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The Global Evolution of the New Energy Vehicle Industrial Chain and China's Transformation: A Literature Review on "Chip Shortages and Soaring Battery Costs"

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Abstract: This paper conducts an in-depth discussion of three key issues by reviewing existing scholarly research. First, it outlines the evolutionary trends of the new energy vehicle (NEV) industrial chain from a global perspective. It analyzes the diversified development characteristics of major economies—including China, the United States, Europe, and Japan—within this industrial chain, as well as the distinct strategies each country has adopted in response to current uncertainties. Second, despite China's remarkable achievements in the NEV sector, challenges remain, such as low added value and insufficient international competitiveness. In this context, the paper explores how China can transition from a "quantitative breakthrough" to a "qualitative breakthrough," further optimizing and upgrading its industrial chain structure to climb toward the higher end of the value chain. Finally, it analyzes the causes of China's "chip shortages and soaring battery costs", and proposes potential solutions. Addressing the issues of chip scarcity and high battery costs, the paper puts forward strategies from both government and enterprise perspectives. These include strengthening top-level design, promoting breakthroughs in core technologies, focusing on research and development in key areas, and placing greater emphasis on talent cultivation within the industry. This study aims to provide a solid theoretical foundation for further research on the NEV industrial chain and offer valuable insights for the development of China's NEV industry.

Keywords: Industrial Chain, New Energy Vehicles, Chip Shortages and Soaring Battery Costs, Value Chain Enhancement

1. Introduction

The New Energy Vehicle Industry Development Plan (2021–2035) explicitly states that the development of new energy vehicles (NEVs) is an essential path for China to transform from a major automobile producer into an automotive powerhouse [1]. Due to their environmental benefits and sustainability, NEVs have attracted widespread global attention and have experienced rapid development in recent years. A thorough analysis of the NEV industrial chain not only helps to understand market dynamics and formulate international trade strategies but also holds critical strategic value for promoting the high-quality development of China's economy. At present, the global NEV industrial chain is undergoing accelerated transformation and restructuring, advancing toward greater intelligence and connectivity. However, the industry continues to face significant

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challenges, such as evident weaknesses in the industrial chain, low added value, and insufficient stability, which are limiting its growth [2]. Against this backdrop, how to ensure the security of the industrial chain and enhance the efficiency of value chain management has become a central topic of discussion among governments and academia worldwide.

The NEV industrial chain encompasses the entire process from upstream raw material procurement to downstream market sales, covering multiple stages including technological research and development, production and manufacturing, and supply chain management. Amidst profound global changes unseen in a century, the structure of the global NEV industrial chain is undergoing deep transformation. Different countries, based on their respective resource advantages and policy orientations, have adopted diverse development strategies.

In recent years, China has made remarkable breakthroughs in the NEV sector. Its production and sales volumes have ranked first in the world for consecutive years, and it has established a relatively complete and highly competitive industrial chain. However, as global market competition intensifies, how to transform China's industrial chain advantages into value chain advantages with greater international competitiveness has become an urgent issue to address.

At the same time, the problems of chip shortages and soaring battery costs have become key obstacles hindering the further development of China's NEV industry. Therefore, an in-depth exploration of the evolutionary patterns of the NEV industrial and value chains, as well as effective strategies for resolving the dilemma of "chip shortages and soaring battery costs", is crucial for accelerating the high-quality development of China's NEV industry.

2. Global Evolution of the New Energy Vehicle Industrial Chain

The global evolution of the new energy vehicle (NEV) industrial chain is key to understanding shifts in the global NEV market landscape. By analyzing the industrial chain from the perspectives of NEV services, NEV manufacturing, NEV production support, and raw materials, it becomes evident that China, the United States, Europe, and Japan hold significant competitive advantages. Current research on the NEV industrial chain largely focuses on the mechanisms and pathways through which these countries and regions optimize and upgrade their industrial chains.

As the world's largest exporter of light-duty electric vehicles, China's evolving NEV industrial chain has garnered widespread global attention. Fan Jin et al. used a stochastic computable general equilibrium (CGE) model to assess the resilience of China's NEV industry and its positioning within the global value chain [3]. Their findings indicate that China's NEV industrial chain is relatively short, carries lower industrial risks, and occupies a downstream position in the global value chain. Similarly, Li Xiaohua pointed out that China has built a comprehensive and highly competitive NEV industrial chain, playing an indispensable role in the global market [4]. In recent years, as developed countries in Europe and North America have accelerated their deployment of NEV industries, this sector has become a strategic high ground in international competition. Therefore, amid current global uncertainties, ensuring that China's NEV industry takes the lead in this emerging sector has become even more urgent. Based on an analysis of the international landscape and drawing insights from the diamond model, scholars such as Gao Yuansheng, Jin Tianyang, and Gong Piming have proposed pathways for enhancing China's NEV industry [5-6]. They emphasize that breakthroughs should focus on the research and development of the "three-electric" technologies (battery, motor, and electronic control) and the domestic substitution of key technologies to strengthen supply chain resilience. Additionally, they highlight the need to integrate innovation across the industrial chain and promote intelligent transformation to optimize industrial services and achieve high-quality innovation-driven development.

Research on the U.S. NEV industrial chain primarily focuses on government policy adjustments. For example, Yang Shuiqing and Kong Ying conducted an in-depth analysis of protectionist policies

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introduced by the Biden administration, such as the Inflation Reduction Act [7]. Their study reveals that these policies aim to reduce U.S. dependence on foreign supply chains and enhance the autonomy and resilience of its NEV industrial chain through subsidies, tax incentives, and domestic production requirements. By examining the theoretical and empirical impacts of these measures on the global NEV landscape, Yang Shuiqing et al. found that although U.S. industrial policies have increased its market share, they have also intensified competition across the entire NEV industrial chain. Furthermore, the crowding-out effect of these policies has directly diminished the market share of Chinese automakers in the global arena.

As the core region for global automobile manufacturing, Europe plays a crucial role in the NEV industry. However, in recent years, the European Union's NEV industry has been increasingly challenged by competition from China and other countries, experiencing a decline characterized by falling sales volumes. Ding Chun pointed out that the EU has been intensifying its NEV protection policies and introducing a series of industrial measures aimed at enhancing its net-zero industrial competitiveness [8].

Japan, as an early leader in the NEV sector, possesses distinct advantages in core industrial support. However, in recent years, it has faced challenges such as market pressure on its leading products and inertia in corporate technological innovation. Wu Chongbo and Wu Yuhe examined Japan's strategic adjustments from both government and corporate perspectives [9]. On the government side, Japan is adopting a multi-technology pathway strategy to address its weaknesses in pure electric vehicles while utilizing a market-driven "functional industrial policy" to provide subsidies for both supply and demand. On the corporate side, automakers, represented by Toyota, are maintaining their competitive edge in the global NEV industrial chain through combinational innovation and market expansion.

The global evolution of the NEV industrial chain is driven by multiple factors, including policy guidance, market demand, technological advancements, and geopolitical dynamics. At the policy level, Zuo Shiquan et al. reviewed NEV policies in five major countries—the United States, Japan, Germany, South Korea, and the United Kingdom—to provide insights for China's policy formulation [10]. Notably, Japan's NEV policies have long been a focus of academic research. Tian Xin analyzed Japan's "functional industrial policy" and found that, compared to China's "selective industrial policy," which relies more on government intervention than market mechanisms, Japan's approach emphasizes market competition and direct subsidies for end consumers, improving resource allocation efficiency [11]. Meanwhile, Xiong Yongqing and Xu Wen stressed that "functional" policies outperform "selective" policies in terms of significance and stability [12].

3. Transformation of China's New Energy Vehicle Industry Chain and Value Chain

Over the past decade, China's new energy vehicle (NEV) industry has achieved remarkable progress, forming the world's most comprehensive and competitive industrial chain. In 2023, China's annual NEV production and sales both exceeded nine million units, marking the ninth consecutive year as the global leader [13]. However, challenges remain, including weak international competitiveness and low value-added output. Therefore, how to transform China's industrial chain advantage into a value chain advantage and enhance its position in the global NEV market has become a key academic concern. Scholars have explored this issue in depth, revealing the critical role of industrial synergy and policy support in the value chain transformation process.

Scholars have analyzed China's NEV industry synergy network using various models and theories, consistently concluding that weak collaborative innovation capacity hampers industrial upgrading. Liu Guowei and Shao Yunfei, employing complex network and social network analysis models, found that China's NEV industry lacks full-chain innovation. Although intra-segment synergy in upstream, midstream, and downstream sectors is strong, cross-segment collaboration remains weak [14]. Suo Qi and Li Changsheng, examining innovation actors and technology perspectives,

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discovered that China's NEV industry exhibits fragile collaborative networks both in innovation entities and technology [15]. He Yao et al., using social network analysis and negative binomial regression models, highlighted significant disparities in innovation capacity and market adaptability across different value chain segments, with weak stability and synergy effects in technology R&D and service networks [16]. Further research has confirmed the positive effects of industrial synergy on the NEV industry. Scholars such as Song Zeyuan and Liu Yingqi, Ma Liang and Guo Penghui, Zhou Quan et al., and Jiang Jianhua et al. have analyzed the impact of knowledge sharing in industrial alliances, cooperative R&D within the industrial chain, patent development, and agile alliances [17–20]. Their findings suggest that transforming China's industrial chain advantage into a value chain advantage requires strengthening collaborative innovation across all links, particularly in addressing bottleneck technologies, where closer cooperation and enhanced innovation mechanisms are essential.

In terms of policy support, most scholars believe that the continuation of policy subsidies helps reduce the burden on automobile enterprises, incentivizes their innovation efforts, and thus promotes the transformation of China's new energy vehicle (NEV) industry chain into a value chain. Chen Aizhen et al. point out that, overall, subsidy policies are conducive to the development of NEV enterprises and can enhance the supportive role of the upstream segments of the industry chain [21]. Han Jiqin and Yu Yuqi, using a multiple linear regression model, find that policy subsidies have a positive impact on corporate R&D investment, with the effect gradually increasing along the upstream, midstream, and downstream segments of the industry chain [22]. Sun Jianfu and He Jia, through a dynamic panel data model incorporating characteristic variables, find that the positive effect of government subsidies on innovation and R&D is influenced by factors such as the nature of enterprise ownership, the enterprise's position within the industry chain, and its geographical location [23]. Li Penglin and Wang Tingting adopt the DEA-Malmquist index and threshold effect models to reveal a significant double-threshold effect between government subsidy intensity and technological innovation efficiency, indicating that only when subsidy levels fall within a specific range can they positively impact innovation efficiency [24]. However, some scholars argue that government support has exacerbated the problem of overcapacity in the NEV industry, which is detrimental to the industry's long-term development. Peng Pin and He Xitu, employing evolutionary game theory, reveal that in the long run, government subsidies can weaken enterprises' core competitiveness. They also point out that imposing moderate penalties on automobile enterprises may, conversely, promote the development of the NEV industry [25]. Yan Weilong et al. conduct a heterogeneity analysis on the negative impact of government subsidies on overcapacity and find that such policies have a more significant effect on the overcapacity issues of private enterprises and smaller-scale firms [26]. Based on the above perspectives, how to formulate precise and effective industrial support policies to promote the healthy and orderly development of the industry and to reasonably optimize resource allocation remains an important direction for future research.

In addition, some scholars have explored this topic from other analytical frameworks. Wang Jinfu et al., using BYD as a case study and applying grounded theory, investigate the mechanisms and pathways through which lead firms' ecological dominance can facilitate the optimization of the industry chain [27]. Wang Jinfu et al. argue that technological innovation leadership, industrial collaboration and integration, and digital transformation empowerment are the three key pathways for promoting the transformation of the industry chain into a value chain. Liu Jianhua et al. propose a "Structure-Dynamics-Performance" analytical framework and, through case studies of Japan, demonstrate that such a multi-agent collaborative innovation model can significantly enhance indicators such as patent volume, product sales, and market share, providing valuable insights for the development of China's NEV industry [28].

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4. Solutions to the Dilemma of Chip Shortages and Soaring Battery Costs

The issue of chip shortages and soaring battery costs has become a key obstacle restricting the deep development of China's new energy vehicle (NEV) industry. Insufficient chip supply and the high price of batteries have led to the accumulation of semi-finished products and prolonged delivery cycles, severely impacting the economic performance of Chinese automobile enterprises. At present, scholars have analyzed the causes of this dilemma from multiple perspectives and proposed various solutions from the viewpoints of governments and enterprises.

In response to chip shortages, many scholars have analyzed the issue from the perspectives of industrial organization, collaborative models, and the level of internationalization. Jin Yonghua pointed out from the perspective of industrial organization that the core reason for chip shortages lies in the absence of leading enterprises with absolute discourse power and core advantages in the key segments of China's NEV industrial chain. In addition, an upstream, midstream, and downstream collaborative development model has not yet been formed, resulting in the inability of enterprises to achieve integrated development. Jin Yonghua believes that government departments should promote collaboration between research institutions and enterprises through models such as "Specialized, Refined, Distinctive, and Innovative Enterprises" to jointly overcome core automotive chip technologies. At the same time, optimizing the business environment is necessary to attract global high-end technologies and talents. Li Fangsheng et al. [29], from an international perspective, pointed out that the uncertainty of the international trade environment and the lack of alignment between certification standards and international norms are major factors hindering the openness of technological innovation, leading to chip shortages. Li Fangsheng suggests promoting multilateral mutual recognition cooperation with other countries in the field of NEV product testing and standard certification. Bai Mei [30] argued that Chinese automobile enterprises are highly dependent on policy subsidies, and their competitiveness needs to be enhanced. She recommends strengthening cooperation with other well-known automobile enterprises to achieve complementary advantages.

In response to soaring battery costs, many scholars have provided analyses from the perspectives of R&D capabilities and the international trade environment. Li Keqing et al. [31] pointed out that China's power batteries face challenges such as insufficient R&D capacity and weak core competitiveness. They proposed countermeasures focusing on advancing battery recycling technology and developing business operation models. Xiao Xu and Qi Yudong [32] reviewed the development status of NEV battery recycling businesses in the United States, Germany, and Japan. They emphasized that China lacks comprehensive planning in battery technology, with noticeable shortcomings in technological foundations and product platforms. Ding Chun et al. analyzed how the European Union's protectionist policies on batteries affect China's battery shortage issues through transmission mechanisms. They suggest strengthening the construction of traceability management platforms for NEVs and promoting the realization of full lifecycle traceability functions for power batteries.

5. Conclusion

Amid the booming development of China's NEV industry, ensuring the security of the industrial chain and moving toward the high-end value chain are crucial for enhancing the country's comprehensive national strength and achieving carbon peak and carbon neutrality goals. This paper comprehensively reviews scholars' research on the evolution of the global NEV industrial chain, how China can transform its industrial chain advantages into value chain advantages, and how to effectively address the challenges of chip shortages and soaring battery costs. Based on these studies, the following conclusions are drawn.

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Major global economies have adopted diverse development strategies during the evolution of the NEV industrial chain. China continues to promote technological innovation, breaking technical barriers, and is committed to transforming its industrial chain advantages into value chain advantages. The United States focuses on strengthening the autonomy of its industrial chain, utilizing policy tools to consolidate its domestic supply chain and reduce external dependence. Europe implements comprehensive strategic layouts, enhancing green standards and establishing market barriers to protect its automotive industry. Japan adjusts its technological paths and market strategies to maintain competitiveness in the new market landscape. These strategies not only reflect each economy's emphasis on new energy technologies and markets but also reveal the dynamic evolution and development trends of the global NEV market.

Transforming the advantages of the NEV industrial chain into value chain advantages is a complex process involving technological innovation, industrial collaboration, and policy support. For China, the number of technology patents and the weakness of charging infrastructure remain bottlenecks in supporting its industrial chain.

To solve the problem of chip shortages and soaring battery costs, multi-level and multi-angle strategies should be adopted. For the government, it is necessary to strengthen top-level design and advance breakthroughs in core technologies through multiple measures. Furthermore, it should improve the industrial chain ecosystem and guide various enterprises to conduct in-depth R&D in their respective fields. For enterprises, emphasis should be placed on the R&D of key segments such as chips and batteries, as well as on talent development, achieving the integration of industrial chains, talent chains, and other related chains.

Today, China's NEV industry is playing an increasingly prominent role in the international market. By strengthening technological innovation, improving policy frameworks, and deepening international cooperation, China is expected to achieve a more significant competitive advantage in the global NEV sector. Future research should focus on these core areas to support the long-term prosperity and leadership of China's NEV industry.

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