews (2005) found

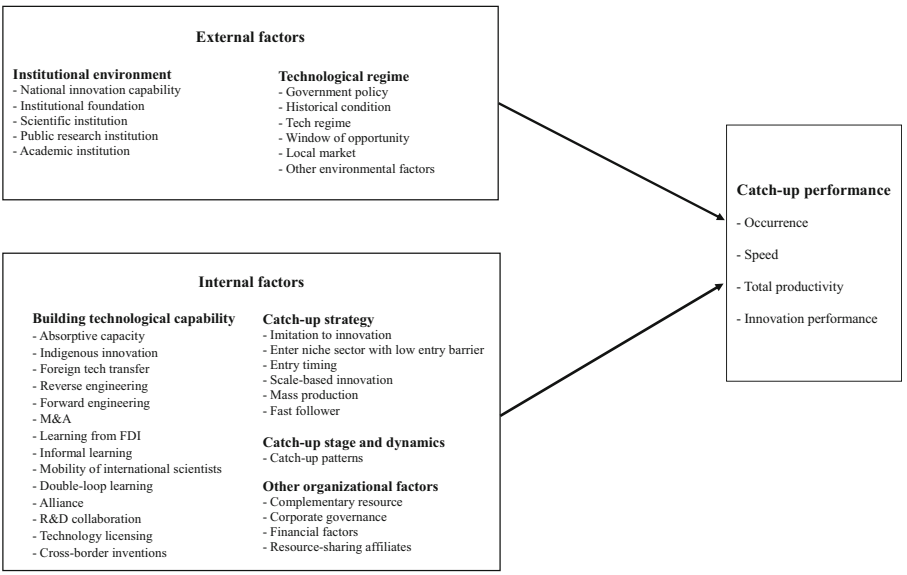

Fig. 3 Integrated framework of technological catch-up

that firms in East Asian countries such as Korea, Taiwan, Hong Kong, Singapore, and China were more focused on development of the institutional foundations of national innovative capacity, targeted more specific sectors, and more often specialized their innovation activities in these sectors compared to firms in a reference group of comparable countries. Similarly, Wang and Tsai (2010) and Park and Lee (2006) compared different innovation patterns and institutional contexts between firms in Korea and Taiwan by analyzing USPTO patent data. They demonstrated that technological catch-up in Taiwan contributed to dispersion of SMEs, while in Korea, the major players were a few relatively large conglomerates.

Furman and Hayes (2004) empirically examined national innovation-related productivity based on a panel dataset of 23 countries operating between 1978 and 1999, revealing that emerging innovators had made the change from imitation to innovation with the help of government innovation-enhancing policies and investment in physical and human capital over time. Bernardes and Albuquerque (2003) suggested that for technological development in less-developed countries, science plays an important role in cultivating absorptive capacity; thus, establishing scientific institutions should be seen as a vital component of industrial policy in these countries. Similarly, Mazzoleni and Nelson (2007) argued that public research institutions contribute to economic catch-up based on cases studies across countries, such as Japan, Korea, Taiwan, Brazil, and the US Mazzoleni (2008) reviewed the history of successful national catch-up in Germany, Japan, the US, Korea, and Taiwan and highlighted the role of academic institutions in the process of technological development despite variations in historical context and local conditions.

Technological regime In addition to institutional factors, some studies stress the importance of technological regime (i.e., changes in technological environment [Nelson & Winter, 1982]) for the success of technological catch-up. This stream of literature suggests that firms should take advantage of exogenous opportunities and choose appropriate technological fields.

The concept of the technological regime was connected to the concept of the sectoral system of innovation in many studies explaining how firms in laggard countries achieve catch-up in certain sectors. Early studies along this line took the form of case studies, such as that of Lee and Lim (2001), who explained that sector-level variations in catch-up patterns were partly determined by the technological regimes in which these industries operated, and characteristics such as cumulativeness of technical advances, predictability of technological trajectory, and the properties of the knowledge base all played a role. Park and Lee (2006) examined the relationship between the technological regime and the occurrence and speed of technological catch-up by Korean and Taiwanese firms using USPTO patent data. They found that catch-up is more likely to occur in technological classes with shorter technological cycle times and larger initial knowledge stocks, while the speed of catch-up depends on appropriability and knowledge accessibility.

Recently, Landini, Lee, and Malerba (2017) developed a history-friendly model to explore the conditions within which catch-up cycles are more likely to occur. In a simulation analysis, they found that changes in leadership depend not only on technological discontinuities, but also on the lock-in behavior of incumbents.

Another stream of literature stresses that firms should take advantage of "windows of opportunity" to catch-up. For example, Niosi and Reid (2007) examined whether emerging technologies such as biotechnology and nanotechnology do indeed offer "windows of opportunity" for less-developed countries to catch-up. They found that only three of the largest countries with emerging economies (China, India, and Brazil) were able to take advantage of these opportunities, partly because of the size of human and investment capital and government support. Notable is the example of the articles collected in a recent special issue in *Research Policy*, including the leading article of Lee and Malerba (2017). This piece identified windows of opportunity along three dimensions (technological, demand, and institutional/policy) of a given sectoral system, and suggested that the combination of these three dimensions determines changes in industrial leadership. Giachetti and Marchi (2017) observed two leadership changes in the 1990s and 2010s. They concluded that catch-up happens when a latecomer takes aggressive competitive action at a time when windows of opportunity are open, and they emphasized the importance of both internal efforts and external opportunities in the catch-up process.

Internal factors influencing technological catch-up

While country- or sector-level studies focus on the influence of the external environment on technological catch-up, firm-level studies focus more on internal capability-building and strategic choice for successful catch-up. Most articles that describe internal factors influencing technological catch-up can be grouped into two categories. One group of studies focuses on how to build technological capability in order to catch-up, while the other focuses on catch-up strategies chosen by firms.

Building technological capability through learning as an antecedent to catch-up Many scholars emphasize technological innovation capability as the key for successful catch-up, examining how firms can improve their technological capability. For example, Kim (1999) presented an integrative framework to describe the process of building technological capability based on the Korean experience, and concluded that crisis construction was an effective mechanism that promoted Hyundai Motors' learning and catch-up efforts. By investigating leading Chinese firms (i.e., Huawei, ZTE, DTT, and GDT) in the telecommunications equipment industry, Fan (2006) emphasized that lagging firms should prioritize building up of innovation capability from the very beginning to ensure competitiveness. Li and Kozhikode (2008) put forward a theoretical model for latecomers and suggested that successful catch-up requires laggards to become emulators rather than blind imitators, learning about the properties and causal mechanisms among objects. They observed firms in the mobile phone industry in China and demonstrated that learning strategies of laggards are influenced by the number of available complementary resources and the absorptive capability of the firms. Using panel data from Chinese manufacturing firms, Wang, Liu, Wei, and Wang (2014) found that catch-up is positively related to the size of the technology gap (with industry forerunners) and firms' technological capabilities.

Scholars have tried to explain the channels through which firms can build up their innovation capability. The channels or methods through which technological capability

can be transferred from advanced country firms to lagging firms in Asian countries has been a particular focus. Most of these studies focus on the complementary relationship between development of internal capability and external knowledge transfer. Fan (2006) concluded that lagging firms should focus on in-house R&D development to improve innovation capability, supplementing this strategy with formation of external alliances. Fu, Pietrobelli, and Soete (2011) suggested that both indigenous innovation and foreign technology transfer contribute to technological catch-up in emerging economies, whereas indigenous innovation matters more in advanced countries. Using USPTO patent data of firms in the emergent solar photovoltaic industry in Taiwan, Korea, and China, Wu and Mathews (2012) demonstrated an increasing dependence on intra-national knowledge rather than international knowledge, indicating that the transition from imitation to innovation is ongoing. Chen (2009) studied Taiwan's machine tool industry and demonstrated that informal learning through local and global knowledge linkages played an important role in the catch-up of Taiwanese firms in low- and medium-technology industries, criticizing high-tech industry-centered models that rely on formal learning mechanisms.

Lee, Park, Ryu, and Baik (2010) examined the benefits of interfirm R&D collaboration for latecomers in terms of timing. In a simulation analysis, they found that R&D collaboration based on cost reduction did not facilitate catch-up, while R&D collaboration for the purpose of sharing complementary resources and creating synergies did promote catch-up. Similarly, Wang, Zhou, Ning, and Chen (2015) examine how learning-by-licensing helps latecomers such as Chinese firms build their technological capability.

Another stream of studies emphasizes the important role of mobility of engineers as the channel through which firms can improve their innovation capability. Song, Almeida, and Wu (2003) found that international mobility of engineers facilitated catch-up of Korean and Taiwanese firms. Similarly, Almudi, Fatas-Villafranca, and Izquierdo (2012) highlighted the role of international mobility of scientists in the catch-up process in science-based industries. More recently, Giuliani, Martinelli, and Rabellotti (2016) found that cross-country collaborations between mobile inventors from the European Union provided opportunities for firms from emerging countries such as China.

Though most of the studies included in this review focus on how to improve firms' technological capability, there are a few studies in which other organizational factors influencing technological catch-up are examined. Xiao, Tylecote, and Liu (2013) illustrated how elements of the micro context, such as corporate governance and financial factors, are important for successful technological catch-up. Comparing leading Chinese automobile groups, Nam (2015) found that coordination and resource-sharing among affiliated firms contributed to technological catch-up of business groups from emerging economies. More research must be conducted to investigate how other organizational factors can affect technological catch-up.

Catch-up strategies Many case or simulation studies have been conducted to determine distinctive catch-up patterns and strategies. Lee and Lim (2001) analyzed the relationship between catch-up and firm performance in six selected industries in Korea. Three different patterns of catch-up were identified: path-creating catch-up (e.g., the CDMA mobile phone), stage-skipping catch-up (e.g., D-RAM and the automobile),

and path-following catch-up (e.g., consumer electronics, personal computers, and machine tools).

Other studies at the firm level looked at organizational or strategic factors that help firms overcome latecomer disadvantages and/or maximize latecomer advantages. For example, Cho et al. (1998) investigated how Korean firms caught up with Japanese firms in the semiconductor industry by overcoming certain latecomers' disadvantages (such as a thin margin and volume building) and maximizing latecomers' advantages (such as time compression, technology transfer, and resource leveraging). Mathews and Cho (1999) developed a model for latecomers' entry strategies including single- and double-loop strategies that involve leverage of external resources and combinative capabilities.

Choung, Hwang, and Song (2014) identified three different evolutionary patterns in innovative activities in the post-catch-up period in Korea, namely deepening process innovation, architectural innovation, and radical innovation, which depend on the timing of laggards' entry in the product life cycle.

Lee and Ki (2017) examined the reasons behind the shift in leadership from the United States to Japan and subsequently from Japan to Korea, contending that the emergence of new technologies served as a window of opportunity for Japanese firms to pursue path-creating catch-up, while Korea's POSCO seized the opportunity during a downturn in the global steel industry to switch its catch-up strategy from path-following to stage-skipping.

Catch-up stages and processes Some researchers have outlined the stages of technological catch-up in terms of capability upgrading. For example, Kim (1997) distinguished several stages of technological development by latecomers: the duplicative imitation, creative imitation, and innovation stages.

Another series of stages is as follows: the OEM (own equipment manufacturing), ODM (own design manufacturing), and OBM (own brand manufacturing) stages.[1] Original equipment manufacturing (OEM) is a specific form of subcontracting under which a complete, finished product is made to exact buyer specifications. Some OEMs evolve into own design manufacturing (ODM) firms, in which most of the detailed product design is carried out, and the customer firms of ODM companies continue with the marketing functions. Further, original brand manufacturing (OBM) firms engage in manufacturing, design of new products, R&D for materials, processing of products, and sales and distribution for their own brands. The path from OEM to ODM to OBM has become the standard upgrading process for latecomer firms.

More recently, Choung, Ji, and Hameed (2011) described an international standardization strategy, analyzing three Korean cases and suggesting that the phases of latecomers' catch-up may evolve from "adoption" to "standard setting" based on their technological capabilities and social/institutional/economic opportunities.

[1] Explanations of these three terms are provided in Hobday (1994).

Future research agenda

In this section, we continue by identifying major issues for future research on technological catch-up by firms in East Asian economies.

External environments influencing technological catch-up

Environmental factors that influence catch-up are mostly examined in country- or sector-level studies. We notice some visible changes in focus in these studies over time, such as from earlier case studies to later quantitative studies using patent data, followed by the emergence of simulation model studies to examine sectoral evolution. One challenge in studying environmental factors is that there are too many factors involved in catch-up and sectoral evolution, and it is not easy to rank them and identify the connections among them. Also, influential factors may differ depending upon the stage of industry evolution; for instance, during the early or emerging stage, accessibility to or transferability of external/foreign knowledge may be more important, whereas at later stages, tacitness and/or appropriability may be more important as determinants of catch-up probability. The complexity of the issue seems to be one of the reasons for the emergence of simulation-based analyses where many variables can be included.

The key question of why most cases of successful catch-up are found only in certain East Asian economies, but not in other Asian or Latin American economies, has been partly answered, as in Kim and Lee (2015), but still remains to be answered to a large extent. While the intensity of innovative effort seems to be one of the differentiating factors, we have yet to explain why other economies failed to invest enough resources and effort toward innovation. The deep-rooted historical conditions in various countries as well as the (in)effectiveness of the catch-up strategies themselves require further study.

Learning channels and targets in the catch-up process

Existing literature illustrates many channels through which lagging firms can source vital knowledge and upgrade their technological capability, helping them to move from imitation to innovation. Those channels include assembly-based production, learning by exporting, knowledge transfer via FDI, licensing, establishment of overseas R&D outposts, joint R&D with public or foreign R&D organizations, R&D collaboration, and mobility of engineers, through all of which Asian lagging firms have accessed foreign technology and know-how in advanced economies (Almudi et al., 2012; Giuliani et al., 2016; Song et al., 2003).

Although existing studies identify different means through which laggards can learn from incumbents and improve their technological capabilities, there are still several avenues not well examined in the existing literature. For instance, in 2002, the Chinese government announced a new strategy for encouraging Chinese companies to "go global" by investing abroad. Some well-known cases include Lenovo's purchase of the PC division of IBM in 2004, Geely's acquisition of Volvo in 2012, and, more recently, Tsinghua Unigroup's aggressive serial takeover of global chip-makers. Although M&A is often viewed as a fast way of acquiring knowledge, its effectiveness as a method of

technological catch-up is still questionable because it depends upon the nature of the knowledge. To the extent that knowledge is tacit, simply acquiring other firms does not guarantee automatic transfer of knowledge from them, especially if key staff of a target firm leaves the company after acquisition. Thus, we call for both in-depth case studies and large-scale empirical analyses that examine M&A as a learning channel and catch-up method.

Research also has yet to identify the most appropriate reference organizations from which firms can learn: incumbent firms in advanced economies or latecomers from home or neighboring countries who succeeded in catch-up. Most existing literature focused on how laggards learn from firms in advanced countries. We know less than we should about how laggards can upgrade their technological capability through learning from reference groups other than incumbent leaders (Miao, Song, & Salomon, 2015). Thus, future studies may identify and discuss not only various learning channels, but also types of appropriate learning targets from which to upgrade their technological capabilities in the process of catch-up.

It is also important to address the intriguing question of how to achieve discontinuous upgrading from low-tier (or productive) skills to high-tier innovation capabilities. Such upgrading is required to sustain catch-up or surpass incumbents.

Variations in catch-up strategies and leapfrogging

Though learning is important for laggards to upgrade their technological capabilities, lagging firms must often utilize appropriate strategies to overcome latecomers' disadvantages and utilize their advantages. These strategies may differ from those used by incumbent firms in advanced countries (Cho et al., 1998). A substantial number of extant studies examined diverse catch-up strategies. Some argued that latecomers may utilize their advantages of time compression, leverage of resources, and technology transfer or learning (Cho et al., 1998; Mathews, 2002) while overcoming disadvantages through a thin margin or volume building (Cho et al., 1998). By leveraging complementary assets to adopt a new technological trajectory and develop appropriability, Samsung caught up with Motorola in the mobile telecommunications industry (He, Lim, & Wong, 2006). Others pointed out that laggards should be careful not to be just blind imitators, but also to be emulators (Li & Kozhikode, 2008).

The question remains as to whether latecomers tend to catch-up using similar or different technologies from those of forerunning incumbents. Using similar technologies implies that they simply attempt to imitate, whereas using different technologies indicates the pursuit of new technology creation and taking a different technological path or trajectory from those of incumbents. This contrast between similar and different technologies is interesting in the literature on technological catch-up. Early studies, such as Lall (2000), Kim (1980), Westphal, Kim, and Dalman (1985), and Hobday (1995), observed that latecomers tried to catch-up with advanced countries by assimilating and adapting the obsolete technology of incumbents. However, Lee and Lim (2001) and Lee (2013) expressed a contrasting view: latecomers do not simply follow previous paths of technological development; rather, they sometimes skip certain stages or even create their own paths that differ from those of industry forerunners.

Song and Lee (2014) suggested that Korean firms had achieved path-creating catch-up by choosing a different path from those of forerunning Japanese firms in the digital TV industry, taking advantage of the window of opportunity provided by a shift in the technological paradigm from analog to digital in the 1990s. Similarly, China also experienced stage-skipping catch-up in the telecommunications industry, jumping directly to digital automatic switches, but skipping the stage of analog electronic switches (Mu & Lee, 2005). Thus, future researchers should continue to search for the best catch-up strategies in different contexts.

The leapfrogging strategy also needs further clarification. Leapfrogging always entails either stage-skipping or path-creating. For instance, in the mobile phone industry, Samsung forged ahead in the 2000s over Nokia. This example can be classified as path creation because Samsung adopted Google's Android OS for its smartphone, which differed from Nokia's feature phone or Symbian OS-based smartphones (Giachetti & Marchi, 2017). Samsung also pursued path-creating leapfrogging at the early stage of its growth, with its invention, together with Qualcomm, of the world's first mobile phone based on the CDMA standard, which was unlike the TDMA-GSM standard of Nokia (Lee & Lim, 2001). Similarly, instances of leadership change in the memory chip sector involved a stage-skipping type of leapfrogging (or dynamic catch-up) because both Japan and South Korea targeted next-generation chips in the catch-up process to be ahead of industry incumbents (Shin, 2017). In the example of leadership change in the camera sector in the 1950s, forging ahead of the Japanese became possible because Japanese companies created a new technological path for the SLR camera (Kang & Song, 2017). In the steel sector, the rise of Japan in the 1970s against the US was definitely an example of path creation in the adoption/follow-on innovation mode, as Japan adopted and further improved the Austrian-invented BOF (basic oxygen furnace) method, whereas the US stuck to the old open-hearth furnace (OHF) method (Lee & Ki, 2017). Thereafter, the rise of POSCO against Japan's Nippon Steel was an example of stage-skipping leapfrogging because the former adopted state-of-the-art technologies in its establishment of a second mill from the mid-1980s to the 1990s.

The consensus seems to be that path creation may be a necessary condition for leapfrogging, but it is not sufficient. However, the generalizability of this argument must be confirmed in detailed research in future. Also, the advantages and disadvantages of adopting this ambitious path-creating or leapfrogging strategy, the risks involved, and management of those risks require further study. The leapfrogging strategy has a higher chance of success when it is conducted during a shift in technological paradigm (Perez & Soete, 1988) because all firms begin at the same point when a new paradigm is introduced, and incumbents may be slow or reluctant to move to the new paradigm. However, it may be difficult to recognize or identify quickly when a new paradigm is emerging as a window of opportunity.

Stages of technological catch-up

Research suggests that latecomer firms find OEM to be an easy way of catching-up at the early stage of economic growth, but they soon face difficulties when forerunning firms move their production to other, lower-wage production sites. Unless these companies can eventually produce and sell their own designs and brands, they remain

in the low-value-added segments, thereby failing to catch-up with industry incumbents. Thus, few firms from developing countries make a successful transition from OEM to the next stages of ODM or OBM. Instead, they continue to remain at the OEM stage, restricted to their home countries. If we conceive these stages of learning as (1) skills, (2) process technology, (3) design technology, and (4) new product development, the transition from stage 2 to stage 3 is the most difficult. The first and second stages largely correspond to the duplicative imitation and path-following stages of catch-up, the third stage corresponds to the creative imitation and stage-skipping stage, and the final stage to real innovation and path-creation or industry leadership. Transition to the third stage requires learning and acquisition of design capabilities or R&D capabilities in general. This transition is often perceived as a high entry barrier or crisis stage in the catch-up process because latecomer firms face serious difficulty in learning how to design and produce higher-value-added products.

Building up technological capabilities so as to move from low value-added activities to higher valued-added activities remains an important topic for research on catch-up. This transition does not occur automatically even if a country is open to trade and FDI. Rather, it often involves deliberate learning and risk-taking by companies and other public actors. The market mechanism serves not as a triggering factor, but as a facilitating factor that stimulates risk-taking and rewards successful actors. More research is needed on the role of government policies and institutions that help latecomers move from the early stage to upgraded stages.

Multi-level and multi-disciplinary framework of technological catch-up

In this literature review, we identified a large number of factors related to catch-up at all three levels—firm, sector, or country. However, it is difficult to rank these factors and identify connections among them. For example, some internal factors examined in existing literature may be related to industry- or individual-level factors (e.g., inventor/employee mobility), or they may involve collaboration between many companies (e.g., knowledge sourcing, M&A). Authors of extant studies failed to address this multi-level issue. One constructive way to tackle this problem in future studies would be to utilize a multi-level and multi-disciplinary framework and method, because catch-up at each level may be influenced by variables at other levels. For example, Jung and Lee (2010) found that sectoral-level variables affected the probability of country-level productivity catch-up between Korea and Japan, whereas firm-level variables affected inter-firm catch-up within countries. Further, we found that existing literature on catch-up failed to recognize contingencies (at different levels) that can moderate or differently shape the main relationships. Additionally, the interaction of these variables may have played a significant role in technological catch-up. Some recent studies such as those of Miao, Song, and Li (2016) and Lee (2013) found that successful catch-up of laggard firms is typically achieved as a result of interactions between strategic choices made by these firms and the environmental conditions they encounter. How different technological regimes across sectors influence laggard firms with different knowledge profiles and learning capabilities is a particularly interesting research question to study further. In this study, we do not classify the literature

examined herein by level of analysis; therefore, we call for multi-level and multi-discipline analyses of the interactions among variables. Such research would be to verify the generalizability of the findings of previous studies using multi-disciplinary approaches. We need more systematic, empirically-grounded insight into the conditions under which latecomers from Asia's emerging economies successfully achieve catch-up and eventually overtake incumbent firms.

Conclusion

In this paper, we reviewed the extant research on technological catch-up by Asian latecomers, especially those from three East Asia countries, Korea, China, and Taiwan. We classified existing articles in terms of theoretical background, data, and research method. We summarized major findings and provided an integrated model of technological catch-up. We then identified research gaps and suggested future research topics.

In terms of methodology, we found that earlier studies using qualitative or case study methods were followed by theoretical conceptualizations of the catch-up phenomenon and the conditions under which latecomer firms find success. Recent research has attempted to generalize the insights of earlier studies by quantitative analyses using larger data sets, often including patent data.

The key areas of focus have been the stages of technological catch-up, learning channels and targets, and types of catch-up strategies (including leapfrogging). All these issues are centered on the theme of how latecomers overcome their initial disadvantages by learning from various targets through various channels to achieve catch-up with or even overtake incumbents utilizing various strategies, such as stage-skipping, path-creating, or leapfrogging. In the catch-up process, the emergence of new innovations or techno-economic paradigms often served as a window of opportunity for latecomers, while for incumbents, many remained locked into existing technological pathways.

Regarding the fundamental question of whether latecomers should use similar or different technologies from those of the leading firms in a given industry, the consensus seems to be that while initial catch-up starts with firms following the path of the incumbent by learning similar technologies, eventual catch-up or overtaking seems to require the latecomer to adopt different technologies to pursue leapfrogging or path creation. However, given the serious risk associated with leapfrogging, we also observe that adopting this strategy alone is not sufficient, but it may be necessary to successful catch-up. Given that more and more Asian latecomers are succeeding in overtaking or surpassing industry incumbents, future researchers should pay more attention to this issue of how to implement leapfrogging strategies while minimizing risk.

Through this article, we classify existing studies based on an extensive literature review, identify gaps in the research, and suggest areas for future research. These recommendations may provide insight into how technological catch-up research can be improved. Though this review paper focuses on technological catch-up in East Asia, we encourage future scholars to investigate whether the main findings and suggestions of this study can also be applied to other geographic contexts such as other Asian areas or other emerging economies.

References

Abramovitz, M. 1986. Catching up, forging ahead, and falling behind. *Journal of Economic History*, 46(2): 385–406.

Almudi, I., Fatas-Villafranca, F., & Izquierdo, L. R. 2012. Innovation, catch-up, and leadership in science-based industries. *Industrial and Corporate Change*, 21(2): 345–375.

Bernardes, A., & Albuquerque, E. 2003. Cross-over, thresholds, and interactions between science and technology: Lessons for less-developed countries. *Research Policy*, 32(5): 865–885.

Chen, L. 2009. Learning through informal local and global linkages: The case of Taiwan's machine tool industry. *Research Policy*, 38(3): 527–535.

Cho, D. S., Kim, D. J., & Rhee, D. K. 1998. Latecomer strategies: Evidence from the semiconductor industry in Japan and Korea. *Organization Science*, 9(4): 489–505.

Choung, J.-Y., Hwang, H.-R., & Song, W. 2014. Transitions of innovation activities in latecomer countries: An exploratory case study of South Korea. *World Development*, 54: 156–167.

Choung, J.-Y., Ji, I., & Hameed, T. 2011. International standardization strategies of latecomers: The cases of Korean Tpeg, T-Dmb, and binary CDMA. *World Development*, 39(5): 824–838.

Fagerberg, J., & Godinho, M. M. 2005. Innovation and catching-up. *The Oxford handbook of innovation*: 514–543. New York: Oxford University Press.

Fan, P. 2006. Catching up through developing innovation capability: Evidence from China's telecom-equipment industry. *Technovation*, 26(3): 359–368.

Fu, X., Pietrobelli, C., & Soete, L. 2011. The role of foreign technology and indigenous innovation in the emerging economies: Technological change and catching-up. *World development*, 39(7): 1204–1212.

Furman, J., & Hayes, R. 2004. Catching up or standing still?: National innovative productivity among 'follower' countries, 1978–1999. *Research Policy*, 33(9): 1329–1354.

Gaur, A. S., & Kumar, M. 2018. A systematic approach to conducting review studies: An assessment of content analysis in 25 years of IB research. *Journal of World Business*, 53(2): 280–289.

Gerschenkron, A. 1962. *Economic backwardness in historical perspective*. Cambridge: Belknap Press of Harvard University Press.

Giachetti, C., & Marchi, G. 2017. Successive changes in leadership in the worldwide mobile phone industry: The role of windows of opportunity and firms' competitive action. *Research Policy*, 46(2): 352–364.

Giuliani, E., Martinelli, A., & Rabellotti, R. 2016. Is co-invention expediting technological catch up? A study of collaboration between emerging country firms and EU inventors. *World Development*, 77: 192–205.

He, Z.-L., Lim, K., & Wong, P.-K. 2006. Entry and competitive dynamics in the mobile telecommunications market. *Research Policy*, 35(8): 1147–1165.

Hobday, M. 1994. Export-led technology development in the four dragons: The case of electronics. *Development and Change*, 25(2): 333–361.

Hobday, M. 1995. East Asian latecomer firms: Learning the technology of electronics. *World Development*, 23 (7): 1171–1193.

Hu, M.-C., & Mathews, J. A. 2005. National innovative capacity in East Asia. *Research Policy*, 34(9): 1322–1349.

Jung, M., & Lee, K. 2010. Sectoral systems of innovation and productivity catch-up: Determinants of the productivity gap between Korean and Japanese firms. *Industrial and Corporate Change*, 19(4): 1037–1069.

Kang, H., & Song, J. 2017. Innovation and recurring shifts in industrial leadership: Three phases of change and persistence in the camera industry. *Research Policy*, 46(2): 376–387.

Khanna, T., Song, J., & Lee, K. 2011. The paradox of Samsung's rise. *Harvard Business Review*, 89(7–8): 142–147.

Kim, L. 1980. Stages of development of industrial technology in a developing country: A model. *Research Policy*, 9(3): 254–277.

Kim, L. 1997. *Imitation to innovation: The dynamics of Korea's technological learning*. Boston: Harvard Business School Press.

Kim, L. 1998. Crisis construction and organizational learning: Capability building in catching-up at Hyundai motor. *Organization Science*, 9(4): 506–521.

Kim, L. 1999. Building technological capability for industrialization: Analytical frameworks and Korea's experience. *Industrial and Corporate Change*, 8(1): 111–126.

Kim, Y. K., & Lee, K. 2015. Different impacts of scientific & technological knowledge on economic growth: Contrasting S&T policy in East Asia and Latin America. *Asian Economic Policy Review*, 10: 43–66.

Lall, S. 2000. The technological structure and performance of developing country manufactured exports, 1985–98. *Oxford Development Studies*, 28(3): 337–369.

Landini, F., Lee, K., & Malerba, F. 2017. A history-friendly model of the successive changes in industrial leadership and the catch-up by latecomers. *Research Policy*, 46(2): 431–446.

Lee, J., Park, S. H., Ryu, Y., & Baik, Y.-S. 2010. A hidden cost of strategic alliance under Schumpeterian dynamics. *Research Policy*, 39(2): 229–238.

Lee, K. 2013. *Schumpeterian analysis of economic catch-up: Knowledge, path-creation, and the middle-income trap*. London: Cambridge University Press.

Lee, K., & Ki, J.-h. 2017. Rise of latecomers and catch-up cycles in the world steel industry. *Research Policy*, 46(2): 365–375.

Lee, K., & Lim, C. 2001. Technological regimes, catching-up and leapfrogging: Findings from the Korean industries. *Research Policy*, 30(3): 459–483.

Lee, K., & Malerba, F. 2017. Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems. *Research Policy*, 46(2): 338–351.

Li, J., & Kozhikode, R. K. 2008. Knowledge management and innovation strategy: The challenge for latecomers in emerging economies. *Asia Pacific Journal of Management*, 25(3): 429–450.

Mathews, J. A. 2002. Competitive advantages of the latecomer firm: A resource-based account of industrial catch-up strategies. *Asia Pacific Journal of Management*, 19(4): 467–488.

Mathews, J. A. 2006. Dragon multinationals: New players in 21st century globalization. *Asia Pacific Journal of Management*, 23(1): 5–27.

Mathews, J. A., & Cho, D.-S. 1999. Combinative capabilities and organizational learning in latecomer firms: The case of the Korean semiconductor industry. *Journal of World Business*, 34(2): 139–156.

Mazzoleni, R. 2008. Catching up and academic institutions: A comparative study of past national experiences. *Journal of Development Studies*, 44(5): 678–700.

Mazzoleni, R., & Nelson, R. R. 2007. Public research institutions and economic catch-up. *Research Policy*, 36 (10): 1512–1528.

Miao, Y., Song, J., & Li, J. 2016. *Technological environment, search strategy and technological catch-up of laggards in emerging Asian economies*. New York City: Mimeo.

Miao, Y., Song, J., & Salomon, R. 2015. *Learning from successful peers: Technological catch-up among Asian laggards*. New York City: Mimeo.

Mu, Q., & Lee, K. 2005. Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China. *Research Policy*, 34(6): 759–783.

Nam, K.-M. 2015. Compact organizational space and technological catch-up: Comparison of China's three leading automotive groups. *Research Policy*, 44(1): 258–272.

Nelson, R. R., & Winter, S. G. 1982. *An evolutionary theory of economic change*. Cambridge: Harvard University Press.

Niosi, J., & Reid, S. E. 2007. Biotechnology and nanotechnology: Science-based enabling technologies as windows of opportunity for LDCs? *World Development*, 35(3): 426–438.

Odagiri, H., Goto, A., Sunami, A., & Nelson, R. R. (Eds.). 2010. *Intellectual property rights, development, and catch up: An international comparative study*. Oxford: Oxford University Press.

Park, K.-H., & Lee, K. 2006. Linking the technological regime to the technological catch-up: Analyzing Korea and Taiwan using the US patent data. *Industrial and Corporate Change*, 15(4): 715–753.

Perez, C., & Soete, L. 1988. Catching up in technology: Entry barriers and windows of opportunity. In G. Dosi, R. Nelson, G. Silverberg, & L. Soete (Eds.). *Technical change and economic theory*: 458–479. London: Pinter.

Shin, J.-S. 2017. Dynamic catch-up strategy, capability expansion and changing windows of opportunity in the memory industry. *Research Policy*, 46(2): 404–416.

Song, J., Almeida, P., & Wu, G. 2003. Learning by hiring: When is mobility more likely to facilitate interfirm knowledge transfer?. *Management Science*, 49(4): 351–365.

Song, J., & Lee, K. 2014. The Samsung way: Transformational management strategies from the world leader in innovation and design. New York: McGraw-Hill Education.

Song, J., Lee, K., & Khanna, T. 2016. Dynamic capabilities at Samsung: Optimizing internal co-opetition. *California Management Review*, 58(4): 118–140.

Wang, J., Liu, X., Wei, Y., & Wang, C. 2014. Cultural proximity and local firms' catch up with multinational enterprises. *World Development*, 60: 1–13.

Wang, J. H., & Tsai, C.-j. 2010. National model of technological catching up and innovation: Comparing patents of Taiwan and South Korea. *Journal of Development Studies*, 46(8): 1404–1423.

Wang, Y., Zhou, Z., Ning, L., & Chen, J. 2015. Technology and external conditions at play: A study of learning-by-licensing practices in China. *Technovation*, 43–44: 29–29.

Westphal, I. E., Kim, L., & Dalman, C. J. 1985. Reflections of Korea's acquisition of technological capacity. In N. Rosenberg, & C. Frischtak (Eds.). *International technology transfer: Concepts, measures and comparisons*. New York: Praeger.

Wu, C.-Y., & Mathews, J. A. 2012. Knowledge flows in the solar photovoltaic industry: Insights from patenting by Taiwan, Korea, and China. *Research Policy*, 41(3): 524–540.

Xiao, Y., Tylecote, A., & Liu, J. 2013. Why not greater catch-up by Chinese firms? The impact of IPR, corporate governance and technology intensity on late-comer strategies. *Research Policy*, 42(3): 749–764.

Yuzhe Miao (PhD, Seoul National University) is Assistant Professor at Sungkyunkwan University. She has published articles in journals such as the *Management International Review* and *Journal of Knowledge Management*. She was nominated as a finalist of the Barry M. Richman Best Dissertation Award of the Academy of Management, and a finalist of the Best Paper Awards of the Academy of International Business and the Strategic Management Society.

Jaeyong Song (PhD, Wharton School of the University of Pennsylvania) is AMOREPACIFIC Professor at Seoul National University. He was elected as an AIB Fellow and served as an editor of the *Journal of International Business Studies* (JIBS). He received his PhD at Wharton and was Professor at Columbia. His papers have been published in journals such as the *Management Science*, *Harvard Business Review*, *Strategic Management Journal*, *Organization Science*, *Journal of Management*, *Journal of International Business Studies*, *California Management Review*, and *Research Policy*.

Keun Lee (PhD, University of California, Berkeley) is Professor of Economics at Seoul National University, and the winner of the 2014 Schumpeter Prize for his monograph on *Schumpeterian Analysis of Economic Catch-up* (2013, Cambridge University Press). He is now the President of the International Schumpeter Society, an editor of *Research Policy*, an associate editor of *Industrial and Corporate Change*, and a council member of the World Economic Forum. He obtained his PhD in Economics from the University of California, Berkeley.

Chuyue Jin (MA, Seoul National University) is a Doctoral Candidate at Seoul National University Business School.