Driving Innovation: China's NEV Development Model and Future Outlook

Bai Xuejie*, Zhu Zeyuan

College of Economic and Social Development, Nankai University, Tianjin, China

Abstract: *In recent years, China's new energy vehicle (NEV) industry has emerged as a crucial component of its modern industrial system, drawing on its advantages in technological innovation, industrial scale, and green, low-carbon development. As one of China's strategic emerging industries, the NEV sector is at the forefront of R&D and breakthroughs in critical core technologies. It is a central industry in terms of industrial agglomeration, highly coordinated supply chains, and the expansion of value chains. NEVs are a key representative of China's manufacturing industry expanding globally in the new era. To maintain a competitive edge, it is critical to expedite breakthroughs in key technologies and ensure autonomy and control over the industrial supply chain. Looking to the future, the industry must optimize data-driven "user-vehicle-road-cloud" collaborative systems, adapt to new environmental changes and market demands through open cooperation, and lead the construction and evolution of China's modern industrial system.*

Keywords: *New energy vehicles (NEVs), strategic emerging industries, industrial innovation, industrial chains*

JEL Classification Code: O14, O33

DOI: 10.19602/j.chinaeconomist.2024.11.02

1. Introduction

The new round of technological revolution and industrial transformation is reshaping the global industrial landscape. To seize the historic opportunities in the context of momentous changes unprecedented in a century, China has embarked on the development of an innovation-driven modern industrial system. This strategic initiative aims to foster emerging technologies like the digital economy, artificial intelligence (AI), new energy, and biotechnology, modernize labor or capital-intensive traditional industries, and enhance overall industrial competitiveness and resilience through digitalization, intelligence, and green technologies (Rui, 2018; Sheng, 2023). China's strategic emerging industries, a cornerstone of its modern industrial system, play a pivotal role in leading the industrial frontier and shaping the future of economic development. As outlined in the *Catalogue of Strategic Emerging Industries* (2023), these industries encompass nine key sectors: new-generation information technologies, high-end equipment manufacturing, new materials, biotechnology, new energy vehicles, new energy, energy conservation and environmental protection, aviation and aerospace, and maritime equipment[1]. As a major strategic emerging industry, the new energy vehicle (NEV) industry overlaps

* CONTACT: Bai Xuejie, email: bxj@nankai.edu.cn.

Acknowledgment: This study is supported by the Major Project of the National Social Science Fund of China (NSSFC) "Research on Major Issues of Constructing an Autonomous and Controllable Modern Industrial System Under the Conditions of a Major Country's Economy" (Grant No.21&ZD099).

[1] The Office of the Leading Group of the Fifth National Economic Census under the State Council: Catalogue of Strategic Emerging Industries (2023).

and competes with gasoline vehicles for industrial infrastructure and market share. However, with revolutionary breakthroughs in dominant technologies, the NEV industry has significantly transformed the traditional auto industry's techno-economic attributes, evolving into a strategic emerging industry with digital, intelligent, and green characteristics. China's NEV innovative development model features both revolutionary technological breakthroughs and business model innovations. It is also the result of China's extensive industrial clusters and robust market competition.

NEV technological innovations are primarily manifested in the iteration and breakthrough of battery technology, electronic control systems, and intelligent connected vehicle (ICV) technology. NEVs have accelerated energy technology transformation in the automotive sector, reduced reliance on fossil fuels and vehicle emissions, and generated significant environmental benefits to help achieve carbon peak and neutrality goals. Chinese NEV manufacturers have been working with universities and research institutions to overcome technological challenges and achieve new advances in NEV batteries. Specifically, numerous NEV R&D and battery technology projects carried out by enterprises and research institutions, including the *Independent R&D and Large-scale Industrialization of Key Components and Vehicle Platforms for a New Generation of Electric Vehicles* led by BYD and the *Key Technologies for R&D and Manufacturing of Power Batteries for Large-scale Industrialization* led by CATL, have won the second prize for National Scientific and Technological Progress Award in 2023.

The modern industrial system involves the smooth connection and mutual support of the innovation, technology, industry, value and service chains (Bai et al., 2022). The emergence of China's NEV industry has been mainly supported by the innovation and technological chains, which are based on first-mover and economies of scale advantages. In terms of industrial and value chain restructuring, the NEV industrial chain includes battery manufacturing, vehicle manufacturing, and charging facilities, bringing together relevant industries to create a new economic growth driver. China's automotive industrial chain has gradually transitioned from relying on engines, gearboxes, and vehicle axles to focusing on core NEV components like batteries, electrical motors, and electronic control systems. During the gasoline vehicle era, the Chinese government implemented a "market for technology" strategy for the auto industry, opening the country's market to a slew of international carmakers, component and parts manufacturers. International corporations have generated technological and managerial spillovers, accelerating industrial chain development in China. In the era of smart and electric vehicles, however, core parts and components for gasoline vehicles were replaced by critical components for electric vehicles. Domestic enterprises, such as CATL and EVE Energy, have gained a technological advantage in power batteries. Meanwhile, software and hardware vendors for smart vehicles, such as Horizon Robotics and Hesai Technology, have emerged as an important link in the innovation chain. Rapid advances in electrification and intelligence have strengthened China's automotive supply chain, resulting in a "dual circulations" landscape of domestic and international markets. In addition to meeting domestic demand, China's auto industry is becoming increasingly important in the global market (Li et al., 2021). Traditional auto industry revolves around the manufacturing value chain. With the arrival of the intelligent EV era, the service chain has become a new value hotspot, and overall NEV competitiveness is dependent on new service capabilities such as digital financial insurance, electric energy supply, and data service.

This paper examines the fundamental rationale for NEV innovations in light of China's NEV development. Compared to traditional gasoline vehicles, the NEV industry represents a technological breakthrough and leap forward. Integrated innovations in battery technology, electronic control systems, and intelligent connectivity provide the automotive industry with the momentum to seize the opportunities presented by the new generation of technological revolution and industrial transformation. These innovations also drive clustered innovation within the NEV industry. Compared to existing

literature on the NEV industry, this paper's unique contribution lies in its analysis of how China's NEV sector can drive collaborative innovation across the entire industrial chain through technological advancements, with the conclusions further supported by practical case studies.

2. China's NEV Industry: Status and Characteristics

China's NEV industry started to develop almost concurrently with the international trend. In 1999, the State Council initiated the "Clean Vehicle Initiative", a joint effort by multiple government departments, signaling the start of the low-carbon transition in China's automotive industry. Before 2008, the NEV industry was primarily in the stage of concept formation and industrial preparation. The Ministry of Science and Technology (MOST) launched the "Major Sci-tech Project for Electric Vehicles" under the "863 Program" in 2001, a key initiative aimed at advancing cutting-edge technologies in China, establishing a "three verticals and three horizontals" development framework for EVs. The 'three verticals' represent three powertrain solutions: hybrid vehicles, all-electric vehicles, and fuel-cell vehicles, while the 'three horizontals' include the powertrain control system, electric motor and control system, and battery and management system. This period is marked by NEV technology exploration and industrial incubation. Between 2009 and 2014, China's NEV industry went through a period of strategic formation, technological and market accumulation. During this stage, China implemented the NEV strategy and accelerated the commercialization of new energy vehicles and critical components, with a focus on acquiring dedicated engine and power module optimization design technology, mass production processes, and cost control technologies. In 2010, the Chinese government designated the NEV industry as a strategic emerging industry, calling for breakthroughs in critical technologies such as power batteries, drive motors, and electronic control technologies as generic technologies, as well as the commercialization of plug-in hybrid and all-electric vehicles. *The Energy Conservation and NEV Industry Development Plan* (2012-2020), published in 2012, identified all-electric vehicles as the primary strategic direction of China's NEV industry.

Digital and intelligent transformations, as well as green and low-carbon development, have emerged as clear trends in China's NEV industry. China's leading NEV manufacturers have pioneered independent R&D and manufacturing, forming an endogenous driving force for industrial chain coordination and vertical development. In 2021 and 2022, China's NEV sales volume increased by 157% and 96%, respectively. By 2023, NEVs accounted for more than 30% of China's domestic automobile sales volume on average, with a higher proportion in medium and large cities. China's NEV industry is gaining prominence on the global stage as a result of its innovative development model and ongoing efforts to improve it (Li, 2024).

2.1 Demand-Side Impetus for NEV Innovation and Development

As shown in Figure 1, China has seen a steady increase in NEV consumption and a shift away from gasoline vehicles in recent years. According to the China Association of Automobile Manufacturers[2], China's new energy vehicle production and sales volumes in 2023 reached 9.587 million and 9.495 million units, respectively, up 35.8% and 37.9% from the previous year. China's NEV sales began to rise rapidly in 2020, reaching a market share of 31.6% by 2023, up from a low of 300,000 units in 2016 and a market share of only 1.8%. In 2023, China exported 1.203 million NEV units, accounting for approximately 25% of its total automobile exports, a 3% increase from 2022. In 2023, global NEV

[2] China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/tjsj.

sales were close to 1.4 million units, with China accounting for 60%, Europe for 25%, and the United States for 10%. Without a doubt, China has the largest NEV consumer market in the world. In terms of exports, China's NEVs do particularly well in emerging and developing economies. Between 2022 and 2023, Chinese NEVs accounted for 40% to 75% of electric vehicle sales volumes in Indonesia, Thailand, and Brazil. With the introduction of more affordable models, this sales volume is expected to rise further[3]. According to the *International Energy Agency's (IEA) Global EV Outlook 2023*[4], global EV sales are expected to exceed 70 million units by 2030, bringing the total number of EVs to 380 million, with an annual new vehicle penetration rate of more than 60%. The massive demand potential will undoubtedly drive NEV development.

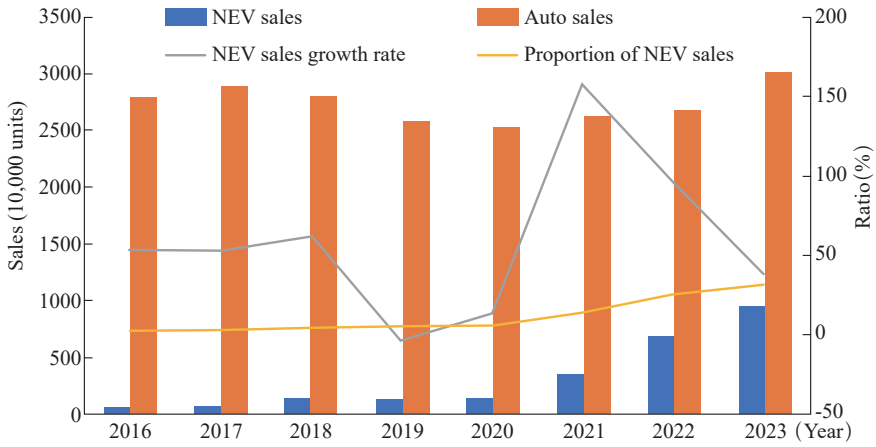

Figure 1: China's NEV Sales Volume, Growth and Percentage (2016-2023)

Source: Drafted by authors based on data from the China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/tjsj.

2.2 Regional Specialization in the NEV Industrial Chain

According to the industrial spatial layout, China's NEV industry is characterized by multi-node clustering and belt distribution, with the majority concentrated in the Yangtze River Delta, Pearl River Delta, Chengdu-Chongqing, and Beijing-Tianjin-Hebei regions. Each industrial cluster has a relatively complete industrial supply chain system, indicating a transition from chain to network development. The Yangtze River Delta is a major NEV manufacturing cluster in China. This region has developed a "four-hour NEV industrial circle" made up of localities with distinct advantages: Shanghai produces the chips and software that make up the brains of NEVs, Jiangsu provides power batteries, Zhejiang provides integrated diecasting machines, and Anhui specializes in final assembly. The complete NEV industrial chain is established within a four-hour circle. In terms of automaker distribution, Shanghai is home to SAIC Motor and Tesla, Jiangsu and Anhui host NIO, Li Auto, Chery, and JAC, and Zhejiang is home to the GEELY Group and some newcomers like Leapmotor. The Pearl River Delta Economic Belt is a key region for NEV manufacturing, home to major companies such as BYD and the GAC Group. BYD manages the entire industrial chain, from vehicle manufacturing to power battery, electric motor, electronic control system, and automotive aftermarket. It has manufacturing facilities in several cities throughout the country. The NEV industrial chain and clustered development pattern had already begun

[3] IEA (2024), Global EV Outlook 2024, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2024.
[4] IEA (2023), Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023.

to take shape in its early stages. It has some similarities with, but goes beyond, the gasoline vehicle industrial clusters.

2.3 China's Emergence As a Major Source of Global NEV Power Battery

China has developed several important industrial clusters for NEV battery manufacturing. According to data from the China Automotive Power Battery Industry Innovation Alliance (CAPBIIA), China's cumulative installed capacity of power batteries reached 387.7 GWh in 2023, a 31.6% increase over the previous year. Chinese enterprises account for approximately 65% of total installed capacity worldwide. Leading Chinese power battery manufacturers include CATL, BYD, China Aviation Lithium Battery (CALB), and Gotion High-tech, which are primarily distributed in southeastern China's coastal regions. Suzhou and Wuxi in Jiangsu Province have established major battery manufacturing sites by implementing advanced manufacturing technology and increasing R&D spending. Jiangsu Province remained China's leader in power battery manufacturing capacity, output, and sales volume in 2023[5]. Jiangsu's power battery industrial clusters follow a coordinated regional development model that includes Changzhou and Nanjing as distribution hubs, Wuxi and Nantong as materials and equipment hubs, and Yancheng, Suzhou, and Zhenjiang as multiple supporting nodes. Changzhou, a new energy town, is home to the headquarters of CALB and Honeycomb Energy, two leading manufacturers of new energy batteries. According to incomplete statistics, Jiangsu has 69 lithium battery industrial hubs, 19 of which are located in Changzhou[6].

2.4 Enhancing Infrastructure and Industrial Development Environment

Charging infrastructure is critical to NEV adoption and user convenience. By May 2024, China's total charging facilities increased by 56% to 9.924 million units. China has established the world's largest and most extensive EV charging infrastructure system, covering major cities and highways across the country, with plans to expand the number of charging stations in the future. In addition, battery swap stations, a new and convenient charging model, are rapidly being deployed and built. In 2023, China added 1,594 battery swap stations, bringing the total number of completed stations to 3,567[7]. NIO has taken the lead in the development of battery swap stations, with 65% of the market share. By June 2024, NIO has built over 2,400 battery swap stations nationwide, providing more convenient power supply services[8].

3. Innovative Development Model of China's NEV Industry

3.1 Pursuing Autonomy and Control over Key Technologies through Independent Innovation

China's NEV industry is primarily market-driven, with an emphasis on independent innovation of key technologies. From the very beginning of its development, China has chosen a path of independent innovation for the "three electrics" technologies—battery, electric motor, and electronic control—which together account for 50% of the cost of NEVs. Furthermore, ongoing efforts have been made to improve the level of independent innovation in high-end component design and manufacturing, as well as ICV technology. According to the *New Energy Vehicle Industry Development Plan* (2021-2035), China

[5] Jiangsu Province Automotive Industry Office: Jiangsu Province Power Battery Industry Development Report (2023).

[6] China Business Industry Research Institute: "China's power battery industry market prospects and Investment Opportunities Research Report".

[7] Yan Fuying, Li Changrui: "Our country has built the largest charging infrastructure system in the world", Xinhua News Agency, https://www.gov.cn/lianbo/bumen/202406/content_6957941.htm.

[8] NIO: https://www.nio.cn/charger-map.

aims to achieve internationally advanced levels in core technologies for new energy vehicles by 2025, including power batteries, drive motors, and in-vehicle operating systems.

3.1.1 Power battery R&D and application

Chinese companies have made technological advances in power batteries, leading the world in this critical NEV component. In the international frontier market, Chinese companies such as BYD and CATL have concentrated resources and overcome technological barriers through independent R&D, gradually surpassing leading Japanese and Korean companies like LG Chem and Panasonic, and establishing themselves as global leaders in lithium battery technology. Technological breakthroughs have increased energy density, reduced costs, and improved the safety performance of power batteries. CATL launched the Kirin battery in 2022, with a volume utilization ratio of more than 72%. The energy density of a Kirin battery with a ternary battery cell is 255Wh/kg, while one with phosphate iron lithium is 160Wh/kg[9]. Kirin battery was named the best invention of 2022 by Time magazine due to its high level of battery pack integration at the time. In 2020, BYD introduced the "blade battery" to address NEV lithium battery safety concerns. This technology eliminates the "thermal runaway" problem with conventional power batteries, providing unparalleled advantage in safety.

3.1.2 NEV electric motors and electronic control systems

Despite their international performance, China's drive motors are heavier in terms of unit power and have a lower power density. The permanent magnet synchronous motor (PMSM) is the primary electric motor technology for China's NEVs, and companies such as BYD and Founder Motor have made significant R&D investments. China's NEV electric motor manufacturers should improve motor performance and durability by upgrading material performance and manufacturing processes.

The new energy vehicle's electronic control system consists of the Battery Management System (BMS), Motor Controller Unit (MCU), and Vehicle Control Unit. These are critical to achieving efficient operation and safety in NEVs. In the early stages, China's NEV electronic control technology was modeled after the electronic control unit (ECU) of gasoline vehicles, and NEV electronic control software lagged behind international standards. For the past few years, China has relied on imported core technologies and components for its electronic control system. For example, international companies such as Maxim, Texas Instruments (TI), and NXP of the Netherlands dominated the market for critical components such as the power voltage collection chip of the integrated circuit board of the battery management system. Infineon of Germany, On Semiconductor of the United States, and Mitsubishi of Japan hold the monopoly on Insulated-Gate Bipolar Transistor (IGBT) for motor control devices. China's BYD and other companies have taken steps to acquire core technologies in electronic control systems through importation and independent R&D, but there is still much room for improvement when compared to internationally advanced levels.

3.1.3 Operating systems and ICV technology

ICV operating systems are classified into three types of technology: vehicle safety control, intelligent driving, and intelligent cockpit[10]. ICV technology is a key direction for future NEV development. China's rapid development of 5G technology, connected vehicles, and autonomous driving

[9] CATL: The world's highest level of integration, CATL released Kirin Battery, 2022, https://www.catl.com/news/6467.html.

[10] ICV Sub-Committee of the National Technical Committee of Auto Standardization: Research Report on General Technical Requirements of Vehicle Control Operating System (2021).

technology provides favorable technological support for NEVs. Huawei's innovation in ICV solutions adds significant dynamism to China's development of intelligent NEVs. This gives China's NEVs a significant competitive advantage on the global market.

3.2 Strong Industrial Chain Fundamentals Create Manufacturing Advantage

NEV manufacturing is distinguished by industrial clustering and modularization. Many NEV industrial clusters have been established in various locations throughout China. The NEV industry spans multiple industrial sectors and is a prime example of modern industrial integration, with long industrial chains, broad coverage, and high complexity. China's NEV industrial chains encompass a wide range of processes, including raw material supply, parts, components, vehicle assembly, producer services, on-board systems, and ICV applications. Close collaboration between upstream and downstream enterprises has resulted in efficient resource allocation and synergy, a key manifestation of industrial clustering and coordination in the modern industrial system. According to a study on Shanghai and Guangzhou conducted by Zhang et al. (2024), China's NEV industrial and value chain coordination model has evolved from "dominance by leading enterprises and close collaboration with upstream suppliers" to "breakthroughs in core technologies that inspire innovation dynamism" and "improving innovation services", which underpin the high-quality development of NEV industrial clusters in China.

3.2.1 Raw material supply and component manufacturing

NEVs require unique raw materials for their batteries, electric motors, and electronic control systems, while other materials are similar to those used in gasoline vehicles. The power battery consists of anode, cathode, separator, and electrolyte, with key cathode materials being primarily lithium iron phosphate and ternary lithium. This has led to a huge demand for raw materials such as lithium, cobalt, and nickel. Companies such as Ganfeng Lithium and Tianqi Lithium have strategically invested in lithium ore reserves across the globe, ensuring a steady supply of raw materials for battery production. The drive motor is made up of mechanical structures like the stator, rotor, windings, and end caps, which require raw materials like earth magnets, silicon steel sheets, copper, and aluminum. The raw materials for the electronic control system include the IGBT power module, EV drive, and controller. Among them, the IGBT is a core component with high technological barriers in the electronic control system.

3.2.2 Midstream parts and components manufacturing and assembly

Midstream industries include the manufacture and assembly of critical parts and components such as batteries, electric motors, and electronic control systems. The most common type of motor is permanent magnet synchronous motors. The three most expensive components are permanent magnets, stator cores, and housings. The electronic control module (electric circuit and control software), EV drive, and power converter are the three main components of an electronic control system. Other components include bodywork, tires, and interior decor similar to those found in gasoline vehicles. The clustered development advantage of China's auto industry has been extended to the NEV industry, ensuring the high quality and low cost of such generic components while also strengthening China's overall NEV manufacturing advantage.

3.2.3 Downstream vehicle manufacturing and services

Vehicle manufacturing, sales, and aftermarket services are examples of downstream NEV sectors. The high degree of regional agglomeration, combined with the advantage of an integrated and collaborative information platform, provides effective support to manufacturing and business operations

across the supply chain. Complete industrial chains have helped to improve vertical integration capabilities. Chinese companies such as Huawei, Baidu, and Xiaomi have entered the NEV market and accumulated a sizable market share. They have also taken proactive steps to expand into the international market, increasing their brand influence and market share while also creating new opportunities for cross-sectoral integration. This has prompted innovation not only in intelligent hardware, but also in the coordinated development of the industrial chain, from software to services.

3.3 The Integration of Value Chains Drives Future Development

The NEV industry is built on highly decentralized industrial chains, with numerous derivative industries and value addition in each sector. The NEV value chains encompass a wide range of links, including R&D, automotive parts and components, vehicle manufacturing, logistics, transportation, advertising, sales, and aftersales maintenance. Automotive peripheral industries are even more diverse, encompassing onboard platform software applications, new energy charging infrastructure, ICV and road sensors, and automotive decorations. These industries form an intelligent NEV value chain network that extends across a wide range of sectors. As intelligent networking and autonomous driving technologies become increasingly mature, NEVs will serve as an important part of future living spaces, unlocking more applicable scenarios and connecting to the latest application platforms.

NEV enterprises can be categorized into the following three business models in terms of their disparate main value chain coverage: First, complete-chain automakers. They include well-established traditional automakers with NEV business expansion and leading new entrants. Those automakers possess strong R&D capabilities, continuous product innovations, efficient distribution systems, and digital ecosystems. Second, distribution, sales and service-oriented auto companies that provide upstream partners with brand promotion, channel development, innovation services, and user operations. Third, automakers focused on vehicle R&D, procurement and manufacturing. With core competencies in cost control and supply chain management, such automakers profit from mass manufacturing[11]. In addition, an increasing number of value processes are generated through value chain extension, giving rise to numerous growth enterprises that contribute to value chain development.

These value chain links have created a massive value chain network, and the integrated "manufacturing and service" development model has accelerated NEV expansion and penetration throughout the industrial system. As a core integrated application platform, the NEV industry will continue to strengthen its position in the modern industrial system, acting as a key driver of future industrial renewal.

4. NEV Industrial Transformative Effect and Corporate Innovation

As a strategic emerging industry, China's NEV industry has grown from a fledgling to a powerhouse over the last decade, becoming a pillar of China's modern industrial system with increased manufacturing capacity. From a manufacturing standpoint, NEVs are far more digitalized than conventional vehicles, accelerating the transition, upgrade, and intelligence of the traditional auto industry. NEV capacity expansion has a significant impact on the technological upgrading of upstream and downstream enterprises. China's massive market is ideal for developing and maintaining comprehensive industrial capabilities and systems, adding to the diversity of the NEV industrial ecosystem.

[11] Deloitte, Report on the Analysis of China's Five NEV Trends and Value Chain Positioning Model and Interpretation of Strategic Reflection Framework, 2019.

4.1 NEVs Spur Conventional Auto Industry to Upgrade

4.1.1 Technology substitution and process change

As a core technology substitution, NEVs have replaced traditional internal combustion engines with electric drive systems, evolving automobiles' "four new features": electrification, connected vehicle, intelligence, and shared use. Over the last decade of technological advancement, the sophistication of battery management systems, electronic control systems, and drive motors has improved vehicle performance and reliability. NEV production necessitates new assembly technologies and testing standards, such as the battery assembly and testing process and the motor installation process. The conventional automobile production line must be overhauled to meet the needs of NEV manufacturing.

4.1.2 Supply chain ecosystem restructuring and improvement

The NEV industry has rebuilt and continuously improved supply chains to keep up with technological advancements and changing demand. This has resulted in a high level of integration between upstream raw material supply, midstream parts and component manufacturing, and downstream vehicle production and sales. China has established a comprehensive industrial system in the NEV sectors, including batteries, electronic control and electric drive systems, electronic products, and software. Charging, battery swap, and battery recycling facilities have all undergone continuous improvements. China's NEV battery installed capacity exceeds 60% of the global total. Six Chinese companies, including CATL and BYD, are ranked among the top ten power battery manufacturers worldwide. China shipped more than 70% of the world's critical power battery materials, including anodes, cathodes, diaphragms, and electrolytes. Election Drive and electronic control companies, such as FinDreams Powertrain, dominate the global market, and many high-end chip and smart driving system software and hardware manufacturers have thrived. China has built over 9 million charging stations in total, as well as more than 14,000 power battery recycling companies, both of which rank first globally. NEV enterprises have significantly increased supply chain efficiency and transparency, as well as their global competitiveness and risk resilience, by working closely with OEM manufacturers.

4.1.3 Market and brand reshaping

Leveraging China's massive market advantage, the rise of NEVs has transformed the competitive landscape of the traditional automotive market, ushering in a new era of automotive market and brand reshaping. Driven by China's massive demand, emerging NEV forces such as NIO, Li Auto, SERES, and Xiaomi have risen to the forefront of the automotive market, becoming household names and breaking foreign brands' monopoly on mid- and high-end auto market segments in the gasoline vehicle era. Among them, BYD achieved global sales of 3 million electric vehicles, becoming the world's top-selling electric vehicle brand and entering the top ten list of automotive brand sales for the first time, marking the rise of Chinese brands.

4.2 Propelling the Digital Transition of NEV Industrial Chain

Digital transition is an important means of increasing industrial competitiveness and efficiency. According to Hong and Ren (2023), integrating innovation and industrial chains is critical to achieving synergy between the digital economy and industrial innovation, as well as creating a digital intelligence empowerment mechanism for the integrated development of digital industrialization and digitalization. The NEV industry has achieved a comprehensive digital transition from production to sales and aftersales service by utilizing automated assembly, big data integration, artificial intelligence (AI), and

the Internet of Things (IoT), among other technology applications. According to Jie et al. (2023), digital intelligent transformation can accelerate NEV innovations by leveraging consumers in addition to developing new production capabilities.

4.2.1 Digitalization of production process and supply chains

The NEV production line has become smarter and more efficient as a result of digital intelligence measures such as automated assembly lines, intelligent warehousing systems, and collaborative production software. This has improved a variety of aspects, including production scheduling, logistics management, energy consumption management, safety management, and quality inspection, resulting in significant improvement in productivity and product quality. Neta Auto used digital simulation and automated visualization of the manufacturing process to improve digital efficiency, increasing production capacity by 60% in 2022 over the previous year[12]. Big data and blockchain technology enable NEV companies to achieve real-time supply chain monitoring, optimize inventory, and improve supply chain responsiveness and reliability. Unlike traditional data lakes, which only store information about equipment, people, tools, inspections, and other production processes, Tesla has used the concept of an "Data Middle Platform" and built such a "platform" for its Shanghai Gigafactory, achieving unified governance of key data. This data mid-end platform, designed for data used in business analysis, imposes constraints on data format, accuracy, and reliability from the input source in accordance with data usage standards, ensuring that data resources are readily available for quality work. Digital supply chain management not only improves efficiency, but it also increases supply chain stability and security. China is a world leader in the intelligent manufacturing of automobiles and NEVs, with widespread application of digital manufacturing technologies. However, there is still a lot of room for improvement in digital design and industrial software.

4.2.2 Sales and service digitalization

The traditional 4S (sales, spare parts, service, and survey) dealership marketing model faces multiple challenges, including a lack of customers, a low conversion rate, high marketing costs, and insufficient marketing innovation. As a result, a new marketing model is emerging that incorporates a variety of elements, including online channels and experienced stores in shopping malls. NEV businesses engage in marketing activities through e-commerce platforms and intelligent sales systems, which help to expand sales channels and improve customer service. Online direct sales and the elimination of intermediaries have increased transaction efficiency while also making it easier to collect and analyze consumer behavior data in order to capture market demand. In terms of aftersales service, NEVs also utilize digital platform technology, in conjunction with intelligent vehicle monitoring systems, to achieve functions such as automatic vehicle diagnostics, making after-sales service more convenient and efficient. Taking BYD as an example, the company's battery monitoring platform incorporates a variety of cloud-based detection and fault warning algorithms, allowing for comprehensive monitoring and early warning for a variety of vehicle models, operational conditions, and fault types. This significantly reduces after-sales maintenance costs while improving battery safety. In terms of incident response and cybersecurity assurance, BYD delivers alarm information to the after-sales team in real time, ensuring continuous 24/7 service. This function is achieved through a combination of its monitoring platform, strong big data

[12] Xinhua: "Faster" and "smarter" production line, cars lead the new direction of "intelligent" manufacturing,http://www.news.cn/fortune/2023-10/27/c_1129942316.htm.

and information technology capabilities, and comprehensive after-sales service system. When a vehicle breaks down, the system will immediately contact the user to confirm the incident and provide a rescue plan, ensuring the safety of vehicle operation.

4.2.3 Data-driven product optimization

Data platforms that use 5G, blockchain, and AI technologies can acquire user ID, vehicle data, and driving behavior data more quickly and accurately. Such a wealth of data can be harnessed to speed up platform iteration and service efficiency, promoting precise empowerment of the upstream and downstream of the intelligent automotive industry. For example, a data-driven energy efficiency mechanism can be established to monitor and analyze energy consumption data in order to identify critical impediments to vehicle range and propose optimization measures to reduce energy consumption. Data-driven product optimization allows NEV companies to respond quickly to market demand and increase their competitiveness.

4.3 NEV Industry Reshapes China's Transportation Network for Smart Cities

Based on the data-linked "User-Vehicle-Road-Cloud" Integration System, NEVs contribute to intelligent and sustainable development of urban transportation, which has been aided by ICV and autonomous driving technologies. Multi-tiered data integration and computing platforms are developed using information from vehicle sensing, traffic control, and urban management to integrate NEVs into the urban transportation system and broaden their applications, ushering in a new era of intelligent and efficient transportation.

Intelligent connected vehicles (ICVs), which are still in the technology development stage, facilitate autonomous driving and path optimization by synchronizing traffic data. Chinese cities and businesses have been actively seeking opportunities for collaboration. By the end of 2023, China had built 17 state-level ICV test experiment zones, seven connected vehicle pilot zones, and 16 pilot cities to coordinate the development of smart cities and ICVs[13]. Huawei serves as an incremental supplier of ICVs. Since 2013, it has conducted extensive research and development on connected vehicles and intelligent driving. After many years of R&D, it launched the intelligent vehicle solution brand HI in 2020, which includes computing and communications architecture, intelligent systems, and a computing platform. Huawei has collaborated with several automakers to create connected vehicle platforms. For example, it has collaborated with the BAIC Group, Changan Automobile, and the GAC Group under the Huawei Inside model, and SERES, Chery, and JAC under the Huawei Smart Selection model. The integrated digital transportation management system can efficiently dispatch and optimize traffic flows, control traffic signals, and choose the best path to avoid congestion and increase traffic efficiency.

Furthermore, the intelligent charging network connects energy consumers and suppliers, making charging services for NEVs more convenient. Advances in ICV and cloud computing technologies have enabled the integration of transportation and energy sectors. In addition to leveraging clean energy resources within and beyond the transportation infrastructure to accelerate the green mobility transition, ICV and cloud computing technologies are transforming the future transportation network into a major energy storage solution. Mutual support between transportation and energy networks improves energy efficiency and controllability.

[13] Ministry of Industry and Information Technology of the People's Republic of China, Interpretation of the "Notice on Carrying Out Pilot Applications of 'Vehicle-Road-Cloud Integration' for Intelligent Connected Vehicles", https://wap.miit.gov.cn/jgsj/zbys/gzdt/art/2024/art_e7c5417e9d8949f194945fc290f54dc3.html.

5. Future Outlook

The Chinese new energy vehicle industry holds a relatively significant advantage in the international market competition, achieving a degree of "overtaking on the curve". Improving ICV infrastructure and autonomous driving technology will further highlight NEVs' future role. To capitalize on future opportunities, China must prioritize NEV development. Geopolitics and economic volatility have also created uncertainties in China's NEV industry. For example, the European Union has increased tariffs on Chinese NEVs, while the United States has restricted high-end chip exports to China. Technological independence and self-reliance are required to build a modern industrial system. In this regard, it is critical to ensure industrial and supply chain security and stability, overcome technological bottlenecks, and pursue research advancements. China's NEV industry has already taken the first steps towards technological independence and self-reliance. Moving forward, it must identify and keep up with technological and market development trends.

5.1 Timely Adjusting Strategies to Adapt to Changing Market and Regulatory Environment

Consumer demand for intelligent vehicles is expected to rise significantly as autonomous driving and vehicle-road integration technologies advance. To maintain technological leadership, NEV enterprises must respond quickly to new market demands while also optimizing design and performance. The spontaneous combustion of lithium batteries creates an unavoidable technological and security issue for the NEV industry. While automakers and battery manufacturers should improve battery security innovations and management, third-party institutions must also strengthen battery safety management during testing procedures. In addition to optimizing battery technology and increasing safety performance, automakers should boost market and consumer confidence in battery safety.

Governments have enacted stringent environmental regulations and incentive policies to encourage the adoption of clean energy passenger and commercial vehicles in response to the growing severity of climate change. The Environmental Protection Agency (EPA) issued stricter emissions standards in March 2024 to reduce greenhouse gas emissions from heavy-duty vehicles such as trucks and buses, with the new standards to be applied to model years 2027 through 2032[14]. In early 2024, the Council of the European Union and the European Parliament adjusted the CO2 emissions reduction targets for heavy-duty vehicles, raising the current 2030 emissions reduction target from 30% to 45% and then to 90% in 2040[15]. Such policy shifts have accelerated the global development of new energy commercial vehicles, necessitating strict compliance with environmental regulations in product design and manufacturing processes, as well as a reduction in carbon emissions.

5.2 Regulating Market Entities through Opening-up and Cooperation

Given the vast NEV industrial chain, the government should promote open institutional development in terms of technological innovation and fair market competition in order to coordinate factor resources based on a comprehensive consideration of policy, capital, talent, land, and infrastructure factors (Liu, 2023). It is critical to highlight the importance of leading platforms like the National New Energy Vehicle Technology Innovation Center (NEVC) and the China Automotive Technology and Research Center (CATARC). Enterprises, universities, and research institutions should collaborate to conduct research and development, increase the supply of critical technologies for the NEV industry, and

[14] US EPA: Final Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles, 2024.

[15] The European Union: Heavy-duty vehicles: Council and Parliament reach a deal to lower CO2 emissions from trucks, buses and trailers, 2024.

establish R&D centers for global NEV innovations. Furthermore, leading public institutions should work together with businesses to create collaboration platforms for standardization and data connectivity, remove technological and information barriers, conduct intelligent product testing and improvement, conserve industrial chain energy and reduce emissions, and foster an industrial environment of compatibility, connectivity, and energy efficiency (Xiao and Qi, 2024). Automakers and data groups should avoid siloed operations and destructive competition.

As the NEV industry enters a new development stage, it is critical to protect market participants' equal rights and prevent monopolistic behavior (Bai and Meng, 2018). Leading NEV companies must strictly adhere to anti-monopoly laws and avoid abusing their market dominance in supply chains, Internet platforms, data usage, and patent management. They should investigate and address anti-competitive practices such as limiting parts and component manufacturing, restricting dealer purchasing and sales, and withholding repair technology information. Regulatory authorities should prevent internet platforms from abusing data, algorithms, and platform rules to exclude or limit competition. Additionally, automakers and internet companies should responsibly utilize performance and user data, ensuring information transparency and fair access. They should also actively explore patent use and sharing mechanisms. To ensure the healthy development of the emerging NEV market, the government must collaborate with businesses to implement fair competition strategies, enforce regulatory compliance, and support open innovation.

5.3 Globalized Manufacturing Distribution Increases Industrial Resilience

A globalized production layout helps enhance the resilience of the new energy vehicle industry, diversify risks, boost competitiveness, and strengthen international cooperation and mutual development. China's NEV manufacturing sector encompasses power batteries, electronic control units, electric motors, and traditional automotive components. Notably, Chinese companies hold a significant advantage in battery manufacturing. CATL led the way in establishing a global battery supply network, with 13 manufacturing sites, including two in Thuringia, Germany, and Debrecen, Hungary. Once operational, the annual production capacity is expected to be 24GWh and 100GWh. CATL's domestic manufacturing sites are spread across 11 provinces, significantly improving supply efficiency and risk resilience. BYD has also invested in foreign factories in Brazil, Thailand, Hungary, and other countries. Competitive NEV companies should be assisted in establishing subsidiaries or branches in countries participating in the Belt and Road Initiative (BRI) through new establishments, mergers, and joint investments, focusing superior resources on exploring key international markets. Automakers, parts and component manufacturers, and infrastructure companies in the NEV industry, as well as relevant institutions, are encouraged to engage in international capacity cooperation, jointly construct industrial parks, and conduct R&D and procurement cooperation to promote coordinated industrial chain development. Enterprises should establish mutual assistance and cooperation mechanisms to share overseas market information, supporting facilities, production capacity, and sales networks, thereby creating positive interactions.

References:

Bai X. J., Meng H. Emerging Industries, Policy Support and Absence of Incentives and Constraints - Taking the New Energy Vehicle Industry as an Example[J]. Economist, 2018(1): 50-60.

Bai X. J., Song P., Ai Y. et al. Theoretical Logic and Practical Path of Building an Autonomous and Controllable Modern Industrial System in China[J]. Economist, 2022(6): 48-57.

Hong Y. X., Ren B. P. Connotation and Approach of Deep Integration of the Digital Economy and the Real Economy[J]. China Industrial Economics, 2023(2): 5-16.

Jie H., Cailou J., Rong L. Does Intelligent Transformation Trigger Technology Innovation in China's NEV Enterprises?[J]. Energy, 2023, 270.

Li F. S., Zhao S. J., Hu Y. B. Key Issues and Measure Suggestions for the International Development of China's New Energy Automobile Industry[J]. Scientific Management Research, 2021, 39(5): 72-78.

Li X. H. The Current Status and Future Trends of New Energy Vehicles in China[J]. People's Tribune, 2024(9): 76-79.

Liu Z. B. Building a Modern Industrial System in the Market-Oriented Reform and Opening up[J]. Frontiers, 2023(5): 15-23.

Rui M. J. Strategic Thinking, Target and Path for the Construction of the Modern Industrial System[J]. China Industrial Economics, 2018(9): 24-40.

Sheng C. X. Essential Characteristics and Pathways for Creating a Modern Industrial System[J]. China Economist, 2023, 18(6): 2-25.

Xiao X., Qi Y. D. On the Ideas and Paths of the Industrial Foundation Reconstruction of China's New Energy Automobile[J]. Journal of Beijing Normal University (Social Sciences), 2024(3): 148-156.

Zhang D. N., Yang X. T., Song X. F. Agglomeration or Cluster: Evolution Research from the Perspective of Industrial Ecological Network -Take the New Energy Vehicle Industry in Shanghai and Guangzhou as an Example [J/OL]. Soft Science, 1-12.