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An Innovation Path of Catch-up by Semiconductor Latecomers: The Semiconductor Manufacturing International Corporation Case

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Abstract

Exploring innovations for latecomers to catch up has been a popular concern in industry and academia. Over the last decade, more and more East Asian latecomer firms have moved beyond imitation and are delivering innovative products and services to the market. However, the semiconductor latecomers from China have limited success in catching up with more mature semiconductor firms. Our study examines how semiconductor latecomers to break through the latecomer's dilemma by innovation and achieve catch-up. We use a single-case approach for the Semiconductor Manufacturing International Corporation (SMIC) vertical development process to analysis its innovation path of catching up. The study's results showed that SMIC relied on the government's policy and funding support, and based on the strategic endurance of entrepreneurs, it persisted in technology R&D investment and independent innovation for 20 years. SMIC finally smashed the dilemma of latecomers and successfully achieved catch-up. With these findings, we believe that the path of catching up innovation for semiconductor latecomers should be equipped with independent innovation of technology, strategic leadership of entrepreneurs and support of government policies. As these factors are combined, latecomer firms' position is expected to rise and catch-up will become visible. Our study contributes to some enlightenment on the innovation

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path for latecomers in China and global semiconductors to achieve their catch-up.

Key words: Innovation, Semiconductor, Latecomer, Catch-up, SMIC, R&D

1. Introduction

In competing with leading firms, how latecomer firms can catch up with innovation has become a highly concerning issue in academia and practical circles (Zhu et al., 2017; Guo et al., 2018). As with late-developing countries, latecomer firms can exploit their late arrival to tap into advanced technologies rather than replicating the previous technological trajectory. They can accelerate their uptake and learning efforts by utilizing various forms of collaborative processes and state agencies to assist with the process, bypassing some of the organizational inertia that holds back their more established competitors (Mathews, 2002). The semiconductor industry arose and was dominated by the U.S. in the 1960s. It was not until the mid-1990s that the Internet and communications revolution occurred, leading to the expansion of semiconductor application fields. Only then did countries such as Taiwan, South Korea, Singapore, and China begin to challenge the U.S. semiconductor industry, leading to a shift in global production of semiconductor industry to emerging Asian countries. However, a large number of latecomers in China, especially domestic semiconductor firms, are facing a daunting late-stage catch-up dilemma (Rho et al., 2015). According to the data of World Semiconductor Trade Statistics (WSTS), in 2019, the sales of global semiconductor reached US $412.1billion,[1) the sales of China's semiconductors were US$113.5billion among them, approximately 27% (CSIA, 2020-03-23).[2) Although China has been a large producer and seller of electronic products, chip market has been monopolized by multinationals such as Intel, AMD, Qualcomm, Samsung and MediaTek, its local self-produced rate is only15.3%.[3) The local semiconductor producers have not been market leaders in China. Nearly all general-purpose processor chips used in manufacturing phones and computers are imports. For example, in 2019, China's IC import volumes were as high as US$305.55 billion.[4) Therefore, China's semiconductor

1) WSTS. https://www.wsts.org/esraCMS/extension/media/f/WST/4622/WSTS_nr-2020_05.pdf
2) CSIA. http://www.csia.net.cn/Article/ShowInfo.asp?InfoID=91411
3) http://www.chyxx.com/industry/202004/853495.html

latecomers need to be equipped to identify potential innovation outbreaks to tackle the catch-up dilemma. In particular, the international semiconductor industry has an inverted pyramid structure, which tends to prove Moore's law and result in an oligopoly where the already strong become more robust. In the "winner takes all" situation, semiconductor latecomers have difficulty adapting to a "high investment, large-scale application, and rapid iteration" mode of competition.

In previous studies, scholars believe that the leading role of the U.S. semiconductor industry stems primarily from the emphasis on technological innovation and regional cluster size (Lou et al., 2010; Ryu et al., 2022). In addition, other scholars have researched latecomers' catch-up in the semiconductor industry. For example, several conceptual and empirical articles address how latecomer firms obtain relevant knowledge and become innovative (Nepelski and de Prato, 2015; Ray et al., 2017; Haasis et al., 2018; Kuo et al., 2018). Catch-up is not simply imitating new technologies but achieving creative improvements and innovations along or beyond the development path of the pioneers (Lee and Kim, 2001). Latecomers' growth is achieved necessarily via technology accumulation for independent innovation; it is a correct way to catch up (Wang and Lim, 2019). The emergence of semiconductor firms from East Asian countries in advanced high-technology sectors has striking features over the past several decades (Mathews and Cho, 1999). Semiconductor latecomers play a form of technological catch-up by accumulating technological capacity, narrowing the gap with the more developed countries (Figueiredo, 2014). For example, South Korean semiconductor firms have expanded their technological capabilities by attracting high-level foreign scientific and technological talent, the practice ability to organize learning, and the reverse period investment strategy to further their independent development (Choung et al., 2000; Kim and Seong, 2010). South Korean governments also provide funds and policy support for semiconductor enterprise catch-up as the primary investment location to realize joint government, industry, university, and research institute cooperation to promote technological innovation (Lee, 2003; Choi, 2014; Kim, 2019). Moreover, in Japan, the government has implemented a series of measures for semiconductor technology workers and operators with a craftsmanship spirit, constituting the 'perfect match' for semiconductor latecomers to catch up (Okada, 2008). China's semiconductor manufacturers are showing only limited success in terms of catch-up in market shares and technology. Some

4) CSIA. http://www.csia.net.cn/Article/ShowInfo.asp?InfoID=91411

semiconductor latecomers in China are entrapped by 'introduction-backwardness-reintroduction-backwardness' (Rho et al., 2015). To achieve catch-up, China's semiconductor firms must have independent R&D activities, and the capacities of rapid technology learning play an irreplaceable role in their technology catching up (Toyama, 2006).

However, previous studies found no scholar who had selected a specific China's semiconductor firm for a case study from a micro perspective. Moreover, they do not discuss how to catch up with China's semiconductor latecomers. Therefore, to address this vacuum and examine the solution, we focus on the experience of a local semiconductor manufacturing firm 'SMIC,' which uses a single case method for its vertical research and examines China's semiconductor latecomers and how to catch up by innovation. SMIC was chosen for this study due to its impact on the semiconductor industry. As the front runner of Integrated Circuit Foundry in manufacturing capability, manufacturing scale, and comprehensive service in mainland China, it is an excellent example of the semiconductor industry. SMIC has made a breakthrough in the 1st generation FinFET technology, representing the most advanced level of independent R&D of IC manufacturing technology in mainland China. Its innovation history is relatively typical. For example, some success factors are shared with Huawei HiSilicon and other semiconductor firms.

Our study focuses on the following two questions. i) RQ1: what is the innovation path of catching up with semiconductor latecomers? ii) RQ2: What factors do semiconductor latecomers rely on to achieve an innovation path of catch-up? By answering these questions, we open the "black box" of the innovation paths of catch-up by semiconductor latecomers and guide for China's semiconductor latecomers to catch up in innovation. In addition, our findings have two main contributions to knowledge in this important area of the semiconductor latecomers catch-up. First, we report SMIC the process of catching up, and how to break an international monopoly by innovation. Second, we provide some suggestions for semiconductor latecomers to catch up, such as persistent technology R&D, Entrepreneur leadership, and policy and funding support from the government.

The rest of the paper is structured as follows: Section 2 reviews the literature, Section 3 presents the research methodology, Section 4 analysis the case, Section 5 discusses the findings, and Section 6 has the conclusion and provides the implications, limitations, and future research.

2. Literature review

Major countries worldwide have been promoting artificial intelligence (AI)-based intelligence as part of their national strategies to usher in the era of the fourth industrial revolution. Not only are the U.S. and China considered global AI powerhouses, but many countries classified as advanced are also developing AI strategies (Kim et al., 2022). With the economic rise of newly industrialized countries or regions such as South Korea, Singapore, and Taiwan, scholars' research on technology catch-up began to focus on these Asian emerging economies, and innovation catch-up paths and strategies became a research hotspot. For example, the scholars in South Korea have been plenty of studies in dealt with catch-up within the semiconductor industry, including technology learning (Kim, 1997; Chung, 2001), catch-up in technological capabilities (Lee and Lim, 2001), countries' policy (Choung and Hwang, 2000), and innovation strategy (Choung et al., 2014). Kim and Seong (2010) suggested that Samsung has focused on accelerating product development in its catch-up strategy. In the process of new technology development, Samsung has maximized first-mover benefits and protected itself from latecomer firms. Hwang and Choung (2014) used the Korean and Taiwanese semiconductor industries as examples. They proposed that differences in industrial specialization in catching-up countries can be attributed to the interaction between technological characteristics and institutional settings, including the role of corporate organization, industrial structure, and the public sector. Moreover, some scholars have also made research achievements for technology, capital, market demand, and business model in China's semiconductor industry (Toyama, 2006; Rho et al., 2015; Feng et al., 2018; Choi et al., 2020; Kong et al., 2016; Wang and Lim, 2021). For example, Liefner et al. (2019) took the case of Huawei in Germany. They suggested that collaborative R&D between firms, universities, and research institutes (URIs) in developed economies is an important tool for latecomers to catch up. Kuo et al. (2018) found that a leading Taiwanese OEM, Acer, has sought a new approach to creating value by using an innovation ambidexterity strategy to maximize its customer value and boost performance to achieve catch-up. Similarly, Senoner et al. (2021) suggested that artificial intelligence and semiconductors are inseparable, as semiconductor manufacturers have validated using interpretable artificial intelligence to improve process quality.

In addition, the factors influencing latecomer firms to achieve catch-up, the existing literature can be mainly divided into external and internal factors (Miao et al.,2018). The external factors mainly include the market and institutional environment, while the internal factors include capacity building, catch-up strategies, models, and other organizational factors. Existing research indicates that the technology paradigm change provides opportunities for latecomers to enter mainstream markets and outperform industry leaders (Lee and Malerba, 2017). The growing local market space and emerging market demand provide a competitive advantage for latecomers to catch up (Schienstock, 2007). Regarding the impact of the institutional environment, most studies have been conducted at the national level to distill the commonalities of the institutional environment behind the successful catch-up of latecomer firms in different countries (Hu and Mathews, 2005; Mazzoleni, 2008). In contrast, previous studies have focused on internal factors from the firm level. For example, Mathews (2002) constructed the 3L framework of Linkage, Leverage, and Learning from the perspective of intra-firm capabilities, using the Asia-Pacific semiconductor industry as an example to explain the mechanism by which latecomers create competitive advantage through international catch-up. Kim et al. (1997) pointed out that innovation catch-up capability is a system that includes several capabilities such as entrepreneurial (team) technological ambition, entrepreneurial vision, technological search, technological selection, technological absorption, and technological improvement. Chuang and Hobday (2013) suggested that semiconductor latecomers should be focused on both the accumulation of technological capabilities and the underlying absorptive capacity of each firm. Zhu et al. (2017) examined the catch-up of China's cell phone manufacturing industry from the business model innovation perspective.

3. Methodology

3.1 Case selection

SMIC was established in 2000 (SSE stock code: 688981, HKSE stock code: 00981, US OTC market trading code: SMICY). It is the fourth-ranked IC foundry in the world and the most technologically advanced, the largest and multinational IC manufacturing firm in mainland China. SMIC is headquartered in Shanghai and currently employs 17,681 people worldwide. SMIC's main business is the manufacture of IC chips based on its own IC designs or those of third parties, providing design and manufacturing services for 0.35μm to 14nm processes. SMIC also provides customers with complete foundry solutions with a seamless flow of services, including mask services, IP development services, and backend design services (including bumping services, wafer probing, final packaging, and final testing). Its goal is to help our customers shorten time-to-market cost-effectively with complete foundry solutions. SMIC has a global manufacturing and service base. For example, SMIC has a 300mm wafer facility, a 200mm wafer facility and a 300mm advanced process wafer facility in Shanghai, a 300mm wafer facility and a 300mm advanced process wafer facility in Beijing, a 200mm wafer facility in Tianjin and Shenzhen, and a 300mm bump processing joint venture in Jiangyin. SMIC also has marketing offices and customer service in the U.S., Europe, Japan, and Taiwan, China, as well as a representative office in Hong Kong, China. Currently, the top 10 international semiconductor design firms are also customers of SMIC, including Ti, Broadcom, Qualcomm, Nvidia, Marvell, LSI Logic, Infineon, and Epilda. SMIC's 2021 annual report shows revenue of US$5.4 billion from US$3.9 billion in the previous year. Its gross margin increases from 23.6% in 2020 to 30.8% in 2021.[5)]

3.2 Methods

Because the successful cases of breaking international monopoly by China’s semiconductor latecomers studied, and it is rare. Obtaining large sample data is extremely difficult. Thus, we use the method of single case longitudinal research. The specific reasons are as follows. On the one hand, a case study, as an important research method in the management field, is mainly used to answer how and why research questions and is suitable for observing and studying a series of reforms in the firm (Pettigrew, 1990). In this study, we research how semiconductor latecomers catch up with innovation, a dynamic process. Thus, it is suitable to adopt the method of a case study. On the other hand, through an in-depth description and analysis of a specific phenomenon, a single case study can hold a more comprehensive view and can thoroughly discuss the complex causal relationship between different variables in the event evolution cycle and better answer the why and how questions (Eisenhardt and Graebner, 2007). Therefore, this method is suitable for our descriptive and exploratory research.

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5) 2021 Annual Report. https://staticpacific.blob.core.windows.net/press-releases-attachments/1412196/HKEX-EPS_20220426_10228620_0.PDF

<Table 1> Data sources

Resource type	Source Name	Source Address	Data content
Literature	Academic Journal	https://scholar.google.com	Concept, features, and theory of semiconductor.
Firm’s website	Official website	https://www.smics.com/en/	Development history, products, and technology of SMIC.
Industry website	Seminews	www.semiinsights.com	Market share and competitors of SMIC.
	Sohu technology	http://it.sohu.com	
	Xinlang technology	http://tech.sina.com.cn	
Author observations	SMIC’s facilities	In Shanghai, Beijing, Tianjin, and Shenzhen.	Product R&D process and interviews with the SMIC’s managers.

Data source: By authors

3.3 Data source

Based on the principle of 'diverse data sources' and 'triangular evidence' (Yin, 2013). We cross-validated the data to avoid impression management and retrospective sensemaking problems associated with primary data, reducing information bias and improving the reliability and validity of the study. Our data include four sources: i) the literature from academic journals. ii) firm's website, such as the official website of SMIC. iii) industry websites, such as semiconductors and industrial media websites. iv) author observations. We conduct practical observations and semi-structured interviews. The interviewees include top management, middle management, technical staff, and firm employees. The specific data sources of this study are shown in <Table 1>.

4. Case analysis

SMIC's path of catching up with innovation has experienced three battles. The first battle achieved technical breakout (2000-2003), the second battle faced a competitive dilemma (2003-2009), and the third battle ushered the independent innovation (2014-present). Ultimately, SMIC achieved the catch-up of the latecomers.

4.1. The First Battle: Technology Breakout (2000-2003)

Considered the hope of Chinese chips, SMIC chose the Cayman Islands as its registered office at the beginning of its creation to avoid the embargo on China's advanced technology under the Wassenaar Agreement. SMIC has achieved capital support by giving money and land by the presence of a large and dispersed number of foreign shareholders. Moreover, SMIC has the technology and customer resources from top-tier international firms, making it a star-level "international team" after its establishment. These resources help SMIC seize the window of opportunity in the market and lay the foundation for rapid market expansion. In 2003, SMIC purchased Motorola's 8-inch production line in Tianjin when it was not yet three years old. Also, SMIC made history again by building the first 12-inch production line in mainland China in Yizhuang, Beijing. SMIC has built three 8-inch and one 12-inch production lines from scratch in less than three years, initially completing the accumulation of essential IC production capacity and successfully achieving a technical breakout.

4.2. The Second Battle: Competitive Dilemma (2003-2009)

SMIC's initial process was similar to Taiwan Semiconductor Manufacturing Company (TSMC), also a foundry. They constituted direct competition, setting the stage for litigation between SMIC and TSMC. First, in December 2003, TSMC sued SMIC in a California court for $1 billion in damages due to technical infringement. In 2005, SMIC chose to settle the case, paying TSMC a total of US$175 million in damages and signing a power of defeat agreement that 'all of SMIC's technology is subject to TSMC's free inspection.' Second, in August 2006, TSMC again cited SMIC's violation of the Settlement Agreement, accusing SMIC of using TSMC technology in its latest 0.13 μm process and demanding compensation. In November 2009, a California court ruled against SMIC, and SMIC surrendered 10% of its shares in addition to a US$200 million cash payment for TSMC. With this win, TSMC has successfully stopped SMIC's growth in the North American market, directly causing SMIC's market in the U.S. to shrink. In addition, SMIC's founder, Richard Chang, resigned as Executive Director, President, and CEO because of 'personal reasons,' SMIC has been in a long period of turmoil ever since.

4.3 The Third Battle: The Path of Independent Innovation (2014-present)

4.3.1 Policy support from Chinese government

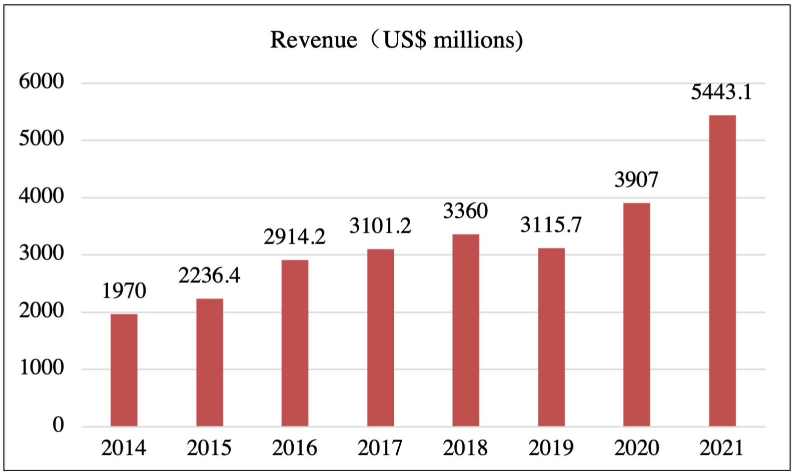
Since 2014, the Chinese government has successively issued supporting policies for developing semiconductors. For example, 'The National Integrated Circuit Industry Development Promotion Program' was published in June 2014[6], and the National IC Industry Investment fund was established by the Ministry of Industry and Information Technology (MIIT) in September 2019[7], in which investment amounted to RMB 140 billion. SMIC, which represents the most advanced level of self-developed IC manufacturing in mainland China, has also received strong funding support from the Chinese government. For example, SMIC's 2020 financial results show that in May 2020, National IC Fund II and Shanghai IC Fund II invested US$150 million and US$750 million as registered capital. Moreover, in December 2020, the National IC Fund II reinvested $1,224.5 million to support the development of SMIC, focusing on 12-inch wafer IC production and manufacturing [8]. In addition, SMIC's annual reports in 2020 and 2021 show that SMIC received RMB 2816 million and RMB 412 million for advanced process, mature process, and other government programs, respectively (see <Table 2>). The government grants received by SMIC are focused on 14nm and more advanced processes and manufacturing technologies with significant market space for applications such as mainstream mobile platforms, automation, and cloud computing. It effectively contributes to the rapid development of high-potential areas such as smartphones, high-speed rail, smart grid, ultra-high-definition video, and security systems in China.

<Table 2> SMIC's government program funding in 2020-2021 (RMB Millions)

Government program funding	Year 2020	Year 2021
Advanced processes	1857	76
Mature process	42	12
Other	917	324
Total	2816	412

Data source: SMIC's annual financial reports in 2020 and 2021

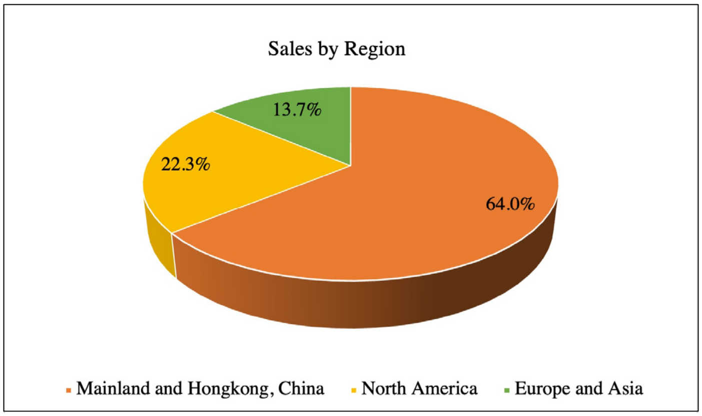
6) http://www.gov.cn/xinwen/2014-06/24/content_2707281.htm
7) http://www.gov.cn/xinwen/2014-10/14/content_2764849.htm
8) https://smic.shwebspace.com/uploads/e00981.pdf



<Figure 1> SMIC's revenue from 2014 to 2021

Data source: SMIC's annual financial reports

The massive funding and policy support from the Chinese government has enabled SMIC to increase production capacity significantly. SMIC's revenue continues to increase. For example, SMIC's 2021 annual report shows that its wafer product production volume reached 6.75 million wafers. In addition, SMIC's revenue shows an increase from 2014 to 2021 (as shown in <Figure 1>). In particular, in 2021, SMIC's revenue was US$5,443.1 million, an increase of 39.3% year-over-year. Among them, revenue from the foundry business is US$4,982.2 million, an increase of 43.4% year-over-year.



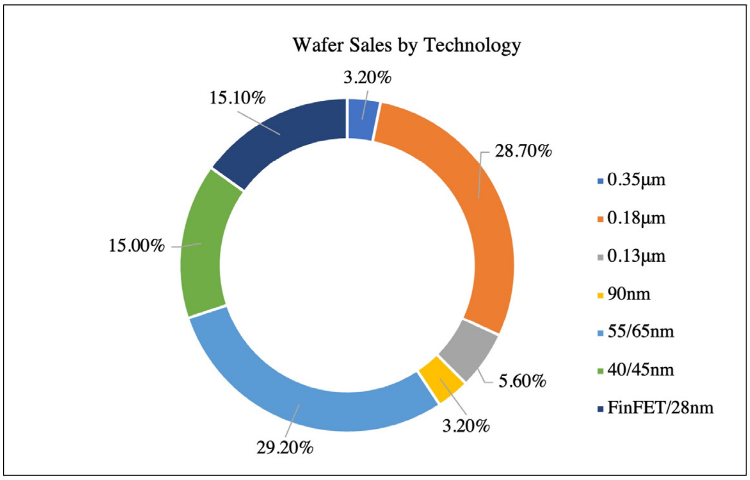
<Figure 2> SMIC’s sales by region in 2021

Data source: SMIC's 2021 Annual Reports

Also, SMIC's 2021 Annual Report shows that business revenue grew in all regions (as shown in <Figure 2>). Among them, revenue from Mainland China and Hong Kong accounted for 64.0% of total business revenue; revenue from North America accounted for 22.3%; and revenue from Europe and Asia accounted for 13.7%.

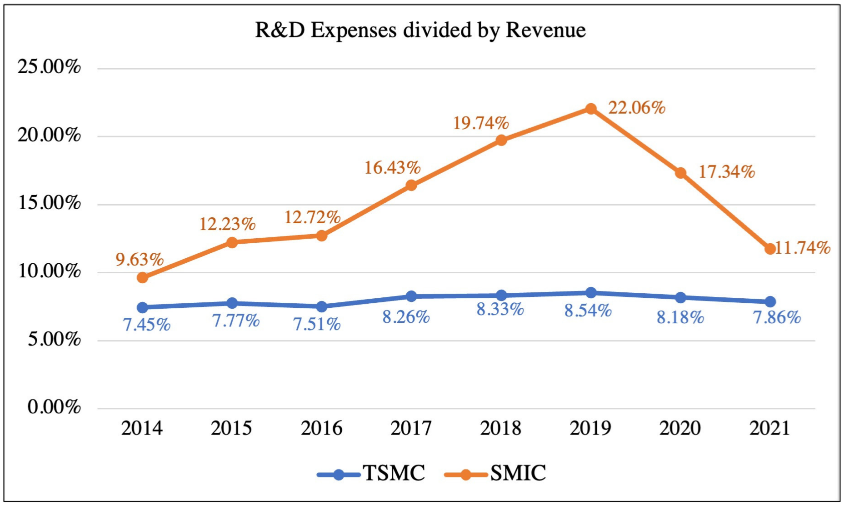
4.3.2 Technical Capabilities

First, SMIC is equipped with China's most advanced photomask production line with technology capabilities spanning 0.5 μm to 45nm, including logic circuits, mixed-signal/RF circuits, high voltage circuits, system-on-chip, embedded and other memories, silicon-based liquid crystals, and image sensors. SMIC's 2021 annual report shows that the percentage of revenue from foundry operations in 90nm and below is 62.5%. The percentage of revenue from 55/65nm technology is 29.2%, from 40/45nm technology is 15.0%, and from FinFET/28nm technology is 15.1% (as shown in <Figure 3>). In addition, SMIC is not only a chip foundry but also provides a full set of value-added services to customers, including design services, photomask manufacturing, chip fabrication, and test services. A third-party vendor provides its packaging and final testing services. The firm partners with world-class design services, intelligent modules, standard cell libraries, and EDA tool providers, who provide customers with extensive and highly flexible design support. Moreover, in terms of mature technology, the eight major product platforms laid out by the firm in the past four years have penetrated the



<Figure 3> SMIC's Wafer sales by technology analysis in 2021

Data source: SMIC's 2021 Annual Reports



<Figure 4> The comparison of SMIC and TSMC in R&D expenses to revenue

Data Source: Annual financial reports from SMIC and TSMC.

existing traditional markets such as mobile, consumer products, and incremental markets such as IoT, panels, electric vehicles, and new energy. In terms of advanced technology, marginal output benefits continually improve under the continuous efforts of the dual-preparation effect of cultivating a diversified customer base and multi-product platforms.

Second, SMIC focuses on R&D investment in technology, and from 2014 to 2021, SMIC's R&D expenses to revenue are much higher than TSMC's, around 8% (as shown in <Figure 4>).

Third, SMIC has accumulated numerous core technologies and formed a comprehensive intellectual property system within the IC field. For example, on December 31, 2021, SMIC accumulated 12,467 granted patents, including 10,698 invention patents. Also, the firm has 94 integrated circuit layout designs.

4.3.3 Entrepreneurs and Talent Team

The legendary Meng-Song Liang joined SMIC in 2017, and since starting the path of independent R&D, SMIC has crossed over from 28nm to 14nm in less than a year and spent less than 300 days to bring the 14nm process to mass production level. <Table 3> shows that in 2015, TSMC achieved 16nm mass production and moved towards 10nm, and in 2018 has achieved 7nm mass production. In contrast, SMIC is still at the 14nm technology level in 2019, indicating that SMIC's technology is 2-3 generations behind TSMC. Therefore, the biggest

<Table 3> The comparison of chip process between SMIC and TSMC in 2014 to 2019

Year	2014	2015	2016	2017	2018	2019	2020	2021
SMIC		28nm				14nm	FinFET	12nm
TSMC	20nm	15nm	10nm		7nm			

Data Source: Company's official website and reports compiled by authors

problem SMIC is still the technology gap. However, starting from 2020, SMIC focuses on advancing the FinFET process, and the 12nm process R&D has entered the customer introduction stage with key breakthroughs. Future advanced production line R&D will help SMIC bring broader development space.

In addition, SMIC's development is inseparable from talent cultivation. Through multiple measures such as multi-channel recruitment, expansion of talent development avenues, and establishing medium- and long-term incentive mechanisms, the firm further optimizes the structure of the talent pool, building a dedicated and innovative team.

5. Discussions

We strung the key events and 'logic mouth' for SMIC's vertical history evolution. Using a snowballing technique (Rasiah, 1994; Zhang, 2020), we found that SMIC's path of innovation stems primarily from the following aspects.

5.1 Seizing the opportunity window of the market in mainland China to expand production capacity

As mainland China becomes the world's manufacturing center, it will correspondingly become the largest semiconductor manufacturing center in Asia and the world. In addition, the Chinese government has been providing policy support to the semiconductor industry. By seizing the opportunity window of the market in mainland China, SMIC has fully expanded the demand for its lower-tier product lines targeting mainland China, expanding its production supply and reaping economic benefits. Our finding is consistent with the results of Rho et al. (2015), who argue that latecomer firms should seize the market opportunity to catch up. In particular, as the overall absorptive capacity of Chinese players increases, the changes and emergence of a new generation of technologies can be a window of opportunity for leapfrogging (Lee and Lim, 2001; Lee and Malerba, 2017).

5.2 Focusing on technology accumulation and realizing independent innovation

SMIC's R&D center continues to expand its R&D capabilities in specialty processes and enhance the competitiveness of mature and advanced processes by its overall strategy and customer needs. The company's product performance has been greatly enhanced. For example, the case analysis results show that SMIC pays much attention to investment in technology R&D for its innovation. SMIC's R&D expenses to total revenue in 2019 reached 22.06%, while TSMC's R&D investment ratio was only 8.54% in the same year, indicating that SMIC's R&D investment is nearly three times higher than TSMC's. SMIC's large-scale R&D investment has provided a good foundation for a technical breakout. Thus, semiconductor latecomers' focus on technology accumulation is conducive to realizing their independent innovation. Our finding is consistent with Rasiah (2010), which similarly argues that high value-added activities related to design and R&D can strengthen the competitiveness of semiconductor latecomers.

5.3 Strategic leadership of entrepreneurs is a key factor

The most important thing for latecomers to catch up with the innovation path is to have strategic endurance, which stems from the industrial vision of entrepreneurs. As Ren Zhengfei, the founder of Huawei, said that strategic patience is non-opportunistic. It is expressed as a firm's durable ability to adhere to its strategic mission over time. The strategic leadership of entrepreneurs can provide the foundation for latecomers to steadily improve their independent innovation capabilities. SMIC's rapid growth also depends on the strategic leadership of several vital entrepreneurs, including Richard Chang, Shang-Zhou Jiang, and Meng-Song Liang. Especially, Meng-Song Liang joined SMIC in 2017, and since then, SMIC has made a "linear overtaking" jump in high-end technology. Chips have increased from 3% to 95% of the excellent rate. SMIC has officially entered the 14nm era directly from the 28nm era, and its 14nm chips have increased from 3% to 95%. Meng-Song Liang plays a crucial role in advancing the rise of SMIC's technology. Thus, entrepreneurs' leadership can be crucial for latecomers on their path to catching up with innovation.

6. Conclusions

6.1 Main findings

This study focuses on a specific case SMIC in China's semiconductor latecomer and analyzes its innovation path using a case vertical study method. As a benchmark semiconductor foundry in China, SMIC's innovation path of catch-up is a microcosm of the development of China's semiconductor industry. Our findings are summarized as follows: First, SMIC's creative journey of catching up is a mixed blessing. SMIC has undergone three stages: technical breakout in the early stage, the competitive dilemma faced in the middle stage, and the path of independent innovation in the later stage. Its development history shows that the catch-up innovation path of semiconductor latecomers should be good at seizing windows of opportunity in the market, entrepreneurs pay attention to strategic leadership, and firms focus on accumulating their R&D technologies. This finding partially supports the view of Rho et al. (2015), who also argue that semiconductor firms combine human capital and R&D capabilities, China's latecomer position is expected to rise, and technology catch-up will become visible. Second, SMIC's success shows that the innovation path for semiconductor latecomers to achieve catch-up depends on multiple factors, including capital assistance, talent gathering, and tacit cooperation between entrepreneurs and the government. The result is consistent with Rasiah et al. (2010), who also argue that the role of the government through funding and development of human capital was critical to local semiconductor firms' technological catch-up process in China.

6.2 Theoretical and practical implications

The innovation experience of SMIC's successful catch-up has some theoretical contributions and practical implications. i) In terms of theoretical contributions, this study adds a contribution to the existing literature by introducing the innovation Path of Catch-up by SMIC case from Chinese semiconductor latecomers. Few previous studies have focused on the innovation paths of semiconductor latecomers in mainland China to catch up (Feng et al., 2018). Instead, scholars have focused more on the innovation paths of semiconductor firms in South Korea, the U.S., and Taiwan, China (Choung et al., 2014; Hwang and Choung, 2014; Lou et al., 2010). ii) In terms of practical implications. First, government policy guidance and funding support are essential for local latecomers to catch up. We believe the Chinese government should continue implementing favorable semiconductor firms' policies. Second, the innovation path of latecomer firms is catching up, and the leaders of the firms must have strategic patience and focus on entrepreneurship. Third, the latecomer firms' innovation path of catch-up needs to rely on long-term R&D investment and technology accumulation, which will be able to build their market gradually through its unique performance. For example, SMIC's strong focus on R&D has provided a good foundation for its success in catching up.

6.3 Limitations and future research

Some limitations leave room for future research on three aspects. First, we only use a single case that targeted the innovation path of catching up for the semiconductor latecomers in China. Future studies should further consider the industry attributes and characteristics of the case, introduce more latecomer firms as samples, and select multiple cases across fields for in-depth research to compare the different paths of innovation in catching up. Second, our study is a qualitative analysis. It inevitably has some subjectivity and incompleteness in case materials. Future studies should explore the latecomer firms’ innovation paths of catching up by using a combination of qualitative and quantitative approaches to reflect the evolution of catching up with more intuitive data. Third, our study has limited analysis of the dynamic process of the cases. Future studies should strengthen the dynamic tracing of case growth trajectories to propose a theoretical model.

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