Integration and Coordination in the Development of China's Electric Vehicle Industry: Mechanisms and Policy Implications

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Abstract: *China's electric vehicle industry has undergone a rapid development over the past decade, boasting cutting-edge technology and a mature domestic market. The growth of China's electric vehicle (EV) industry is prominently characterized by integration and coordination along the industrial supply chain. This paper provides a systematic analyze on China's EV industrial integration and develops a framework to investigate its mechanisms in promoting industrial development. In particular, we explored the crucial role of coordinated integration along the industrial supply chain in leveraging the comparative advantages of each segment and building overall international competitiveness. Finally, pathways and policy recommendations are proposed for promoting the high-quality development of other strategic emerging industries through industrial integration and coordination.*

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1. Introduction

In recent years, China has witnessed the rise of several strategic emerging industries that have driven technological advancement and overall industrial development. Among them, the electric vehicles (EV) industry is currently at the forefront of international industrial competition and is crucial for decarbonizing the road transportation sector, promoting the growing automotive industry, and achieving national energy security goals. In the short span of the last two decades, China has emerged as a leader among the world's major producers of electric vehicles, and a number of its EV original brand manufacturers (OBMs) has surpassed traditional global automotive leaders in sales growth, market penetration, and production technologies. As of 2023, the total sales of Chinese EV OBMs contributes over 50 percent in the global EV market, and along with the high quality and performances of the EV products, the production costs and average prices are significantly lower than their foreign counterparts (IEA, 2024). Moreover, the success of China's EV producers does not take place in isolation. It is

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accompanied with the emergence of innovative and globally competitive local enterprises in various supply chain segments of EVs. This phenomenon has led to the following questions: Does the supply chain integration and coordination contributes to the development of China's EV industry, and what are the key driving forces?

Existing research and discussions have investigated the level of integration for the EV industry, including local clustering and integrated innovation networks for the EV and other industries in countries such as the United States, Europe, and Japan, and analyzes the differences in the composition and network structure of China's relevant industrial chains and innovation networks (Zuo et al., 2020; Xiao et al., 2022). In terms of the integrated development of upstream and downstream industrial chains, some research literature has delineated the thematic characteristics of the overall structure and coordinated development of the innovation and integration of China's new energy industry through the creation of a patent citation network (Guo and He, 2017; Su and Cao, 2022). Integration of producer services with EV or other manufacturing sectors is critical for increasing service efficiency and realizing economies of scale and specialization, and the EV industry must embrace technological and product innovations to achieve high-end development (Wu and He, 2016; Liu and Shao, 2020). However, in the literature, less attention has been devoted to investigating the development patterns and the nature of EV supply chain integration and the synergies with other emerging sectors.

In this paper, we systematically analyze the development of China's EV industry through the lens of its industrial supply chains, clusters and networks. We examine the development experiences of upstream, midstream, and downstream sectors within China's EV supply chain, in order to gain a comprehensive understanding of the integration and coordination among different segments. By exploring how these segments interact and align, we highlight the mechanisms driving the industry's rapid growth and comparative advantages on the global stage. This analysis provides insights into how strategic integration across supply chains can enhance efficiency, innovation, and market responsiveness. Furthermore, we offer policy implications for other emerging industries, emphasizing the importance of fostering a coordinated approach to supply chain management that can drive sustainable growth and technological advancement. Our findings serve as a roadmap to promote the integration and coordination of industrial systems and technological development..

The remainder of this study is organized as follows: Section 2 examines, the development experiences of China's EV industrial chains and how upstream, midstream, and downstream sectors leverage its comparative advantages based on endowment structure and industrial technology positions. Section 3 analyzes the mechanism of how coordination and integration promotes industrial development, focusing on the industry's key characteristics. The final section puts forth policy suggestions.

2. Integration and Coordination in China's EV Industry

Amidst the intensifying economic globalization and inter-firm division of labor, industrial chains have emerged as a key factor for industrial development. At a granular level, industrial chains represent supply-demand relationships for the exchange of raw materials, technologies, intermediate inputs, and services between upstream and downstream enterprises, forming a chain of intra-product division of labor (Shao and Li, 2007). As a key aspect of industrial chain coordination, firms share and combine resources such as capital, technology, talent, and information to raise efficiency and reduce cost. In comparison to such coordination, industrial chain integration is a dynamic process where in-depth interactions and collaborations have blurred the boundary between manufacturing and service processes, enhancing their level of integration and giving rise to an interactive ecosystem through the permeation and overlap of various industrial sectors. By facilitating the flow and aggregation of resources, information, and technologies within individual industries, the integration of industrial chain sectors enables companies to combine resources effectively, develop synergy for technological innovation, and promote the technological progress and upgrade of industries (Zhao, 2014). In the development of China's EV industry, the endowment structure and technological progress of the upstream, midstream, and downstream sectors have jointly contributed to the collaborative integration of the industrial chains, serving as driving forces for the EV industry to maximize its potential comparative advantages and enhance its international competitiveness.

2.1 Development of China's EV Industrial Chains

Over the past two decades, China's EV industry has risen to global prominence in terms of technological performance, sales volume, and production capacity. Furthermore, innovative Chinese companies have sprung up in a variety of industrial sectors, exhibiting international competitiveness. EV industrial chains are divided into three sectors: upstream, midstream, and downstream. The upstream sector manufactures anode and cathode materials, as well as mineral resources. The midstream includes battery research and development, as well as manufacture of motors and electronic control systems. The downstream industry includes automobile production, software, electronics, as well as the construction and operation of supporting infrastructure, such as charging and battery swap facilities, as well as smart power grid systems (Figure 1). Over the past two decades, China's upstream EV industrial chains have developed and reached global standards, and downstream EV production has also made remarkable progress. The increase in demand has pushed local producers of critical components to attain world-class manufacturing, cost management, and technological refinement at the midstream level within a few years. Furthermore, rapid progress has been made in the area of downstream charging infrastructure.

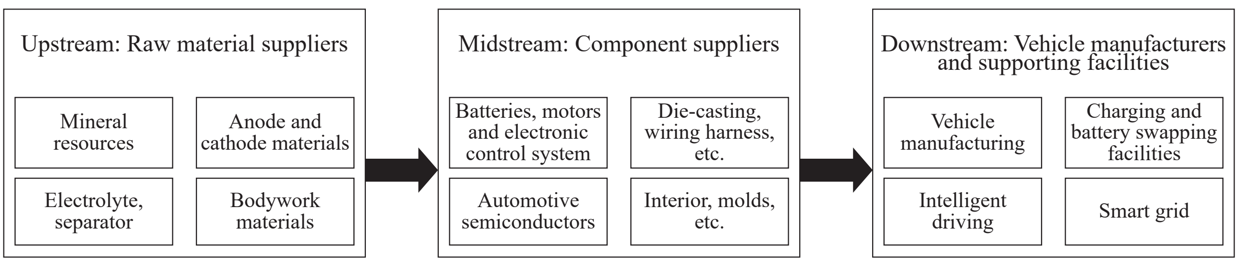

Figure 1: Composition of the EV Industrial Chains

Source: Compiled based on Chen and Wang (2014).

Japanese businesses occupied 90% of the global lithium-ion battery market during the 1990s due to their groundbreaking innovations in the technology. China is still in the research and development phase of technological advancements in the consumer electronics sector, which is the primary market for lithium-ion batteries. With the rapid growth of the global consumer lithium battery market and globalized supply chain distribution, Japan and South Korea moved certain lithium battery production operations to China in the decade following 2001. Meanwhile, Chinese companies began to produce and export key battery components.

The '863 Program', which began during China's 10th Five-Year Plan (FYP) period (2001-2005), unveiled an embryonic stage in China's EV industry. As companies and universities made technological strides and secured patents, the upstream and downstream EV industrial chains started to take form. In 2009, the Chinese government launched large-scale EV demonstration pilot programs, such as the "Ten Cities, Thousand Vehicles" initiative. In the following five years, China's EV production and sales soared. In 2015, China surpassed the United States to become the world's largest EV market. Between 2016 and 2017, Chinese companies made significant advances in the core materials and technologies of batteries, motors, and electronic control systems. Rapid breakthroughs in power battery technologies, along with significant production cost reductions, have resulted in continual improvements in EV range. Burgeoning private-sector consumption and rapid market growth have supported China's global market leadership.

Since 2018, China has removed the market access threshold for foreign-funded companies. As a result, many EV makers and parts and component suppliers which lacked proprietary production capabilities withdrew from the market. Competition has led to greater industrial chain sophistication. With a spike in EV sales, the downstream sectors including charging infrastructure and other facilities expanded swiftly. The growing availability of charging points paved the way for higher EV adoption rates. China's EV industry now has fully integrated local industrial and supply chains, efficient and low-cost production capabilities, and six regional industrial clusters. The EV industry has progressed from a vertical supply relationship to an integrated, efficient industrial system built on specialized division of work.

2.2 Endowment Conditions for Industrial Chain Integration

Unlike the traditional automotive industry, the EV industry features key technologies that allow for integrated industrial chain development. The enabling factors can be summarized as follows: First, technology characteristics and industrial openness. Compared to traditional automobile internal combustion engine technology, key EV technologies such as batteries, motors, and electronic control systems are based on codified knowledge and are more transmissible, and widely applicable across the industry. Technological progress in the traditional automotive industry is more reliant on implicit knowledge gained during internal manufacturing processes, which is detrimental to information interchange and shared technical innovation between companies. Meanwhile, EVs do not require engines and gearboxes seen in conventional gasoline vehicles. The EV industry is neither subject to traditional market access obstacles and monopolistic tendencies, nor is it reliant on a certain technology route or business strategy. This has given EV enterprises in various countries equal opportunities to compete with each other from nearly the same starting point.

Second, rapid technical and product development. EVs have simpler powertrain and chassis systems than typical automobiles, reducing the complexity of gearbox and engine compatibility. This simplicity has allowed EVs to be manufactured at lower costs and with faster technological and product cycles. To remain competitive, businesses must improve product performance through continuous R&D and product innovation. Rapid technology improvement and product innovation necessitate continuous R&D investment to meet shifting demand and consumer expectations for high-performance, intelligent products.

Third, close ties with cutting-edge technologies. The EV industry is intertwined with artificial intelligence (AI), IT, renewable energy, and other transformative technologies. The EV industry, driven by electrification, intelligence, and Internet-based operations, is built on cutting-edge technology ranging from products to processes. In comparison to the traditional automotive industry, the EV industry invests a major portion of its sales volume in R&D and employs a relatively large number of R&D personnel, expediting intra-industry innovation, technological breakthroughs, and knowledge spillovers. The EV industry provides important technological assistance and a diverse range of innovation opportunities to numerous industrial chain sectors, accelerating technological progress and market development.

China's endowment structure and technological superiority have paved the ground for integrated development throughout EV industrial chains, allowing potential comparative advantages in various processes to be converted into competitive strengths[1].

2.2.1 Upstream raw materials: Cost advantage amplified by downstream demand

Upstream raw materials supply for the EV industry includes materials for the battery system and bodywork components. Mining operations for battery raw materials, refining, chemical processing, and anode and cathode material manufacturing are among those that have a significant impact on the overall performance and cost of EVs due to their resource and capital-intensive nature, complex preparation process, and diverse technological paths. China's natural resource endowment and factor endowment have enabled local firms in the industry to cut their manufacturing costs. China has a competitive advantage in other raw material areas such as steel smelting and alloy production. The benefits of low cost and great efficiency in upstream industrial chains can be amplified by economies of scale resulting from huge downstream demand.

In terms of raw materials, most electric vehicles (EVs) use lithium batteries as their power source. In contrast to the strong demand, critical mineral resources such as lithium, cobalt, and nickel, which are required for battery manufacturing, have remained in short supply. As a result, raw materials have become a major impediment to the EV industry in various countries. China has a relatively abundant supply of raw materials for power batteries, including lithium, iron, manganese, alkene, and graphene, and its mineral resource suppliers and refinery firms are among the largest in the world. The inherent self-sufficiency of vital materials resources results in low mining and transportation costs[2]. According to McKinsey & Company, China currently produces 28% of the world's lithium and 23% of its cobalt. Furthermore, Chinese firms have ensured the supply of raw materials by purchasing significant overseas natural resources and forming long-term supply partnerships. As a result, they have compensated for supply chain gaps caused by manufacturing process constraints and a lack of raw material self-sufficiency, lowered the risk of supply shortages and raw material procurement costs, and boosted business profitability[3]. Chinese enterprises have gained a competitive edge in the production of critical raw materials for lithium-ion batteries such as anode and cathode materials, separator, and electrolyte through mature preparation technologies, effective cost control, and manufacturing capacity expansion driven by massive demand from downstream sectors such as consumer electronics and power batteries. Figure 2 shows that Chinese manufacturers account for more than 50% of EV upstream manufacturing and supply capacities, giving them a dominating global position.

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[1] The endowment structure, according to the new structural economic theory, consists of natural endowment, factor endowment, and institutional endowment. Factor endowment structure refers to the relative abundance of capital, labor, human capital, and land, which, along with natural resource endowment, determines enterprise production costs; institutional endowment contributes to production costs by influencing business transaction costs. Refer to Justin Lin et al. (2019) for detailed discussions.

[2] According to USGS data, China holds the world's largest rare-earth reserves, accounting for more than 90% of medium and heavy rare-earth resources. China holds around one million tons of lithium ore deposits, accounting for 7.14% of total reserves and ranking fourth in the world, as well as 55 million tons of graphite reserves, accounting for 22% of the total and more than 65% of total production output.

[3] Tianqi Lithium, for example, acquired a 51% stake in Talison Lithium and a 26% stake in Chile's SQM lithium producer in the Atacama salt flat; Jiangxi Ganfeng Lithium owns nearly half of Austria's Mt Marion lithium mine project and more than 80% of Argentina's Mariana lithium brine project (Sanderson, 2019).

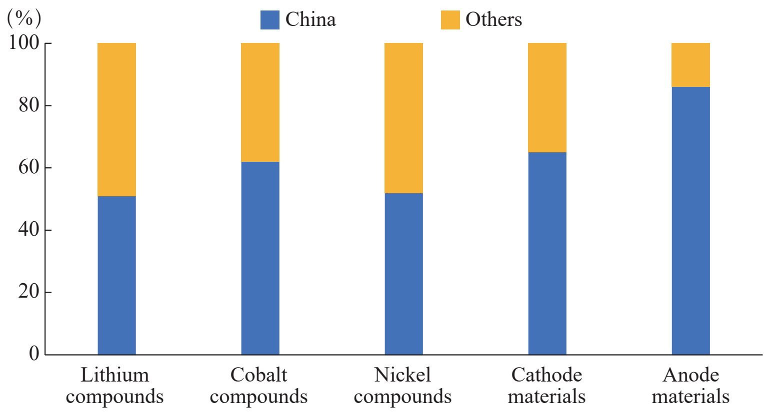

Figure 2: Share of China's EV Battery Raw Materials in Global Supply

Source: Kumar (2020).

China's abundance of professionals, cutting-edge technologies, and strong talent pool in the composite materials and electrochemistry sectors offer new development opportunities for the raw material preparation technologies. Leading Chinese companies have made significant strides in various advanced technologies through continuous research and development efforts. Notably, China leads the world in patent filings for two key anode material technologies—lithium iron phosphate and ternary lithium—demonstrating the technological prowess and innovation capabilities of Chinese firms (see Figure 3).

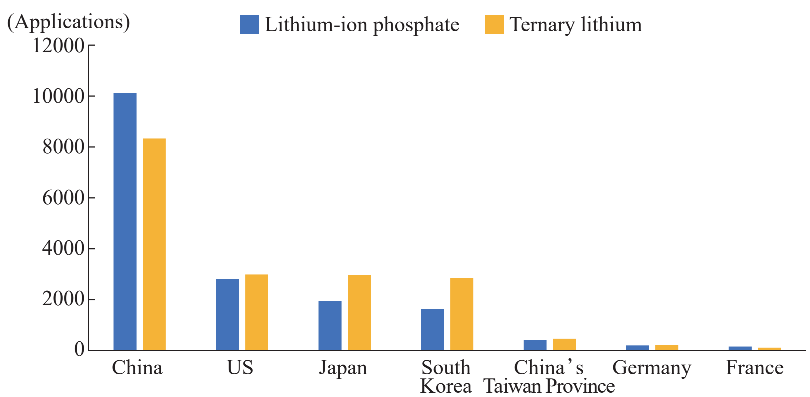

Figure 3: Number of Cumulative Patent Authorizations for Cathode Materials under Different Technological Paths

Source: WIPO database.

2.2.2 Midstream components: Technological strength promotes vertical integration

Midstream manufacturing of components, including electrical and smart components, has a direct impact on the core competitiveness of EV products. These components are high-tech and capital-intensive with a high degree of specialization. Due to relatively short product and technology cycles, EV components are subject to functional and technical compatibility requirements. Therefore, their technological progress is primarily driven by downstream demand.

We divide different EV components into labor-intensive, capital-intensive, or technology-intensive based on their factor intensities. Interior and exterior, as well as car glass, are among the most labor-intensive components. Such activities as manual assembly and quality inspection necessitate considerable manual or semi-automated tasks. Capital-intensive components mostly include integrated diecasting machines, high voltage wiring harnesses, molds, and connectors, which need considerable upfront investments in factory building, equipment purchase, and process development. With the technology and experience in supplying traditional automotive components, Chinese component makers have built a considerable cost advantage and technological accumulation, resulting in fairly high overall product competitiveness. Driven by downstream consumer demands for lightweight bodywork, optimal spatial layout, and quick charging technology, EV makers have helped to increase technology content and value addition of traditional components. Currently, Chinese companies have exhibited considerable technological advantages with integrated diecasting machines and molds. There has also been a tendency of domestic substitution and technological catch-up for high-voltage harnesses and connectors. Furthermore, Chinese companies lead the world in terms of output, manufacturing, and technology for new products like skylight glass and automobile intelligent interactive headlamps.

The majority of technology-intensive components are emerging electrical and smart features, such as batteries, motors, and electronic control systems, as well as automotive-grade chips. To stay ahead of the curve in core technologies, Chinese companies must keep investing money into research and development. In the power battery sector, raw material manufacturing and R&D complement each other, as does the component industry. On the one hand, upstream cost advantages are transferred to midstream power battery makers. On the other hand, both parties have developed synergy through a close R&D relationship. Manufacturers of power batteries have expanded the range and charging rates of their products, as well as sped up the production of semi-solid-state batteries, thanks to innovations in electrolyte materials, long-range power batteries, and ultra-high nickel ternary batteries. Furthermore, Chinese battery makers have enhanced cell materials and structures in collaboration with upstream suppliers to meet the technological criteria of high energy density, fast charging, and long cycle life. As a result, they have achieved international leadership in lithium-ion phosphate batteries and ternary lithium battery technologies. Figure 4 shows that six of the top ten global firms in terms of power battery installations in 2023 were from China, accounting for 63.5% of the total market. CATL has been ranked top in the world since 2017[4].

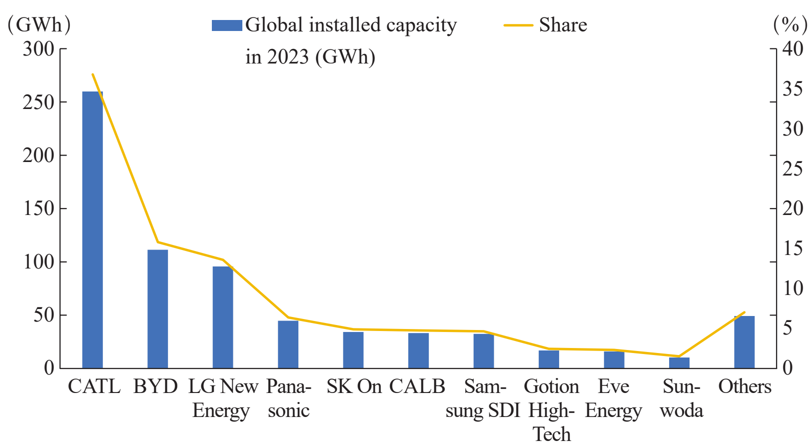

Figure 4: Global Installed Capacity of Power Batteries (GWh) and Share (%) in 2023

Source: SNE Research (2024).

[4] According to SNE Research (2024), the global installed capacity of power batteries increased by 38.6% in 2023 from the previous year, which pales in comparison with the growth rate of 40.8% for CATL and the growth rate of 56.9% for BYD.

When it comes to motor and electronic control systems, Chinese midstream manufacturers and downstream automotive OEMs have achieved fairly good coordination and synergy through investment or acquisition. Because of their low production output and high initial procurement costs, most automotive OEMs have made significant investments in independent R&D of electrical powertrain technology. With rising sales volumes, some automotive OEMs began to build their own motor systems. Companies such as FinDreams Powertrain, a BYD subsidiary, have held a leading position in the motor and electronic control systems sector, which develops alongside automotive OEMs. The motor and electronic control systems of mid and high-end vehicle models are created by automotive OEMs with a low market concentration. In terms of research and development, EVs must meet rigorous specifications, such as lightweight design, which necessitates integrated motor and electronic control systems. Chinese automotive OEMs, represented by indigenous EV brands, have achieved significant progress in integrated solutions, establishing a leading industry position.

The electrification, intelligence, and networked features of EVs have increased demand and performance expectations for automotive-grade chips. However, companies from Europe, the United States, and Japan have nearly monopolized the market for medium-end system-grade chips and high-end AI chips in China. This underscores the reality that China has yet to build its own capabilities for key automotive-grade chips, although it is closing the gap. Chinese businesses led by Huawei and Horizon Robotics have developed independent R&D capabilities for low-performance system-grade chips, but they are behind developed countries in terms of processing power and manufacturing process.

2.2.3 Downstream vehicle manufacturing and services: Application scenarios drive cross-sectoral collaboration

Downstream industrial chains generally involve vehicle manufacturing, sales, service, and the installation of auxiliary charging and battery swapping infrastructures. Automakers, as key players in the EV industrial chains, have gained experience in electrification and intelligence technology R&D, mass manufacturing, and differentiated marketing strategies. Meanwhile, the rapid development of auxiliary charging and battery swapping infrastructure is driving the further growth of the EV industry.

In recent years, Chinese automakers have made great advances. They have controlled costs by integrating component supply while maintaining supply chain security and stability, hence enhancing their viability. Based on their understanding of consumer needs and access to shared information from suppliers, they can differentiate their products to gain a competitive advantage. According to the Ministry of Industry and Information Technology (MIIT), Chinese-made EV brands accounted for 80.2% of total domestic EV sales in 2023. Economies of scale from increased EV manufacturing output have provided automakers with a cost advantage while also paving the road for smart vehicle technologies. Intelligence is a vital trend in the development of EV downstream supply chain, and self-driving is based on two technological pathways: visual technology and multi-sensor integration. During their early stages of development, China's EV manufacturers invest heavily in self-driving technologies, gaining an first-mover advantage. Meanwhile, many of the conventional automakers are looking for ICT solutions to overcome technological impediments to automatic driving. With their powerful underlying R&D capabilities and proprietary automotive ECU chips, Huawei and other ICT companies were the first to achieve advanced smart driving in urban districts at high speeds without the use of HD maps, offering competitive solutions to traditional Chinese automakers. Downstream automotive OEMs have formed close links with companies in AI, big data, and the Internet of Things (IoT) through collaborative R&D.

As a public good, downstream charging infrastructures are essential to the sustainable development of EV industry. According to data from the China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA), China surpassed Europe in 2016 as the world's largest market for public charging infrastructure. In 2019, China accounted for more than half of the world's charging piles, more than the United States, Europe, and Japan combined. China leads the world in technological performance, thanks to its strong capabilities in quick charging and battery swap technologies. According to data from the International Renewable Energy Agency (IRENA), China surpassed the United States in 2017 in terms of the number of charging pile patents globally. As of 2021, China accounted for over half of all charging pile patents worldwide (see Figure 5). China's current charging system, based on the 400V platform design, is technologically mature, low-cost, and has a wide range of applications. Chinese EV makers have increased their focus on developing quick charging technology to suit consumers' demands for range and charging speed, producing high-rate charging models based on the 800V high-voltage platform and hastening fast-charging development for both the vehicles and charging stations.

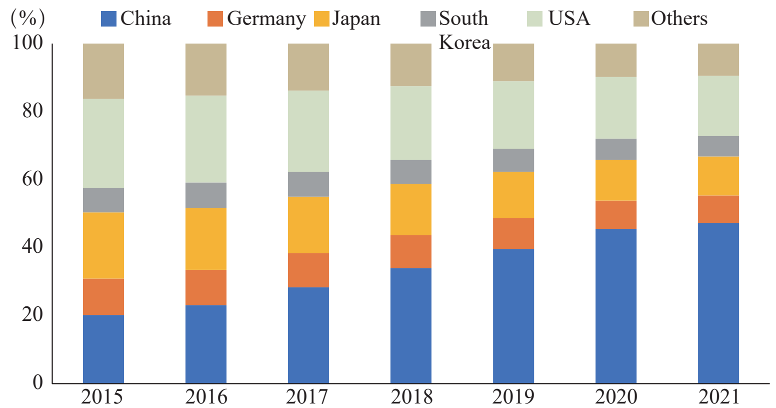

Figure 5: Cumulative Number of China's EV Charging Pile Patents as a Share of World Total

Source: IRENA (International Renewable Energy Agency).

2.3 Problems of the Coordination and Integration within the EV Sector

Over the past two decades, China's EV industrial chains have reached a high degree of integration. However, the long-term, difficult, and complex nature of the EV industry's future development cannot be underestimated.

China is catching up with leading nations in terms of patent filings for essential technology used in the upstream of the supply chain. As latecomers, Chinese enterprises have focused on the functional and application components of their patent inventions, such as formula ratio adjustments and improvements. Chinese companies are at a disadvantage in core technological competitiveness because they rely on European, American, Japanese, and South Korean companies for raw material patents, which are required for R&D and manufacturing[5].

Meanwhile, driven by the growth of intelligent cockpits and autonomous driving technologies, both the volume and performance requirements for automotive-grade chips have continued to escalate. While domestic firms such as Huawei and Horizon Robotics have achieved independent research and

[5] For instance, in terms of cathode materials, the American company 3M and Hydro-Québec of Canada have monopolized the basic patents of ternary materials and lithium iron phosphate cathode. For electrolyte and separator, Panasonic and other Japanese enterprises have registered the basic patents.

development in low-performance system-on-chip (SoC) designs, they have yet to make breakthroughs in the core manufacturing technologies for autonomous driving–related AI training chips. In this domain, there remains a pronounced gap in both computing power and process nodes when compared with international frontiers. In particular, with regard to AI training chips for autonomous driving, the first-mover advantages held by U.S. chipmakers such as NVIDIA continue to constrain Chinese firms' capacity for technological innovation. As a result, supply bottlenecks persist in automotive-grade chips, ultimately restricting the advancement of higher computing power, enhanced algorithms, and large-model-based autonomous driving solutions.

At the same time, mid-stream segments of the industrial chain, specifically the new energy vehicle (NEV) components sector, face dual pressures from intensifying market competition and accelerated industry consolidation. In recent years, rapid expansion of the downstream NEV market combined with a broadly shared consensus on green transitions have attracted large-scale inflows of social capital, resulting in a certain degree of "herd behavior" (Lin, 2007). This has led to a mismatch between capacity expansion and actual market demand, pushing the industry into a phase of structural adjustment. If the market fails to spontaneously adjust and achieve effective clearance, exacerbating problems may not only lead to the underutilization and waste of resources such as capital, land, and skilled labor, but also squeeze profit margins and reduce overall industry profitability, undermining the sustainable development of the electric vehicle sector. As the industry matures, a process of survival of the fittest is inevitable, placing higher demands on cost control and product innovation among mid-stream component manufacturers. This pressure, in turn, compels firms to further integrate and optimize their supply chains and production processes. Ultimately, it drives enterprises to enhance their market competitiveness through technological innovation and product differentiation.

3. Policy Paths for Coordination and Integration of EV Industry

China's EV industry has risen quickly as a strategic emerging industry for two reasons: first, many stages within the EV sector have gained international competitiveness in terms of cost, efficiency, and security through collaboration, integration, and synergy. They range from raw material supply to core component manufacture, EV production, and infrastructure construction. Second, upstream and downstream industrial chains have decreased the risks of independent innovation by collaborating to build cutting-edge core EV technologies. Therefore, producers are able to quickly upgrade its products and to maintain technological advantages.

In terms of the coordination and integration within the EV sector, the critical characteristics of strategic emerging industries have revealed significant differences in the core mechanism by which upstream and downstream EV supply chains contribute to coordinated industrial development when compared to traditional industries. As a result, we need to look at potential policy avenues from multiple dimensions that might allow these sectors to work together more effectively.

3.1 Characteristics and Mechanisms of EV Supply Chain Integration and Coordination

After two decades of cultivation and development, China's EV industry has not only grown by leaps and bounds, but also made significant strides in industrial supply chain integration. Compared to traditional gasoline vehicles driven by the internal combustion technology, China's EV industry has shown distinct features that have transformed industrial organization and accelerated innovation and growth. First, the industrial organization of the supply chain has been evolving. Traditional automotive industry chains have a static, linear structure from upstream to downstream sectors. In contrast, EV industrial chains have evolved into a networked nonlinear ecosystem that goes beyond the traditional hierarchical supplier system. The blurring of boundaries in the division of work and manufacturing process has led to a production process ecosystem.

For instance, China's emerging EV brands position themselves as automakers while many of them do not actually participating in vehicle manufacturing and assembly. They have optimized resource allocation and fostered core competitiveness by focusing their company operations on high-value functions such as sales, branding, and R&D via outsourcing and partnership. Second, various stages of the EV supply chain have engaged in interactive extensions. In the EV industry, linkages between upstream-downstream industrial chains extend beyond the product supply-demand relationship. Companies have hastened the diffusion and application of breakthrough technology by investing in equity and establishing collaborative platforms. With their extensive experience in product R&D, sales, and supply chain management, IT companies like Huawei have established smart driving open platforms for automakers to embrace electrification and intelligent transition. Besides, the scope for integration and coordination is broadening. The development of core technologies in various stages of EV supply chains has shifted from an production-based to a scenario-based approach of innovation driven by the consumer market and user needs, with a greater emphasis on commercialization in the downstream market to stimulate product R&D and innovations. Companies from different sectors have teamed up to launch intelligent and customized solutions that meet customer demand for smart driving and connected cars, among other emerging technologies.

The mechanisms for coordination and integration along the supply chain are threefold. First, the integration may increase upstream and downstream economies of scale. Since 2001, China has developed a "vertical structure" in which state-owned enterprises (SOEs) dominate the sector of upstream intermediate inputs and private enterprises dominate the downstream sectors (Li et al., 2014). Upstream-downstream integration has allowed for the transmission of low-cost manufacturing advantages from upstream to downstream sectors, resulting in lower costs and higher profit margins for final products. Price cuts will unlock market potential for strategic emerging industries and support the expansion of downstream end products, which will drive growth in upstream capacity expansion, lower marginal costs and create a virtuous cycle of reciprocal reinforcement.

Second, industrial chain integration can efficiently shorten the complete product lifecycle, from concept to R&D and manufacturing. Time-to-market is critical in strategic emerging industries due to fast technological progress and a relatively short R&D cycle. Being able to quickly launch new products will allow businesses to respond to market demand, gain market share, and secure a valuable window of opportunity for future product improvements and market development. Hence, upstream, midstream, and downstream integration can give companies a market advantage by building efficiency-based competitive strengths.

Third, integration of the supply chains may encourage companies to work together on R&D, speed up innovation and the dissemination of technology and know-how, and encourage collaborative value chain upgrades along technology paths that could give companies in the upstream, midstream, and downstream sectors a competitive edge. By sharing information, technology, and resources, upstream companies can conduct targeted product R&D based on user needs for downstream products, resulting in value chain upgrades at both ends. Meanwhile, disruptive innovations in the upstream may result in distinct innovations in the downstream, which would also lead to creation of products with higher value-added. Finally, major-power competition has evolved into competition among their respective supply chains. Industrial chain integration and development will not only avoid 'chokepoint' problems in the supply of upstream products while ensuring supply chain security and stability, but will also reduce uncertainty in downstream product demand, increase supply chain resilience, and develop a security comparative advantage. As a result, promoting upstream and downstream supply chain efficiency, stability, and integration will provide a significant boost to strategic emerging industries.

3.2 Pathway for Promoting Integrated Industrial Chain Development

As demonstrated by the mechanisms outlined above, vertical coordination among upstream, midstream, and downstream sectors leverages each sector's potential competitive advantage based on its endowment structure. Meanwhile, cross-sectoral integration may open up new avenues for encouraging R&D and creation of new goods and technologies, allowing China's EV industry to advance toward the global forefront and strengthen its competitive edge. Therefore, the synergistic development of the EV value chain in strategic emerging industries should focus on integrating resources vertically across different sectors within China's robust industrial structure. Fostering horizontal innovation and collaboration across sectors will capitalize on China's comprehensive and interconnected industrial networks, driving further technological breakthroughs and reinforcing the industry's global standing.

3.2.1 Coordinating vertical industrial chain integration for complementary advantages of various sectors

Coordinating vertical interactions and cooperation among industrial chain companies will highlight the comparative advantages of the upstream, midstream, and downstream sectors. In the EV industry, efforts should be taken to reduce information asymmetry and the cost of collaboration between upstream raw material suppliers, midstream component makers, and downstream product or service suppliers. The rational manufacturing distribution and the development of various forms of collaboration for innovation and R&D have effectively given rise to the comparative advantage of endowment structure in each sector, forming an efficient and stable supply chain system and strengthening international competitiveness in terms of cost, efficiency, and technology.

For the opportunities, China's EV industry stands out for large potential market demand, short technological cycles, and cost advantages for upstream and midstream component manufacturers. With sufficient information flow, downstream manufacturers can respond quickly to automakers' requirements while also completing process and technical advances in line with the trend of artificial intelligence (AI). Chinese manufacturers have demonstrated considerable scale and technological advantages in the production of basic electrification components such as batteries, motors, and electronic control systems. They have effectively collaborated with upstream raw material suppliers and downstream automakers, fostering a virtuous cycle of shared resources and collaborative R&D. This partnership model not only reduces the uncertainties of innovation and R&D, but also enhances core competitiveness from R&D to product innovation, leading to a unique strength of the EV industry.

On the challenging side, China's strategic emerging industries face unstable supply of essential components, as well as significant patent barriers in the context of global industrial competition. This could severely hamper sustained industrial growth. To ensure sustained development of the industry, upstream, midstream, and downstream sectors must consolidate effort and form long-term partnerships, for instance for the R&D alliance of EV intelligence component makers to support the design and manufacturing of automotive semiconductors and the advancement of autonomous driving technologies. Such collaboration is vital for overcoming fundamental technological barriers and addressing weaknesses within the industrial chain, paving the way for greater self-reliance and resilience.

3.2.2 Propelling horizontal integration to unleash cross-sectoral innovation potentials

Deepening cross-sectoral and cross-hierarchical interactions and collaboration will result in an industry-wide ecosystem that promotes EV innovations. The new round of technological revolution has blurred the lines between economic sectors, creating opportunities for coordination and integration. China's EV industry has benefited from the trends of electrification and intelligence, capitalizing on its huge skill pool and technological accumulation to upgrade traditional industries such as power batteries and motors. Furthermore, integration with AI solutions has resulted in the emergence of new technologies and products.

Technological integration between industries and companies is a key driver of industrial development. Companies can generate more diverse and competitive products and services by breaking down industry barriers and integrating technical capabilities and know-how across sectors. There has been an increasing trend of closer collaboration between EV firms and new-generation IT companies, which is driving the upgrade and transition of automotive supply chains. With their AI professionals, technology, and ecosystems, tech titans led by Huawei have enabled Chinese EV manufacturers to produce smart products and services, thereby increasing their core competitiveness in autonomous driving, smart power grids, and connected cars.

Furthermore, joint R&D between industry, universities, and research institutions is a vital step toward developing a sectoral innovation ecosystem. The goal of such collaboration is to facilitate the mutual permeation, intersection, and reorganization of technologies and know-how across various sectors, as well as to match the results of frontier scientific research conducted by universities and research institutions with the actual needs of businesses to generate groundbreaking new technologies and products. Numerous platforms for collaboration between industry, universities, and research institutes have been formed under the "three horizontal, three vertical" structure, which includes hybrid cars, electric vehicles, and gasoline vehicles, as well as batteries, motors, and electronic control system. Universities and research institutes have partnered with midstream and downstream industrial enterprises for basic research into new technical routes and solutions, such as sodium-ion batteries and hydrogen fuel cells. Such research alliances have the potential to break away from foreign monopolies on core patents for anode and cathode materials, separators, and electrolytes, establishing an early-mover advantage along emerging technical paths.

4. Concluding Remarks and Policy Inspirations

As a key driver for enhancing energy security, promoting green economy, and upgrading of the automotive industry, China's EV industry provides valuable lessons and insights to other strategic emerging industries. Over the past two decades, China's EV industry has emerged as a new global leader in terms of manufacturing technology and cost-effectiveness across various segments, from upstream raw material supply and midstream component production to downstream vehicle manufacturing and related services. By adopting an integrated development strategy, different sectors within the China's EV industry have shared resources to accelerate technological advances and industrial upgrading, thereby enhancing their global competitiveness. This development experience sheds light on the ways in which other strategic emerging industries might pursue coordinated and integrated development.

Strategic emerging industries serve as a catalyst for economic restructuring and global competitiveness due to their ingenuity and growth potential. They are ready to serve as new engines that propel China's high-quality development forward. However, strategic emerging industries face various obstacles as a result of their technological sophistication, knowledge and technology-intensive nature, as well as positive spillovers. Externally, some multinational corporations have transferred manufacturing activities to other countries due to geopolitical and supply chain security concerns (Ni and Tian, 2021). Internally, China's strategic emerging industries remain heavily reliant on imported critical upstream components, such as core equipment, semiconductors, and essential chemicals, which are vulnerable to supply interruptions.

In this context, different sectors of strategic emerging industries must share and integrate resources along the vertical axis of supply chains. Furthermore, it is critical to leverage China's advantage of complete industrial chains to boost innovation and collaboration across sectors. The following lessons can be drawn from the coordinated development of EV industry: first, proactive efforts should be made to coordinate the vertical integration of industrial chains in strategic emerging industries, and by lowering transaction costs between companies, foster a virtuous cycle in which EV sectors complement their strengths. Close collaboration between different stages of the supply chain will speed up the process from conceptual design to product marketing, offering businesses an early competitive advantage. Second, the horizontal integration of different sectors creates an innovation ecosystem by encouraging technical integration among enterprises from various sectors. On the one hand, the government may construct a mechanism to promote technological integration, such as technical exchange platforms and integration funds, to provide opportunities and financial support to enterprises seeking to integrate technology. On the other hand, enterprises should improve their R&D and innovation capabilities, as well as actively explore opportunities for collaboration with those from other sectors to horizontally extend the scope of integration and coordination. By encouraging vertical integration and horizontal coordination, the government should promote the integration, clustering, and ecosystem development of industrial chains, as well as fully exploit the endowment and advantageous scale of China's industrial chains, in order to increase the international competitiveness of strategic emerging industries and maximize their role in the development of the modern industrial system. CE

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