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How latecomers catch up to build an energy-saving industry: the case of the Chinese electric vehicle industry 1995-2018

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How latecomers catch up to build an energy-saving industry: the case of the Chinese electric vehicle industry 1995-2018

ABSTRACT

This research identifies how windows of opportunity (WOP) emerge and influence the catching up process of the Chinese electric vehicle (EV) industry between 1995 and 2018 by analyzing technological, institutional, and market demand elements of the WOP. Our case study indicates that government policies play a vital role. Along with the development of Chinese EV industry, government policies evolve from initiation to consolidation and finally reposition. Meanwhile, WOP emerge but diverge in their patterns; from institutional to technological and finally to the market demand WOP. Our study further elaborates the interplay of the above-mentioned three kinds of WOP, which provide feedback to the government authorities and work jointly to facilitate the catching up of Chinese EV industry. Based on the evidence of the Chinese EV industry, we continue the discussion of the emergence and interplays of WOP during the industrial catching up in latecomer countries like China, who is eager to build an energy-saving industry. Our case study provides a fine-grained analysis of policy evolution and its role in opening the different kinds of WOP, which eventually contribute to the successful catching up of a latecomer industry. It also offers new insights for policymakers when building a sustainable system.

Keywords: Windows of opportunity; latecomers; catching up; electric vehicle industry; emerging market; China

Highlights

- The catching up of the Chinese EV industry is mainly led by governmental policies
- Governmental policies evolve from initiation to consolidation and finally to reposition
- Institutional, technological, and market demand windows of opportunity emerge and interact in industry catching up
- WOP show the critical features of heterogeneity and dynamics in the catching up process

1. INTRODUCTION

Statistics from World Bank showed that 23% of global CO₂ emissions are from the transportation sector (Baeumler et al., 2012, p.237-238). There has been progress towards a consensus to reduce CO₂ emissions in the transport sector and improve its energy efficiency (United Nation Climate Change Conference, 2017). New energy vehicles, including electric vehicles (EVs) and other clean-energy vehicles, are seen as increasingly advantageous in light of energy conservation and environmental protection (Axsen, 2013). Developing new energy vehicle industry or EV industry is valuable and indispensable in reducing greenhouse gas emissions (IEA, 2019)

As China accounts for the most CO₂ emissions globally (Ritchie and Roser, 2020) , the Chinese government promotes the EV market to tackle the pollution problems arising from car emissions and supports progress towards a sustainable transportation system. Underpinning this policy there exists the additional issue of energy safety. The percentage of China's oil imports being much higher than the international security threshold (65%). Also, with over ten years development since 1995, China has become the world's largest EV market (50.40% of global EV volume). By 2050, EV vehicles are expected to become the dominant element of the Chinese car market (Sun and Wang, 2018). The evolution of the Chinese EV industry demonstrates successful catching up; the country gradually closed the gaps with international leaders in building energy-saving industries (Zhao et al., 2019).

The windows of opportunity (WOP) play an essential role among the factors that accelerate the Chinese EV's catching up (Yap and Truffer, 2019). WOP is defined as the industrial dynamic discontinuity and is categorized in technological, market, and institutional domains (Lee and Malerba, 2017, p.339). For successful catching up, latecomer companies' strategies and capabilities resulting from their understandings of and reactions to WOP are critical in each domain (Lee and Malerba, 2017). Our study follows such categorizations and

examines how different kinds of WOP emerge and how certain types may interact with each other to facilitate catching up. Yet, the contributions of the potential interplays of different kinds of WOP to catching up remains unclear. Studies in how to respond to and utilize WOP to realize catching up — especially those in emerging industries — are insufficient. For instance, established literature on WOP sheds light on the catching up of developed and newly industrialized economies, such as Japan and Korea (Malerba and Nelson, 2011; Shin, 2017). How WOP might emerge and help latecomer countries in catching up is still unknown. Therefore, we selected the newly emerged electric vehicle (EV) industry in China and studied this research question: *how windows of opportunity emerge and influence the catching up process of an emerging industry?*

This paper focuses on the technological catching up of an emerging industry of a latecomer country. In particular, with attention to the potential interplay of different types of emergent WOP. Studies on catching up strategies consider how latecomers close the gaps to leaders (Malerba and Nelson, 2011). In the selected automotive industry, the latecomers are a local group of firms in China, and the incumbents are an international group of automotive firms with industrial leaders operating in China. Furthermore, latecomer domestic firms and leading foreign entrants may benefit from preferential policies when working in China (Gao, 2015; Xiong and Monin, 2015). Thus, the institutional regulations would play a critical role in the Chinese EV sector's catching up. This research aims to identify how critical governmental policies related to EV may influence the emergence of the WOP. It also analyzes how this WOP may interplay and jointly contribute to the catching up process of the Chinese EV industry. This study examines how different kinds of WOP emerge and lead domestic latecomers to respond to the evolution of the industry in China. So doing expectedly allows us to enrich our understanding about energy-saving policy decision-making. Our study provides new insights on policymakers' decision-making when constructing sustainable development,

not only for an environmental-friendly industry but also for building a reliable national system for the future.

2. LITERATURE REVIEW

2.1 Catching up

Lee and Malerba (2017) define the catching up process as reducing the gap in market competence between domestic latecomers and foreign incumbents. The latecomer's market share dominance demonstrates its success in catching up. Existing studies on catching up mainly focus on learning perspectives (Guennif and Ramani, 2012) and capability evolution (Fan, 2006). At the industrial level, studies of catching up processes emphasize the role of windows of opportunity (WOP) (Kang and Song, 2017).

Capability building is considered to be essential for latecomers in seizing technological and market WOP. Latecomers should consider the economic, institutional, market, and social factors to facilitate the technological capability building. Leading incumbents can create barriers to prevent latecomers' catching up. Therefore, latecomers must develop technological innovation, maximize local advantages and learn from foreign incumbents to break the obstacles (Du et al., 2017). Other studies identify the importance of government support in the catching up process, such as: R&D support in the Chinese wind turbine industry (Qiu et al., 2013), policy design for improving Nigeria's renewable energy (Gungah et al., 2019), and preferential government policies in the Chinese hypermarket industry (Xiong and Monin, 2015).

2.2 Windows of Opportunity

WOP have been widely applied in catching up studies. Perez and Soete (1988, p.460) state that "catching up involves being in a position to take advantage of the window of opportunity"

created by technological transitions temporarily. Perez and Soete (1988) coined the term “windows of opportunity,” referring to the transition of techno-economic paradigms in the process of latecomers forging ahead and catching up with forerunners by adapting the new paradigm. Scholars have noted that the emergence of WOP may generate from changes to the prevailing policy, technology, and market demand (Kang and Song, 2017; Lee and Malerba, 2017; Lema et al., 2020). Firms’ responses and the evolution of sectoral innovation systems influence the opening and closing of WOP (Lee and Malerba, 2017). Vértesy (2017) view government support, talent training, financial and technological capability as “preconditions” for catching up. These work alongside WOP to influence the firms’ catching up processes. Other scholars highlight the internal factors of firms when WOP emerge, such as the agility of emerging firms (Lema et al., 2020) and capabilities to interact with the windows (Xu et al., 2014). The path-following catching up strategy can enhance the competitive advantages of latecomers in the early stages of industry evolution. But Lee and Lim (2001) also identify the disadvantages of technology imitation and believe that independent, innovative capabilities and a path-creating strategy will be more effective in attaining successful catching up. The taxonomy of Lee and Malerba (2017) organizes the various WOP into three types relevant to their association, with institutional, technological and market demand factors.

Lee and Malerba (2017) further explain why latecomers can overcome the entry barriers, gradually catch up, and forge ahead and can potentially revert backwards. Early studies also demonstrate that those market opportunities that emerged along with the time and changes are vital in catching up processes (Malerba, 2004). During the evolution of the policy and contexts, abundant potential opportunities may exist within “the houses with windows”, and there needs to be “external or internal strengths” to “install” and “open” the “windows” and seize the potential opportunities inside the “houses” Lee and Malerba (2017). They further argue that

the critical elements of the three different WOP windows, namely technological, market demand, and institutional windows, are crucial to catching up.

Technological WOP

The literature reveals that disruptive innovation may alter market positions if incumbents fail to adapt to new technologies (Chandy and Tellis, 2000). This failure may arise due to risk avoidance regarding the new technology or technology lock-in with the existing technologies. The latter being defined as an “incumbent trap” (Lee and Malerba, 2017). However, latecomers can adopt new technologies by learning from incumbents without the potential technology lock-in or inertia (Christensen, 1997). In this situation, technology-related WOP may emerge, providing latecomers with the possibility to catch up (Lee and Malerba, 2017).

Market demand WOP

New demand for innovative products and services can present opportunities to existing players (Mathews, 2005). Some industrial leaders fail to adapt to change due to a preference for remaining with current market positions. This creates a market window for latecomers to catch up (Mathews, 2005). In the interim, many multinational enterprises implement a global strategy with a low level of localization. This conduct leaves local latecomers’ market WOP with local advantages (Malerba, 2004).

Institutional WOP

Lee and Malerba (2017) explain institution-related WOP as opportunities generated by governmental support, such as beneficial policies and incentive plans. Local governmental support (i.e., taxation and R&D budgets) can support latecomers in developing their

capabilities in innovation, stimulating international collaboration, and deploying local market resources (Malerba and Nelson, 2011).

The opening of WOP can bring forth different responses from incumbents and latecomers, thereby causing changes in industrial leadership (e.g., Kim et al., 2013; Malerba and Lee, 2020; Zhou et al., 2020). For instance, in the sectors where the characteristics of the technologies are precise, explicit, and are easily embedded in equipment, the technological WOP tends to occur. This can be seen in the case of the catching up of Korean firms to that of Japanese counterparts (Jung and Lee, 2010). Hence, this paper examines the signals of catching up and WOP. This is achieved by comparing and analyzing the evolution of EV policies, the fluctuation of the number of EV patents, and sales volume between selected foreign incumbents and domestic EV latecomers.

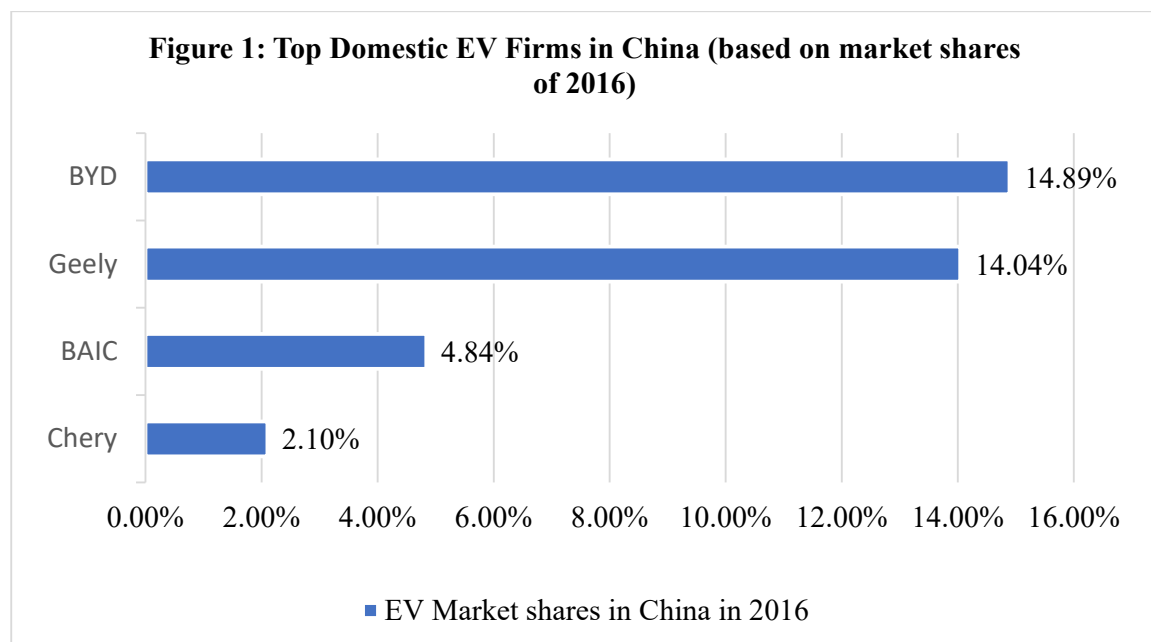
3. METHODOLOGY

3.1 Method

To analyze the catching up on the Chinese EV industry phenomenon in-depth and answer the research question of “how”, a case study approach is employed (Yin, 2014). This enables us to capture the contextual situation in the catching up of the Chinese EV industry and provides us with a better understanding of the interactivity between complex factors. We answer an explanatory question of “how”, which presents the need to trace the chronological sequence of interrelated events and identify their association (Yin, 2014). Therefore, the research question points to a case study investigating the current condition where relevant factors are not controllable.

3.2 Sampling

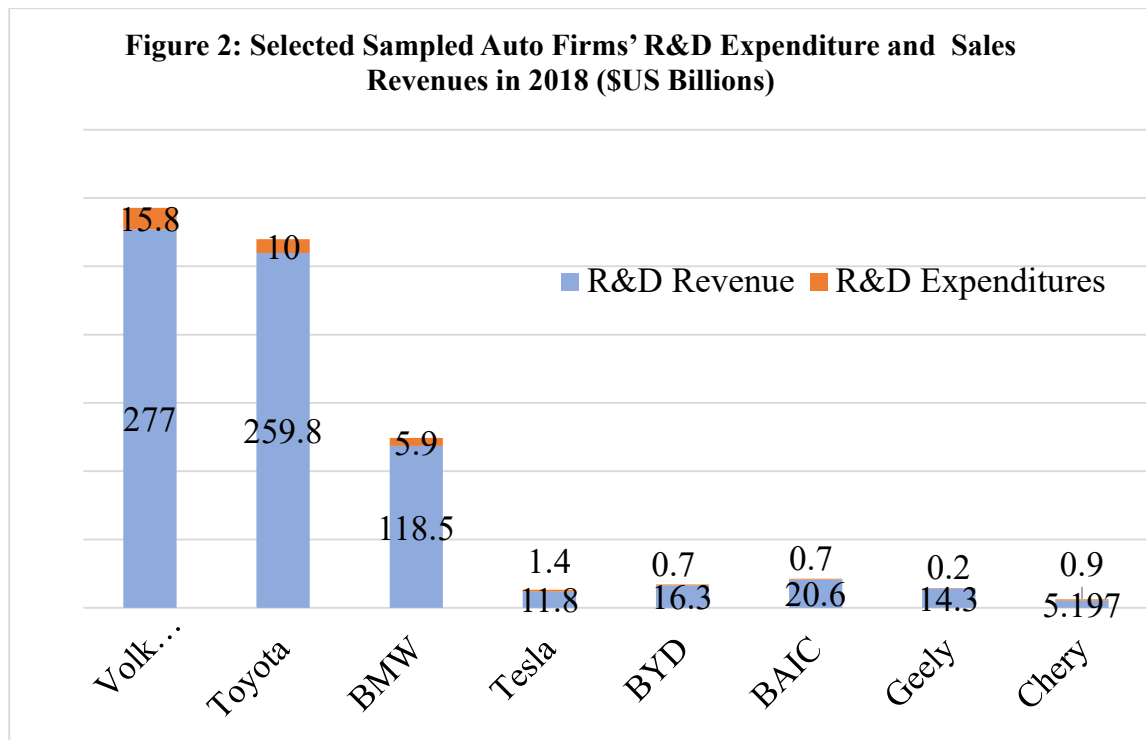
Faced with the growing market demand and the challenges arising from the problems of continuous increasing pollution, in 2012 the Chinese central government listed the Chinese electric vehicle (EV) industry as a strategic emerging industry (State Council, 2012). This action signifies that the local government is to provide financial and policy support such as tax credits and exemption to EV automakers and EV purchasers (Technavio, 2016). This paper divides the Chinese EV industry into the Chinese latecomer group and the foreign incumbent group. The domestic latecomer group includes the local EV firms: BYD Auto, BAIC Group, Geely Automobile, and Chery Automobile, based on the EV market share in 2016 (CATARC, 2016, Figure 1).



Source: Summarized from China Automotive Technology & Research Center, 2016

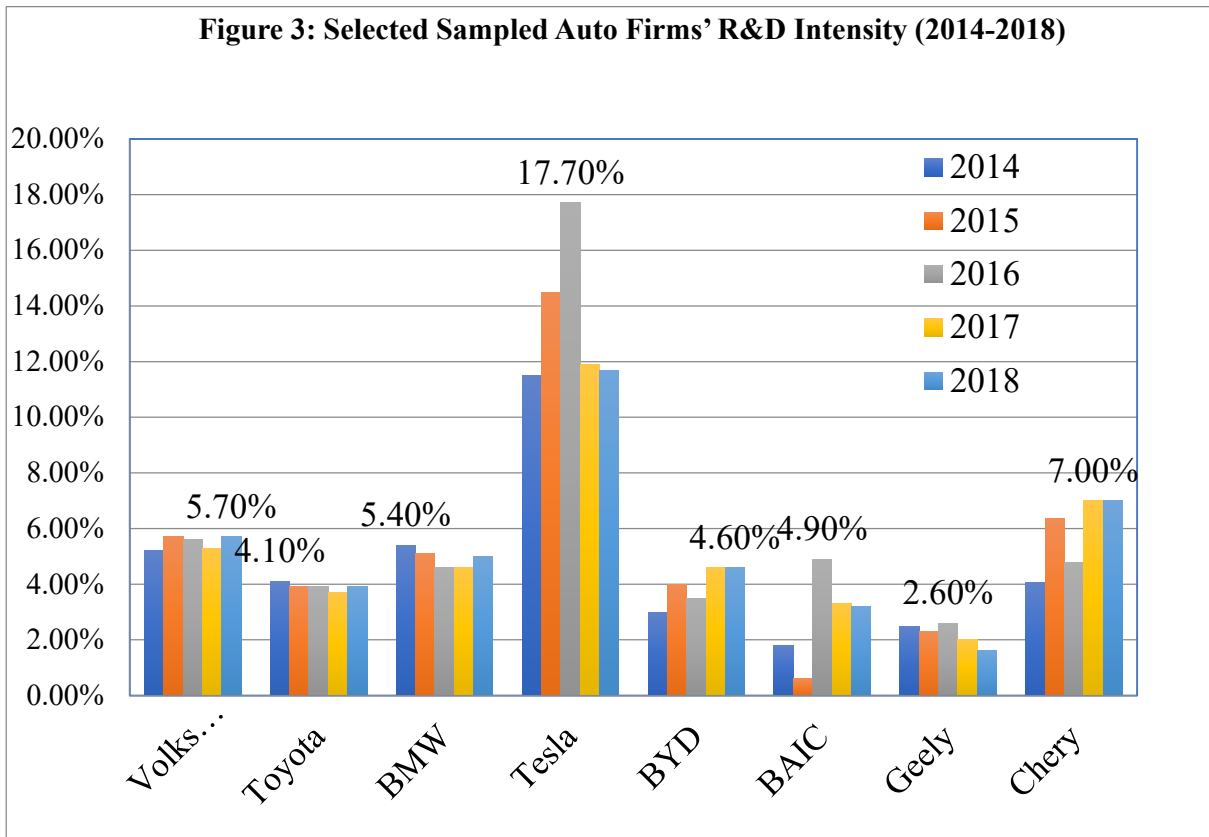
The foreign incumbent group includes BMW (Germany), Tesla (United States), Toyota (Japan), and Volkswagen (Germany). These two groups are selected because of the difference between the country-of-origin effect (Fortanier and van Tulder, 2009) and their technology

level, market experience, and production capacity in each group. As Figure 2 demonstrates, a considerable gap exists in R&D expenditure between the domestic EV latecomers and the foreign incumbents. Since EV R&D programs come with high initial investment costs and long-time frames for returns on investments, domestic automakers may face the difficulty of technological catching up. Such an empirical setting meets the research question of this paper.



Source: Summarized from PWC, 2019. 2018 Global Innovation 1000 | Most Innovative Companies

Figure 3 shows that the gap in R&D intensity between the sampled foreign and domestic firms narrowed between 2012 to 2018. To illustrate the general EV development of the country, we use the EV development of the leading domestic and foreign firms as representatives.



Source: Summarized from PWC, 2019. 2018 Global Innovation 1000 | Most Innovative Companies

3.3 Data Source

As Table 1 demonstrates, the data comes from three sources: semi-structured interviews, archival data, and field observations. Data was collected via a two-stage process. 30 semi-structured interviews and secondary data from April to July 2018 were also collected. In this round, we first obtained the critical policies issued by the Chinese government, in order to understand the influences on the development of the Chinese EV industry, and the WOP that emerged along with the industry evolution. For the second round, in June and July 2021, an additional 15 semi-structured interviews were conducted, as well as more secondary data. In this round, the data collection focuses on how different kinds of WOP interact and work together to facilitate the catching up processes of the Chinese EV industry. In total, we collected

45 semi-structured interviews, 76 government and industry reports, other secondary data (such as literature and press reports), as well as field observations of selected Chinese EV firms.

3.4 Data Analysis

Table 1. Data Sources

Semi-Structured Interviews	Interview Time	First Round: April to July 2018, 30 interviews	Second Round: June to July 2021, 15 interviews
		2,085 minutes	
	Total Informants	45 Informants	
	Targeted Informants	EV firms' managers; Industry experts from both domestic and foreign EV firms	
	Language	Interviewed in Chinese and then translated into English	
Archival data	Existing literature and Reports	76 copies (Government reports, Industry reports, Firm reports, Media reports, and Literature on Chinese EV industry and EV firms)	
Field Observation	Selected fields	Record the selected EV maker's products and services in their marketing and sales departments	

Following the case study approach, we aggregated and classified the archival data and to analyze the periodical characteristics we utilized categorization and theme analysis techniques (Miles and Huberman, 1984). Assisted by NVIVO 12, we established coding terms to analyze the responses from the selected domestic EV firms and to set their current catching up strategies. The coding process included selecting initial codes, axial codes, selective codes and cited examples. Any errors and misunderstandings that appeared in the coding were carefully clarified and corrected. Similar to Zhao et al. (2019), we followed the national five-year plan announced by the central government of China and the development of the Chinese EV industry to examine how WOP may emerge and interact alongside the industry evolution. We

summarized the three critical stages of the Chinese EV industry as the policy initiation (1995 to 2005), policy consolidation (2006-2015), and policy reposition (2016 to 2018). This was followed with the analysis of the critical roles of WOP as well as their interplays.

4. FINDINGS

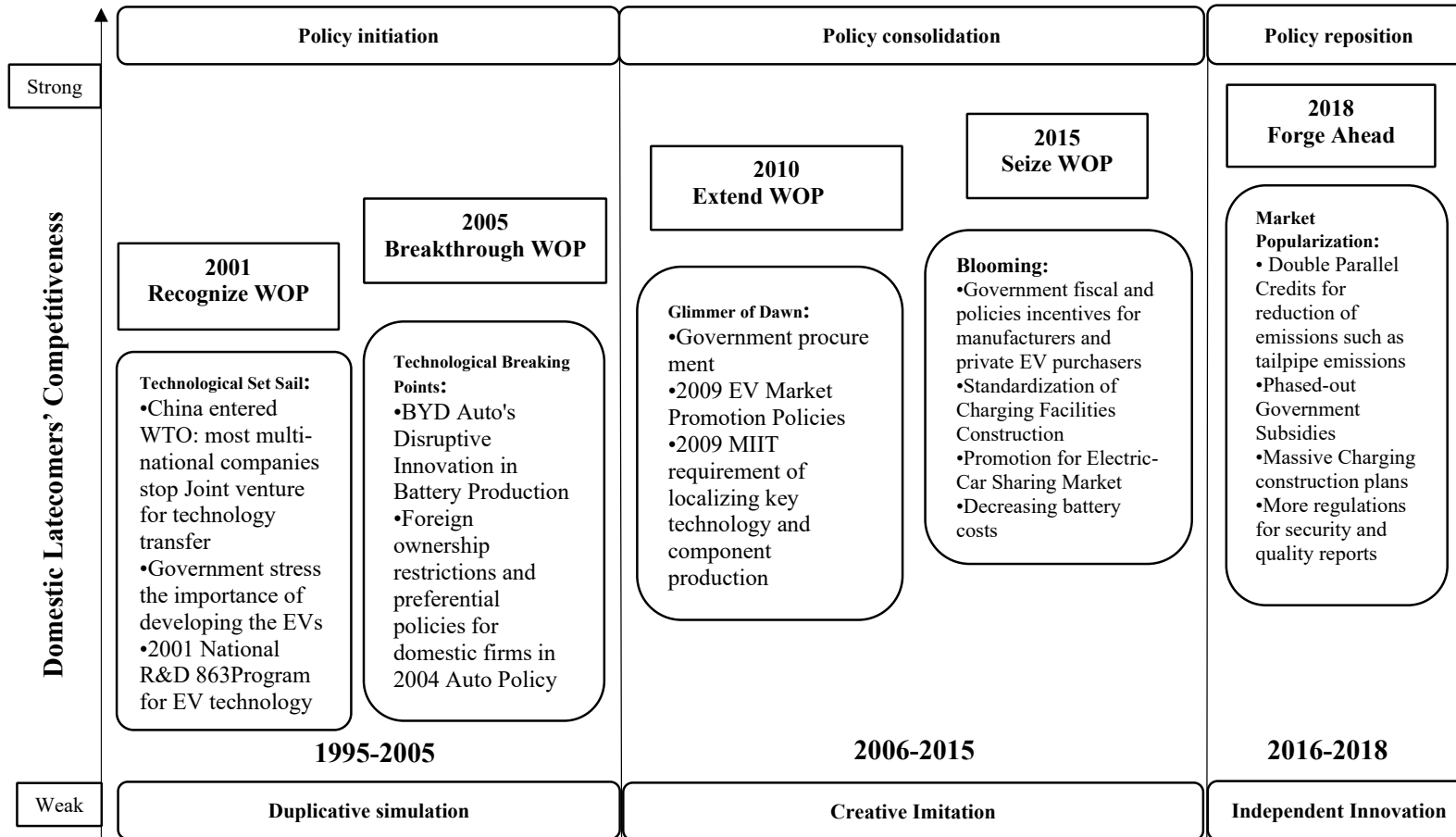
4.1 Policy-leading catching up in the Chinese EV industry

In the past two decades, the Chinese EV industry has grown from its humble beginnings and has seen rapid development. Our interview results indicate that EV development experienced three critical stages marked by policy evolution along with Chinese industry history. The three stages are policy initiation (1995 to 2005), policy consolidation (2006-2015), and policy reposition (2016 to 2018). This is shown in Figure 4. Chinese central and local policies have played crucial roles in each stage.

4.1.1 Policy initiation and industry emerging (1995 to 2005)

Similar to many other industries' catching up efforts, the catching up of the Chinese EV industry commenced from its attempt of duplicative simulation of foreign incumbents. During this emerging period, the government, enterprises, and institutions jointly demonstrated the concept of EV as a new automobile industry trend. The demonstration purpose held greater significance than its practical application. The main objectives of the Chinese government were to construct industry policy and approve new energy vehicle production qualifications for automobile manufacturers in China. This production of new energy vehicles were mainly for some demonstrative and promotional projects in the public sector.

Figure 4. Catching up progress in the Chinese electric vehicle industry



During this stage and from a policy perspective, the central government issued many favorable policies to facilitate the start of its domestic EV industry. The government formulated some epoch-making policies as shown below.

In the early 1990s, the Chinese government launched an international collaborated program with the United Nations called “*The Clean Energy City Plans*” to promote EVs. This move was considered to significantly affect market trends. It also announced that the traditional automotive industry in China, had entered the era of industry conversion. The promulgation of “*Policy on Development of Automotive Industry*” encouraged the domestic and foreign automobile industry to embark on various convenient ways of docking, promoting projects and expanding the scale of the industry. This policy also led to the launch of joint research and development projects between domestic and international automobile firms (Autohome, 2019). To fully exploit the EV market policy, guidance alone was not enough. In the 1990’s the crucial challenge for developing EV technology, was the problem of insufficient capital.

This challenge was mitigated to some degree as China joined the World Trade Organization (WTO) in 2001. “*The National 863 R&D Program*” commenced and reflected a more open and available Chinese market benefiting from a more precise direction of government investment and preferential policies than before. “*The National 863 R&D Program*” made financial support available to domestic firms, as well as opportunities for latent learning and technological collaboration with research institutions, universities, and foreign incumbents (Gov.cn, 2012). This program invested two billion CNY (approximate 242 million USD) in R&D to create three technical lines and three standard technologies. The technical lines were pure electric, hybrid electric, and battery. The three standard technologies were: power storage battery, drive motor, and powertrain control system (Tebon, 2020). These efforts heralded the establishment of a comprehensive technology foundation of the Chinese EV industry. For example, BYD’s disruptive innovation on the production processes and techniques of batteries signaled potential for creative imitation. BYD created semi-automation battery production lines in replacement of labor-operated machines. This turned the EV industry from capital-intensive to labor-intensive, thereby averting the problem of capital

shortage associated with the advantages of sufficient and low-cost labor (Auto.ifeng.com, 2020).

In 2000's, the Chinese government proposed the development of energy-saving and environmentally-friendly electric and hybrid vehicle technologies. The series of policies issued and implemented offered a solid foundation for further growth and development in the Chinese EV industry. For example, "***The National Policy on the Development of the Automobile Industry***" was announced and implemented in 2004. This policy prospected the automobile industry to become a pillar of the Chinese national economy.

As well as such policy endorsements, the Chinese EV latecomer firms also enhanced and accumulated the technology and its capabilities by imitation. Due to the favorable policies and technological development, the domestic EV companies began to increase their market share. Since then, "*China has been embracing the growth in automobile production and sales, yet the traditional energy vehicles were still the mainstream in the market*" as explained by a BYD manager (Interview#20210705, 2021). At this stage consumer recognition of the EV and its market demand were still trivial.

4.1.2 Policy consolidation and industry catching up (2006-2015)

During this stage, the Chinese EV industry witnessed rapid growth, boosted by a series of promoting policies. For instance, "***The New Energy Vehicle Production Access Management Rules***" in 2007 approved several new electric vehicles for mass production. Between 2009-2010, the government approved EVs for use as service cars. This procurement implied that the governments financial investment into the EV industry was even greater than previously. To maintain their leading industry position and reduce the risks of imitation from local Chinese firms, international EV firms continued their strategic deployment of EV patents in China. In 2009, *The Ministry of Industry and Information Technology of China* issued "***The New Energy Vehicle Demonstration and Application Project***". This required Chinese firms to manufacture EV auto parts locally, and to master the core technology, thereby, playing the dual role of promotion for the domestic latecomers and resistance for the foreign EV firms. This policy sought to ease the foreign firms concerns about technological imitation from China as

well as to foster Chinese local EV industry. For example, BYD's first EV, F3DM, was an outcome of the creative imitation, rather than a simple copy, of Toyota's Corolla (Auto.163.com, 2009).

After setting the development in motion by duplicating learning, the Chinese EV industry entered a launching stage where policies were enhanced and updated. Not only did the policies focus on EV production, they also facilitated the construction of relevant infrastructure. For example, for improving the convenience of charging EVs, the domestic EV firm Zhongxing Telecommunication Equipment (ZTE) invested in wireless charging technology. They were assisted by the Chinese government's infrastructure plans, such as "***The 2015-2020 Chinese Charging Infrastructure Construction Guidance***". Informants from Geely and BYD emphasized that the government-led construction plan decreased firms' financial hardship in the construction phase, and increased the public awareness of EV via growing frequent exposure. A manager in BAIC also mentioned government support, stating that:

"We long for further government support or intervention in industry upgrading, collaboration stimulation, charging piles and points construction and sharing supplier network and so on, which could increase industry synergies." (Interview#20180600, 2018).

Fostering Chinese local EV industry required financial support from the government. The subsidy policies for new EV entered a phase of rapid promotion and application by the following report: "***The Interim Measures for the Management of Financial Subsidies for Private Purchase of New Energy Vehicles***" in 2010. Subsidies were allocated to the EV manufacturers, and accordingly, individual buyers or leasing companies could benefit by acquiring the EV's at a reduced price. "Plug-in hybrid passenger cars are subsidized up to 50,000 CNY (approximately 8,070 USD) for each, and pure electric passenger cars are subsidized up to 60,000 yuan (approximate 9,684 USD) for each." (Denza, 2013). "***The White Paper on China's Energy Policy***", announced in 2012, stated that China would unswervingly and vigorously develop new and renewable energy. As a result, a notice on the expansion of the demonstration and promotion of the hybrid bus was issued, with a goal of putting 3,000-

5,000 energy-saving, low-emission buses into use. Consequently, 17 EV companies and 69 models of hybrid buses were offered subsidies and benefits (Caeshc.com.cn, 2013). Since then, the Chinese automotive industry has made the rapid switch from gas-burning to a new energy strategy, and with the benefits from government subsidies and policies, various types of new energy products emerged and entered the market (e.g., Cell to Pack technology by Contemporary Amperex Technology, Blade battery by BYD, etc.).

4.1.3 Policy reposition and industry forging ahead (2016 to 2018)

For the previous two stages, EV sales from domestic EV firms were mainly driven by Chinese government subsidies. During this next stage of policy reposition, the government reduced its subsidies to the EV industry. In 2015, ***The Ministry of Finance of China*** and four other ministries and commissions of China jointly clarified that, from 2017 to 2020, the subsidy standards for all EV models (except for fuel cell vehicles), would be appropriately regressed. “*The subsidy standard from 2017 to 2018 decreased by 20% on the basis of 2016, and the subsidy standard from 2019 to 2020 decreased by 40% on the basis of 2016.*” (Gov.cn, 2016). In 2017, ***The Ministry of Industry and Information Technology of China*** issued “***The New Energy Vehicle Manufacturers and Product Access Management Regulations***” to clarify and reinforce the new EV production and product access requirements. From this date, the existing subsidy policy started to decline, and simultaneously the government lowered the threshold requirements (e.g., drivable range and battery energy density) for making pure electric passenger cars, thereby, allowing more players to enter the industry. The government also noticed that some new manufacturers started producing EV’s only to take advantage of generous policy subsidies. This could impact EV quality which may not be guaranteed. Consequently, ***The Ministry of Industry and Information Technology of China*** demanded high quality development of the EV sector and emphasized the establishment of a justice and competitive market order. They achieved this by abolishing discriminatory regulations, urging EV companies to compete with the advantages of technology, quality, price, and services.

This reduction in subsidies had shaken out incompetent companies and retained qualified ones. Such changes in the Chinese EV industry consolidated the technological

competence of the domestic EV firms and their complementary assets, such as the EV-related infrastructures. One example was the battery sector of the EV industry. The number of electric vehicles urgently needing simultaneous construction of charging facilities was rising. This influenced the need to accelerate the pace of the power stations and charging pile constructions. When compared with electric motors and electronic control systems, power batteries were the main technological breakthrough for new energy vehicles. In the field of power batteries, a timeline of technological progress exists. This is similar to Moore's Law — which indicated that energy density increases chronologically. Innovative battery technologies became commercially available. New energy vehicles range and safety was effectively enhanced; and their cost structure was optimized. Together with the battery technologies and other key technologies, Chinese EV companies endeavoured to construct the comprehensive industry chain. For example, a government report introduced the achievement of a veteran domestic company as:

“BAIC Group's has put 1,725 EV to commence its layout of intelligent logistics. And it deploys strategies in areas such as solid-state batteries, 5G and vehicle networking to lay the foundation for its technological innovation.” (Gov.cn, 2019).

Due to technological advancement within EV firms and the enhancement of EV-related infrastructures in China, the EV market quickly expanded during this stage of policy repositioning. Consumers purchased an EV because of its energy-saving concept and its low cost. They also gained other benefits from owning an EV e.g., individual drivers could easily get a title of their cars if the car were an EV. In the Chinese domestic market, electric vehicles were mainly used in consumers' daily lives, such as commuting to work or driving family and friends. EV users embraced the energy-saving and environmental protection that new energy cars (mainly the electric vehicles) provided and paid attention to the vehicle's intelligence and of the advanced technological applications. In the critical EV technology field, China had established a holistic R&D structure to enable independent intellectual property achievements. For instance, the Chinese EV patents span all categories of EV production. These met the expectations and preferences of EV users and eventually contributed to the rapid development

of the market in China. An industry report captured such technological advances driven by market demand:

“The majority (of Chinese EV patents) associates with automotive powertrain technology (B60L and B60K) account for 31.3%, followed by the power batteries category (H02J and H02M), which consists of 23.1%, and patents for electric motors account for 8.2%, marked as the third.” (Evpatner, 2016).

Table 2. Overview of policy evolution in the catching up process of the Chinese EV industry

Stage	Regulations	Authorities	Industrial theme
Policy initiation	-The Clean Energy City Plans (2001) -Policy on Development of Automotive Industry (1994) -The National 863 R&D Program (2001) -National Policy on the Development of the Automobile Industry (2004)	-Instrumentalities of the State Council -State Development and Reform Commission -State Council	Duplicative imitation
Policy consolidation	-The New Energy Vehicle Production Access Management Rules (2007) -New Energy Vehicle Demonstration and Application Project (2009) -The Interim Measures for the Management of Financial Subsidies for Private Purchase of New Energy Vehicles (2010) -The White Paper on China’s Energy Policy (2012) -The 2015-2020 Chinese Charging Infrastructure Construction Guidance (2014)	-State Development and Reform Commission -The Ministry of Finance -State Council	Creative imitation
Policy reposition	-General Planning for Technological Innovations of Industries during the 12th Five-Year Plan Period (2011) -The Notice on Further Promoting the Pilot Program for Energy Conservation and New Energy Automobile Demonstration and Popularization (2011) - New Energy Vehicle Manufacturers and Product Access Management Regulations (2017)	-The Ministry of Industry and Information Technology -The Ministry of Finance -The Ministry of Science and Technology -State Development and Reform Commission	Independent innovation

4.2 Emergence and interplays of Windows of Opportunity in the Chinese EV industry

The conception of China's EV industry began with China's strategic policy of building an automotive industry. This change from traditional automobiles to EV was crucial for combatting climate change and in promoting sustainable development. The government's vital concern and support for this industry made it possible for China to launch EV as an industry. For the purpose of developing the EV industry, many policies and regulations had been issued to provide support (directly and indirectly) for scientific and technological progress, and for market prosperity. Institutional, technological, and market demand windows of opportunity (WOP) opened up sequentially. Institutional WOP were rooted in the policies and regulations that first allowed the EV industry to emerge and grow. The opening of institutional WOP induced the beginning of technological and market demand WOP, which jointly flourished the EV industry in China.

4.2.1 The heterogeneity of WOP emergence

In the process of Chinese EV's catching up, the WOP emerged from the promulgation of government decrees, the evolution of technology, and the transformation of market demand. In such a process, the importance of WOP from different sources varied. For example, at the initial stage of development, institutional WOP was considered the dominant WOP and regarded as the essential WOP. The technological WOP and market demand WOP were marginal or had not yet even appeared. We recognize these different sources and importance of WOP emergence as the heterogeneity of WOP emergence.

When reviewing the development of the Chinese EV sector, it was clear that the institutional WOP triggered the technological and market demand WOP. From a chronological point of view (i.e., horizontal comparisons), the critical change nodes in the evolution of policy, technology, and market demand reflected the opening of WOP. From a dynamic point of view

(i.e., vertical comparisons), the switches of the three aspects of WOP influenced each other. For instance, during the late stage of rapid development (2006-2015), investment into technological development of various emerging EV enterprises became overheated, and the industrial rules were unclear. The government, very quickly issued restraint and regulation of the industry, reacting to technological WOP. During the process of the EV industry's catching up, the opening, maintenance, and interaction of all three aspects of WOP were not independent, but interacted and restricted each other. These interactions and correlation of institutional, technological, and market demand WOP are summarized in Figure 5.

At the commencement of the Chinese EV sector, the rapid launch and development was credited to the guidance and support of policy and marked the opening of institutional WOP. In 2001, the new energy vehicle research project was listed in "*The National 863 R&D Program*", marking the starting point of China's clear strategic and systematic development of the new energy vehicle industry. This was significant and symbolized the opening of institutional WOP. Institutional WOP were posed by supportive regulations; for instance, according to a national sales manager of one key supplier of BYD, "*The National Policy on the Development of the Automobile Industry*", was seen as the "*dominant driving force*" in the Chinese EV sector (interview#20210630). At the beginning of the Chinese EV industry, institutional WOP significantly revealed its orientation function. Yet, the market, hardly responded to the new EV, which was likely due to customers having a wait-and-see attitude. The situation changed with the opening of the institutional WOP, where regulations were set and sufficient capital was offered to the EV companies. Most importantly, this created favourable public opinion and sent clear positive signals for the companies to conduct R&D and increased confidence of EVs production. As a result, in 2009 the market responded to the EV products.

“The market introduction phase of the new energy vehicle industry began in 2009. In 2009, we organized and implemented the demonstration project of ‘Ten Cities and Thousands of EV’. In 2016, we carried out the pilot project of private EV.” (The National Development and Reform Commission of China, 2010). Since then, many policies have been issued to powerfully boost the development of the industry so that institutional WOP continues to expand. In the later stage of development (around 2015), the policies and regulations at the government level shifted from fiscal and tax support, and technological R&D to a regulation and management system — to better administer the development of the industry.

The government provided incentives for manufacturing EV, and the EV companies started a technological and production competition. The institutional WOP opened in 2001, and simultaneously China entered into the WTO. In the early stage of catching up development of the EV industry, local Chinese EV enterprises began to absorb the foreign experience, technology, capital, and products, which allowed for imitation learning. Consequently, the technological WOP immediately opened up. For example, in 2014 after Tesla lifted its patents, the quality and quantity of patented technology used in China’s EV industry grew substantially. Hence, domestic EV enterprises had a more precise reference template for development. This rapid improvement brought in a discontinuity in the level of technical knowledge. The opening of the technological WOP led to the emergence of more EV start-ups and advanced the EV technology.

Due to the convenience of using the lifted foreign technology patents, China’s local R&D capacity weakened. As shown in Figure 5, when compared to 2011-2013, the number of EV patent applications filed in 2014 and 2015 decreased. This decline was not only caused by technological WOP but also by governmental policy consolidation of industrial standard regulation.

The increased number of EV companies and their competition provoked incremental and radical technological breakthroughs. Chinese internet giants also entered the EV industry, which generated fierce competition. *“The rise of the EV is with the help of Internet enterprises. The new forces of car building generally have an Internet background, and in the process of growing up, they have reaped a lot of investment and financing from Internet giants. Internet companies have also repeatedly participated in the intelligent networking transformation of traditional car companies as intelligent solution providers.”* (People.cn, 2021). Apparently, the opening of technological WOP in the EV industry resulted in the continued increase of Chinese EV patent applications since 2016.

Market demand as an initially exogenous WOP generated by the institutional WOP, in turn, affected the technological WOP. In 2009, the market demand WOP opened when EVs were permitted to be traded in the Chinese market. This occurrence was the milestone for the demonstrating application period and the market introduction period of the EV industry. To expand the market demand, the Chinese government provided incentives for individual consumers encouraging them to purchase EVs. Manufacturers and standardized EV charging infrastructure construction sectors were also incentivized to increase production and related products. As a result, between 2014 and 2015, the key indicators of market condition and EV technology development (i.e., the number of charging points, sales and production, as well as patent applications) increased. The sales of Chinese domestic latecomers started to surpass those of international incumbents. In 2015, the technological gaps shrank significantly. Table 3 summarized these results. In addition, in this period, government was not the only force to lead the EV industry. EV companies largely developed their products (vehicles) and the whole EV industry accelerated, because they sensed huge buying power from individual consumers. Also, since 2015, the growth rate of the industry has slowed down. As the primary division for the promotion and application of new EVs, sales of the new energy passenger vehicles grew

steadily. In contrast, the growth rate of commercial vehicle sales continued to decline (Sina, 2019). To realize virtuous growth, the Chinese EV industry must rely on the non-policy-driven market and technological advances. The purpose of manufacturing and developing EV was not simply for receiving favorable government subsidies. Rather, EV companies focused on consumers and made numerous efforts to improve EV quality, safety, and endurance. Thus, the policy’s action of stepping back may bring forth another technological WOP.

Table 3. Total Number of EV Sales, Foreign Incumbents VS Domestic Latecomers in Chinese EV market

Year	Types of Groups	2005	2010	2015	2017
Total Sales (Units)	Foreign incumbents	175,700	403,200	148,939	270,365
	Domestic latecomers	N/A	7,181	104,023	343,373
Total Number of Patents applied for in China	Foreign incumbents	660	2,236	3,230	3,258
	Domestic latecomers	37	910	2,320	2,937

Source: summarized by authors

4.2.2 The dynamics of WOP interplays

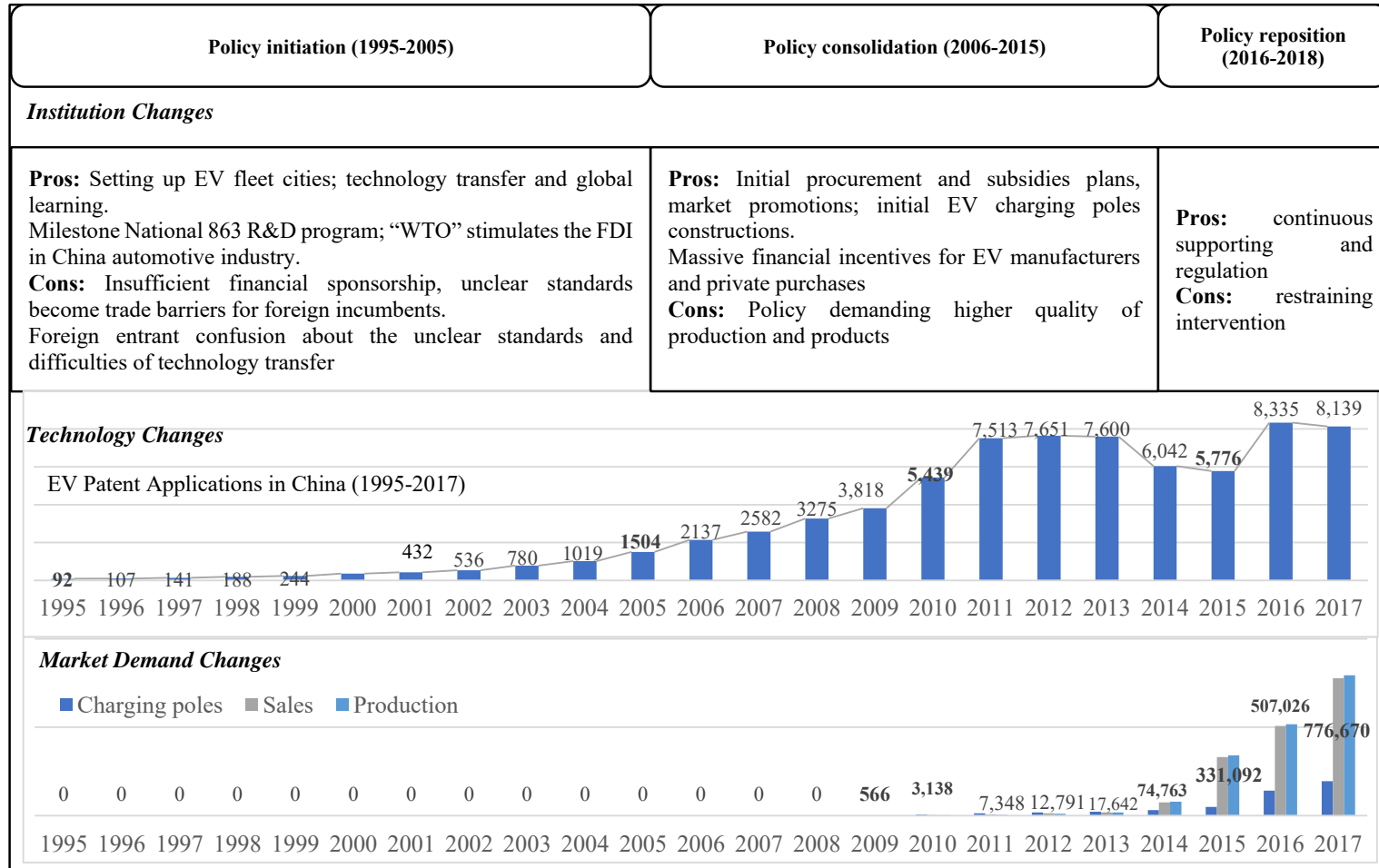
By vertically observing and comparing the timeline of the three opportunity windows (shown in Figure 5), we identified that the interaction among different opportunity windows was dynamic. Generally speaking, one window of opportunity created the next WOP sequentially. The importance of varying WOP change as time progressed, and the WOP’s effects on catching up are different.

The characteristics of the early stage in Chinese EV development were institutional WOP driven and technological WOP empowering. After this stage, EV-related patent applications increased every year (See Technology Change in Figure 5). This trend indicated

that technological WOP opened following the influence of institutional WOP. When the institutional WOP opened, the government offered the industry financial subsidies and other supporting regulations. Accompanied by the technological achievements and product quality improvement, the market showed strong consumer purchase intentions towards EVs. These high-tech industrial advancements can create technological WOP, attracting various players to enter the EV sector. Traditional and emerging car manufacturers, Internet companies, third-party service companies, and various service providers flocked to the telematics industry. This saw its market scale increase and its technology advance. The telematics platform made interconnectivity possible among cars, drivers, and urban infrastructure. *“The addition of more technology companies or other new forces will also further enrich the supply of EV products and bring more and better driving and service experiences to consumers, which is beneficial to the cultivation and growth of the EV market.”* (Xinhuanet.com, 2021).

The rocketed development in the EV industry contained noises in the company foundation, industrial chain operation, vehicle registration, and market. The original policy of direct financial support had been tightened and replaced by regulatory measures of indirect support. Some policies were issued for adjusting and balancing the rapid development and disorders that were required for higher standard production processes and a higher quality end product. *“To further promote the healthy development of the EV industry, continuously improve the level of industrial technology, enhance the core competitiveness, and do a good job in the promotion and application of EV, the government has updated some items based on the original supportive policies. The aim is to ‘adjust and improve the subsidy policy for popularization and application, implement the responsibility of the main body of promotion and application, and establish a punishment mechanism’.”* (Gov.cn, 2016). Policy triggered growth in market demand brings with it direct subsidies and sales profits to companies, so that EV company’s production and technology development receive considerable financial support.

Figure 5. Changes in Institutional, Technological and Market Demand WOP in Chinese EV Industry from 1995 to 2018



The change in subsidy policy resulted in the liquidation of the tail-end enterprises. At the outset, EV companies needed their own funds to complete production and sales before they were eligible to apply for subsidies. This procedure brings financial pressure on the EV companies. *“When focusing on the domestic EV market, EV manufacturers are influenced by the decline of the subsidy policy. The growth rate of the whole market slows down, and the industry enters a reshuffle acceleration period. Some products having not met the market demand are gradually eliminated. In this context, how to further promote the marketization of domestic EV has become one of the main issues facing the whole industry.”* (People.com.cn, 2020)

From this case study, we summarized the characteristics of WOP emergence and interplays. WOP emergence has heterogeneity, and WOP interplay presented dynamics. Prior to the formation of China’s EV market, the cultivation and encouragement of the Chinese government stimulated the industrial R&D and supply of this emerging industry. Policy-led Institutional WOP, laid the foundation for this newly conceived and unformed industry, drew a blueprint, guided the direction, and provided support. Technological R&D and production then benefited from policy support, showed their varieties in development through imitation and assimilation, and created technological WOP. Under the joint action of industrial-technological progress, improved production efficiency, and the government’s preferential subsidy policies, the market demand gradually increased. Excellent market performance and a new consumer atmosphere formed market demand WOP. This market demand WOP reflected the production side, encouraged increased excellence in R & D investment, and induced a new technological WOP. When chaos existed in the development of the emerging markets, policies came into play in time to regulate. Thereby, pushing the industry to be independent to subsidies and to be market-tested. The successive opening of each window of opportunity, progressive

iteration, and mutual coordination were critical for the sustainable development of China's EV industry in catching up.

5. DISCUSSIONS

Our case study on the catching up of the Chinese EV industry shows that government policies have always been the significant factor dominating the development of a latecomer industry. This domination endogenously generates institutional WOP. Institutional WOP accompanied industrial evolution together with the sequentially triggering of the emergence of technological and market demand WOP, which in return influence the institutional WOP.

In the industry emerging stage (policy initiation), the government issued various policies and that led to the institutional WOP. The opening of institutional WOP brings forth the embryonic period of the Chinese EV sector. Thus, forming the fundamental industrial standard, constructing infrastructure and providing financial resources. Thereby providing technological WOP with emergent possibilities. In the stage of industrial catching up (policy consolidation), the policies benefit technological progress, promote the development and production of Chinese EV companies, and incubate the market demand in China. Direct subsidies, e.g., purchase subsidies, insurance and tax reduction; and indirect incentives e.g., dedicated parking spots and exemption from traffic restrictions — have significantly increased consumer recognition and purchase intention. Then at the stages of industry forge ahead (policy reposition), the market demand WOP opens, which, in turn, led to increased revenues for EV companies and further investment in technological progress. As new EV companies came flooding in, the market became overheated and industry expansion became frenzied, EV companies were motivated by beneficial governmental subsidies rather than decent production. This resulted in disorder for the EV sector. It provides insight and feedback to policymakers that further potential government interventions should take into consideration.

Our case of the Chinese EV industry demonstrates a clear pattern of how WOP emerges heterogeneously and how local latecomer EV firms seize the different types of WOP. The year 2001 was significant and marked the window opening when Chinese EV firms became involved in government-led R&D programs. Later, 2005 represented a breakthrough with the WOP due to the disruptive innovation of battery production in China. 2010 was the starting point of extending the market window. This was mainly triggered by Chinese government purchases. Within the various technological, market, and policy factors, 2015 demonstrated the catching up and indicated that the Chinese EV market had become the largest globally. By taking advantage of the WOP, domestic latecomers can catch up by maximizing their economic benefits and learn from the leading foreign EV companies.

Our study of the Chinese EV industry as a strategic emerging industry in latecomer countries complements the existing literature, mainly focusing on the high-tech sector (e.g., the telecommunications industry of Fan (2006)) and the traditional sector (e.g., the regional jet industry of Vértésy (2017)). Based on multiple sources, we provide a fine-grained case analysis of how latecomer countries catch up in building an energy-saving industry. We analyze how governmental policy evolves from initiation to consolidation and finally to reposition along with the development of the Chinese EV industry. The institutional WOP, technological WOP, and market demand WOP open sequentially. Our results further demonstrate that the government policy and the interactions of the different types of WOP can interact and eventually contribute to the rapid development of the Chinese EV industry.

Our evidence on the Chinese EV industry is consistent with the established literature (Lee and Malerba, 2017; Vértésy, 2017; Lema et al., 2020). The government policy, such as the monetary and non-monetary interventions on technology development and market systems, form the preconditions for catching up — which drives the Chinese EV industry. More importantly, our findings complement the existing literature on WOP, such as Lee (2005) who

asserts that WOP can appear simultaneously within the same industry. We further reveal that different types of WOP emerge heterogeneously, and the dynamics of different kinds of WOP along with the development of the Chinese EV industry lead to its final catching up.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Our results have important theoretical implications. First, our study provides new understandings of the government policy evolution and its influence on the latecomer industry's catching up. The evolving role of policy initiation, consolidation, and repositioning extends the previous literature on the critical part of government intervention (such as Gao, 2015). Second, this study advances understanding of the catching up process by highlighting the different types of windows of opportunity that underpin it (Lee and Malerba, 2017). Our results indicate that different types of windows of opportunity emerge heterogeneously throughout the stages of the catching up process. Also, the dynamics of the different types of WOP facilitate the industrial catching up. Finally, we select the Chinese EV industry and conduct an in-depth case study based on multiple data sources. Our fine-grained analysis of the policy evolution and WOP provides new understandings of latecomer countries such as China who are eager to build an energy-saving industry and achieve sustainable development.

Our study also demonstrated an essential consideration for policymakers and business practitioners when entering emerging industries. Policymakers should recognize and understand that government policy may evolve alongside industry development. In our case, governmental policy evolves from initiation to consolidation. Eventually, repositioning itself alongside the development of the Chinese EV industry. Attention should also be given to industry feedback, such as the opening of WOP in a heterogeneous manner. Business practitioners should seize the different types of WOP, which are most often led by governmental policy. Yet, the heterogeneous nature of the institutional, technological, and

market demand WOP, such as those that have emerged in the Chinese EV industry, requires business executives to understand its dynamics in greater depth. The successful catching up of the Chinese EV industry reveals that the dynamics of the institutional, technological, and market demand WOP might be more important than having only one type of WOP's opening.

Our study also has its potential limitations. Although we analyzed closely the national policies on electric vehicles, we did not consider in detail the local policies. To date, there is no EV firm that has made a strong national presence. Future studies may consider both macro and micro policies on the energy-saving industry. Additionally, we did not differentiate the new EV venture from the EV firms transformed from the traditional automakers. Due to their differences, government policies, WOP, and their contributions to the development of the EV industry should be considered in future studies.

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