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Research on the Digital Collaborative Mechanism of New Energy Vehicle Supply Chain Enabled by Digital Intelligence Technology and Driven by Chain Leader Orders: An Empirical Study Based on Zhangjiagang Industry

Mo Li

Shazhou Professional Institute of Technology, Suzhou, China
229813781@qq.com

Abstract: *The digital collaboration of the new energy vehicle supply chain is the key path to enhance industrial resilience. Taking Zhangjiagang industrial cluster as the empirical object, based on the platform supply chain and dynamic capability theory, this paper analyses the practical dilemma of supply chain collaboration driven by the lead order of the chain, and constructs a collaborative mechanism model enabled by digital intelligence technology. The results show that the chain leader enterprises play a role of bridge and empowerment through order traction and quality standards, but the core obstacles are data fracture, limited scope of cooperation and solidification of the whole zero relationship. Digital intelligence technology realizes collaborative empowerment from three dimensions: data penetration, intelligent decision-making and ecological embedding. The three-dimensional collaborative model of " chain leading-technical support-mechanism guarantee " is constructed, which provides the core idea, architecture design and implementation path of the system for digital collaboration of supply chain. The research can provide theoretical reference and practical enlightenment for the digital transformation of supply chain in Zhangjiagang and similar industrial clusters.*

Keywords: *Digital intelligence technology; Chain leader enterprise; Supply chain collaboration; New energy vehicles; Zhangjiagang*

1. Introduction

Driven by the strategic goal of dual carbon and the wave of electrification and intelligentization of the global automobile industry, the new energy automobile industry has become a strategic highland for the transformation and upgrading of China's manufacturing industry [1]. In 2024, China's new energy vehicle production and sales exceeded 12 million, ranking first in the world for many consecutive year. However, the rapid expansion of industrial scale has also exposed deep structural dilemmas : long supply chain, many participants, high complexity of coordination, data island and standard separation lead to low efficiency of coordination, and supply chain resilience is facing severe challenges [2]. In 2025, the Ministry of Commerce and other eight departments jointly issued the " Special Action Plan for Accelerating the Development of Digital Intelligence Supply Chain, " which clearly requires promoting the intelligent development of the manufacturing supply chain, and building a digital intelligence management platform integrating material procurement, demand forecasting, automatic scheduling, inventory dynamic management and other functions. The policy shows that the digital intelligence transformation has risen from the independent choice of enterprises to the strategic task of systematic industrial change.

As an important gathering place of the new energy automobile industry in the Yangtze River Delta, Zhangjiagang has gathered nearly 400 enterprises in the whole automobile industry chain, including more than 90 enterprises above designated size. It achieved an output value of nearly 50 billion yuan in 2024, and clearly put forward the development goal of breaking through 100 billion yuan by 2027 [3]. The chain leader enterprises represented by Beam Automobile drive the coordinated development of local parts enterprises through order traction and quality standard output. However, Zhangjiagang's industrial practice also exposes deep challenges : the weak digital foundation of small and medium-sized enterprises, the opaque data of multi-level suppliers, and the limited collaborative radius of chain owners.

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These problems reflect the general shortcomings of the current supply chain collaboration mechanism. Based on this, this paper aims to explain the internal mechanism of order-driven supply chain digital collaboration of the leader enterprises of the digital intelligence technology enabling chain, reveal the key collaborative dilemma in Zhangjiagang's industrial practice, and systematically build an effective digital collaboration mechanism, and strive to provide theoretical reference and practical enlightenment for the digital transformation of the supply chain of the new energy automobile industry.

2. Theoretical Basis and Analytical Framework

2.1. Definition of Core Concepts

The chain leader enterprise refers to the enterprise that occupies the core position in the industrial chain and has strong resource integration ability and competitive advantage. It usually plays a leading and guiding role among upstream and downstream enterprises through order distribution, technical standards and quality requirements as the core manufacturer or brand. In the field of new energy vehicles, the chain leader is not only the ' demand initiator ' of the order, but also the ' standard setter ' of the collaborative rules [4]. Order-driven refers to the whole process operation mechanism of the upstream supplier's production, scheduling, delivery and so on, which is driven by the purchase order of the leader enterprise of the chain. Its core feature is the supply chain response mode of pull rather than push [5]. The digital collaboration of supply chain refers to the efficient integration and real-time sharing of information flow, logistics and capital flow by the participants in the supply chain with the help of digital technology, so as to achieve collaborative operation in the planning, procurement, manufacturing, delivery and other links. Digital intelligence technology empowerment emphasizes the integration and application of digital technology and intelligent technology, that is, based on artificial intelligence, digital twin, blockchain and other technologies, through data penetration, process optimization and intelligent decision-making, to improve the overall operation efficiency of the supply chain [6].

2.2. Relevant Theoretical Basis

This study is based on platform supply chain theory and dynamic capability theory. The platform supply chain theory points out that intelligent manufacturing needs to build a platform-based supply chain organization to integrate resources to meet the needs of mass customization. This theory reveals several new characteristics of the platform supply chain, including the bilateral uncertainty of supply and demand, the complexity of subject interaction, the coexistence of digital intelligence technology empowerment and risk [7]. The dynamic capability theory provides an analytical framework for understanding the reconstruction of resources and capabilities under the background of enterprise digital intelligence. Some researchers have used this theory to construct an intelligent transformation model of cloud-end-edge integration, and analyze the main bottlenecks of the intelligent transformation of new energy vehicle supply chain [8]. The above theories together constitute the theoretical basis for this paper to analyze the dilemma of supply chain collaboration and design the empowerment mechanism.

2.3. Construction of theoretical analysis framework

Based on the above platform supply chain theory and dynamic capability theory, this paper constructs a three-dimensional progressive analysis framework of "chain leader traction-technology empowerment-ecological symbiosis" as shown in Figure 1 to systematically explain the evolution logic and implementation path of digital synergy of new energy vehicle supply chain.

The first dimension is ' chain leader traction ', which emphasizes the initial power and leading role of chain leader enterprises in supply chain collaboration. By virtue of their market position and resource allocation ability, the leader enterprises of the chain form a de facto " power anchor " through the scale effect of order quantity and the technical output of quality standards, so as to drive the production and delivery behavior of upstream suppliers in reverse with demand pull, and at the same time drive the capacity improvement of small and medium-sized enterprises with technology spillover. This dimension corresponds to the governance model of the ' chain leader-led supply chain ' stage, which is characterized by the one-way output rules of the chain leader enterprise, the passive response of the supplier, and the overall coordination with the interests of the chain leader as the core orientation. The second dimension is ' technology empowerment ', which focuses on how digital intelligence technology can break through the linear boundary of traditional supply chain and realize the transition from point-to-point connection to network coordination. Specifically, data penetration technologies such as industrial Internet, unified

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platform, etc., can break the information island, so that the data of multi-level suppliers can be gathered and shared in real time; intelligent decision-making technologies such as demand forecasting, intelligent scheduling, digital twins, etc., optimize the efficiency of resource allocation and abnormal response. The essence of technology empowerment is to transform the supply chain from "rule of man" to "rule of number," and promote the evolution of organizational form to the stage of " platform supply chain. " It is characterized by multi-agent online collaboration, process automation and intelligent decision-making. The third dimension is ' ecological symbiosis ', which transitions the supply chain parties from short-term transaction relationship to long-term value co-creation and strategic mutual trust. The core of this dimension lies in transcending the thinking pattern of zero-sum game, cultivating multi-win-win ecological partnerships through trust mechanisms such as blockchain quality traceability, smart contracts, etc., and benefit distribution mechanisms such as quantifying collaborative behaviors as revenue-linked indicators. Ecological symbiosis corresponds to the evolution direction of ' multi-center digital ecological supply chain ', which is characterized by decentralized governance structure, open platform ecology and sustainable collaborative cycle.

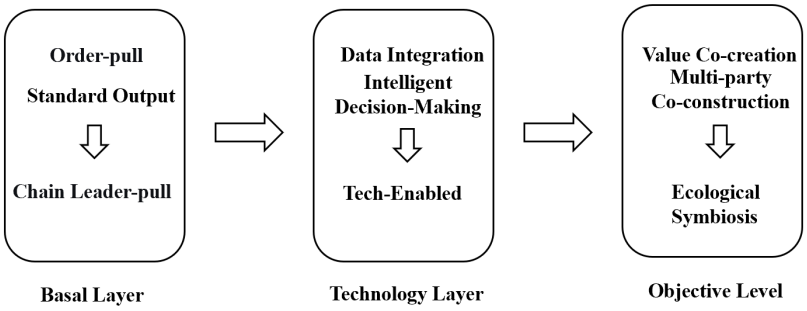

Figure 1: Three-Dimensional Analytical Framework for Digital Collaboration In the New Energy Vehicle Supply Chain

The above three dimensions are not juxtaposed, but constitute a clear progressive logical chain: the main traction of the chain is the initial driving force for collaborative upgrading, which provides a demand scenario and implementation basis for technology empowerment; technology empowerment is the core means of evolution, which creates data conditions and decision-making ability for ecological symbiosis. Ecological symbiosis is the ultimate goal of development, which reflects the fundamental transformation of supply chain from control to co-governance, from efficiency to value. The framework system reveals the evolution path of digital collaboration of new energy vehicle supply chain, that is, from the main chain to the platform supply chain, and then to the multi-center digital ecological supply chain. Based on this theoretical analysis framework, the following will deeply analyze the supply chain collaboration dilemma of Zhangjiagang new energy automobile industry cluster driven by the chain leader's order, and on this basis, design the coordination mechanism of digital intelligence technology empowerment, in order to provide theoretical guidance and path reference for industrial practice.

3. Current Development Status of Zhangjiagang New Energy Vehicle Industry Cluster

3.1. The development status of Zhangjiagang new energy automobile industry cluster

Zhangjiagang has gathered automobile industry chain enterprises, covering power battery raw materials, intelligent chassis parts, new energy automotive electronics and intelligent cockpit, body lightweight parts and other core areas. As the crystallization of the strategic cooperation between BMW and Great Wall, Beam Automobile is the most prominent chain leader, and it is positioned as the global manufacturing base of the new generation of electric MINI. As of March 2026, the company has produced more than 100,000 MINI electric vehicles, sold products to nearly 100 countries and regions, and promoted the coordinated development of 45 local auto parts enterprises. Its ' one car one piece ' exclusive supply mode enables the chain master's production plan to directly determine the production scheduling rhythm of the supporting enterprises, forming a highly collaborative whole part collaboration system. In terms of digital intelligence, the local government of Zhangjiagang clearly proposed to ' improve the level of intelligent transformation and network connection ', supports enterprises in implementing intelligent transformation, digital transformation and network connection, and establish the cultivation mechanism of ' lighthouse factory ' in the automobile industry. At the same time, the local government established the new energy automobile industry federation, which provided a good policy

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and financial environment for the digital coordination of supply chain. However, under the seemingly prosperous industrial appearance, the deep-seated contradictions of supply chain collaboration are gradually emerging.

3.2. Core pain points of supply chain collaboration driven by chain leader order

Although the Zhangjiagang new energy automobile industry cluster has achieved remarkable results, the supply chain digital collaboration driven by chain leader order still faces multiple pain points, which are summarized in the following table 1.

Table 1: Overview of supply chain collaboration of new energy vehicles in Zhangjiagang.

Dimensional	Status description	Main Problems
Chain leader enterprise	Beam Auto drives 45 enterprises	Limited collaboration radius
SMEs	Nearly 400 enterprises, weak foundation	Insufficient digital capability
Data flow	Primarily manual transmission	Data silos, fragmented standards
Vehicle-parts relationship	Passive order execution	Zero-sum game, lack of trust

First, data islands and standard separation coexist. In the traditional supply chain, there are repeated constructions, different standards, and prominent data barriers. Parts enterprises face multiple sets of information systems under different OEMs, resulting in high operating costs and low coordination efficiency. Although the chain leader enterprise has achieved a high level of digital management, its system often cannot be directly connected with upstream suppliers. A large number of key data rely on manual transmission, which is poor in timeliness and error-prone. Second, chain leader's collaborative radius of the chain is severely limited. At present, only 45 local enterprises are driven by Beam Automobile, while nearly 400 industrial chain related enterprises are located in Zhangjiagang. A large number of small and medium-sized enterprises have weak digital foundation, lack of technical ability and financial conditions to access the digital platform of chain owners, and ' scattered but not connected ' seriously restricts the release of the overall efficiency of the cluster, and also makes it difficult for chain owners to obtain sufficient and flexible capacity support in the face of order fluctuations. Third, supply chain resilience is still fragile. Although the level of digital intelligence continues to improve, there are still management ' blind spots ' in quality early warning, inventory transparency, and abnormal response. Fluctuations in any link may be amplified step by step and trigger a chain reaction. For example, the shortage of raw materials or quality defects of a secondary supplier often need to be discovered when a primary supplier is assembled, at which time the production plan has been seriously affected. Fourth, the transformation of the whole relationship is difficult. There is a typical " zero-sum game " between traditional OEMs and suppliers. Chain owners tend to lower procurement prices. Suppliers lack the motivation to improve under the compression of profit space. The shift to " co-creating value " needs to break through deep-seated trust barriers and mechanism barriers. Some small and medium-sized enterprises in Zhangjiagang still remain in the stage of passive execution of orders and lack the willingness and ability to actively participate in coordination. The above pain points are intertwined and mutually causal, which constitute the core obstacle to the deepening of digital synergy in Zhangjiagang's new energy vehicle supply chain, and also puts forward a clear realistic demand for the mechanism design of digital intelligence technology empowerment.

4. Construction of the Digital Collaborative Mechanism for the New Energy Vehicle Supply Chain Enabled by Digital Intelligence Technology and Driven by Chain Leader Orders

4.1. Construction of a Chain Leader-Led Digital Collaborative Mechanism Model

In view of the core pain points of Zhangjiagang's new energy vehicle supply chain collaboration, the construction of a collaborative mechanism enabled by digital intelligence technology should follow three interrelated and progressive ideas. The mechanism structure is shown in the following figure 2.

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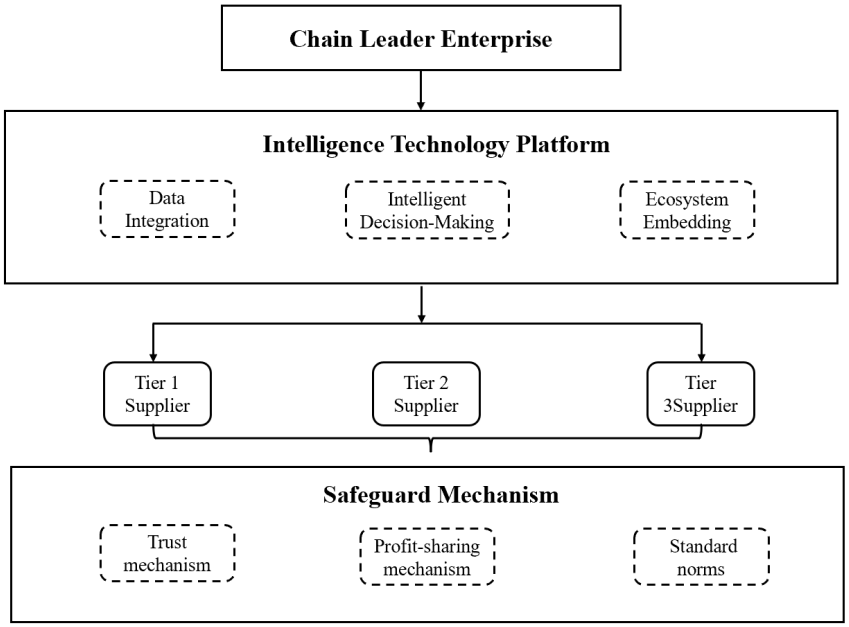

Figure 2: Mechanism Model of Digital Intelligence–Enabled Supply Chain Collaboration Driven by Chain Leader Orders

First, break information islands with data penetration. A unified supply chain collaboration platform is built to realize the real-time sharing of core data such as production, quality, logistics and inventory between the chain leader enterprise and the multi-level supplier [9]. The platform needs to have heterogeneous system compatibility capabilities, can dock with existing ERP, MES and other systems of different suppliers, and provide lightweight SaaS access tools for small and medium-sized enterprises with weak digital foundation, so as to promote the faultless circulation of the whole chain data. In terms of specific implementation, the collaborative platform should adopt a hybrid architecture of ' centralization + edge nodes ' : the chain master enterprise deploys a centralized data platform, which is responsible for core data aggregation and global optimization decision-making ; each supplier deploys edge nodes to localize and desensitize its own data and to upload it on demand, which not only guarantees data sovereignty but also meets collaborative needs. Second, improve collaborative efficiency with intelligent decision-making. On the basis of data penetration, the algorithmic models such as demand forecasting, intelligent scheduling, abnormal early warning and path optimization are introduced to automatically convert the order demand of the chain leader enterprise into the production instructions and logistics plans of each supplier, so as to reduce the delay and error caused by manual intervention. The digital twin technology is used to construct the virtual image of the supply chain, support multi-scenario simulation analysis, and help the chain leader enterprise to evaluate the capacity matching degree and delivery risk in the order receiving stage. Specifically, a three-layer digital twin system can be constructed: the order layer twin simulates the capacity occupation and delivery cycle under different order combinations; the production line layer twins map the key process status of each supplier in real time; logistics layer twin dynamically plans part transportation paths and inventory turnover. The three-layer linkage can provide the chain owner with the whole process decision support from the order to the delivery. Third, reconstruct the vehicle-parts relationship with ecological embedding. Intelligent collaboration is not only a technical problem, but also a governance problem. Its ultimate goal is to promote the supply chain from the one-way control of the chain owner to the multi-party ecological co-construction [10]. Therefore, it is necessary to embed trust mechanisms such as quality traceability and smart contracts based on blockchain in the platform, as well as a reasonable benefit distribution mechanism, to quantify collaborative behavior as measurable indicators and link it with actual returns, so as to form a positive incentive cycle and fundamentally change the zero-sum game pattern. It is suggested to adopt the dual-chain collaborative governance model : one is the quality traceability chain, which records the whole process quality data of parts from raw materials to finished products, so as to realize the source can be traced, the destination can be traced and the responsibility can be investigated ; the other is the contract settlement chain, which writes collaborative indicators such as on-time delivery rate, quality qualification rate, and information sharing timeliness rate into smart contracts, automatically triggers settlement and incentives, and enables the supplier’s collaborative contribution to be instantly

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converted into economic returns.

The above three ideas are not independent in operation but follow a progressive logic: data penetration provides the basis for intelligent decision-making, intelligent decision-making creates technical conditions for ecological embedding, and ecological embedding provides institutional guarantee and continuous power for the former two. Therefore, a three-dimensional collaborative model of " chain leader dominance-technical support-mechanism guarantee " can be constructed: chain leader dominance is embodied in order traction and rule output, technical support is embodied in the construction of collaborative platform and digital twin system, and mechanism guarantee is embodied in the design of trust mechanism and benefit distribution mechanism. The three-dimensional collaborative model provides an overall framework for the subsequent landing path and safeguard measures.

4.2. Implementation Path and Safeguard Measures for the Collaborative Mechanism

The effective implementation of the above coordination mechanism needs to follow the progressive logic and be supplemented by system guarantee.

From the perspective of landing path, it can be divided into three progressive steps. In the stage of basic consolidation, we should focus on completing the system integration and data governance within the chain leader enterprises, screening several core first-level suppliers to pilot and deploy the basic modules of the collaborative platform, realizing the data penetration of orders, production scheduling and inventory, verifying the technical feasibility, and accumulating cross-enterprise collaborative experience. It is suggested that the first batch of 3 to 5 parts enterprises with high standardization of product types and good digital foundation should be selected as pilot partners to reduce the initial running-in cost. On this basis, it enters the stage of expansion and deepening, extends the collaborative platform to all first-level suppliers and some key second-level suppliers, implements online intelligent scheduling, quality early warning, dynamic order allocation and other functions, and introduces blockchain for certificate storage at key nodes such as quality inspection and delivery confirmation. At this stage, the supplier digital maturity evaluation system should be established synchronously to provide targeted assistance to substandard enterprises. Finally, it enters the stage of ecological maturity, realizes full coverage of multi-level nodes in the supply chain, achieves a closed loop of data transparency and intelligent decision-making across the whole chain, and gradually evolves the collaborative platform into an open ecology, attracting third-party service providers such as logistics, finance and testing to settle in, forming a value-symbiotic supply chain network, and exploring credit financing services based on supply chain data to help small and medium-sized enterprises ease financial pressure and further enhance ecological stickiness.

In terms of safeguard measures, it is necessary for the government, chain enterprises and suppliers to work together. At the government level, the local government of Zhangjiagang should improve the special policy of " intelligent transformation and digital transformation, " provide financial subsidies and technical guidance for the digital transformation of small and medium-sized enterprises, promote the docking of public data platform and chain leader enterprise platform to reduce the cost of cross-platform data interaction, take the lead in formulating local or group standards such as data interface, communication protocol and quality identification of new energy vehicle supply chain to provide institutional infrastructure, and set up " supply chain digital collaborative special guidance fund, " and give additional rewards to small and medium-sized enterprises that take the lead in completing platform access and achieve remarkable collaborative results. At the level of chain owners, the digital collaborative platform should be positioned as the core competitiveness, continue to invest in R & D and operational resources, form a special team to be responsible for platform promotion, supplier training and problem response, and moderately transfer short-term benefits such as extending the billing period and providing technical support to attract suppliers to participate deeply. At the same time, the white paper on supply chain collaboration should be released regularly, and key collaboration indicators and excellent cases should be disclosed to form an industry demonstration effect. At the supplier level, especially small and medium-sized enterprises, they should take the initiative to improve the digital maturity, actively access the main platform of the chain, change the passive waiting mentality, actively feedback the production capacity status and improvement suggestions to strive for more cooperation opportunities, and set up a digital mutual aid group, which can be driven by the leading enterprises to drive the backward enterprises and reduce the overall transformation cost. In addition, talent training and organizational change are soft guarantees. Zhangjiagang can rely on local universities and vocational colleges to set up supply chain digitization related courses and training projects to transport compound talents. The main chain enterprises and suppliers should promote internal process reengineering and establish an organizational structure and performance appraisal system that matches digital collaboration. For example, a ' Supply

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Chain Digital Collaborative Office ' is set up within the main chain enterprise, and a special digital docking specialist is designated within the supplier enterprise to form a normalized communication mechanism.

Through the coordinated promotion of the above paths and safeguard measures, the supply chain coordination mechanism enabled by digital intelligence technology is expected to move from theoretical design to effective implementation, and effectively enhance the overall competitiveness of Zhangjiagang new energy automobile industry cluster.

5. Conclusion

This paper takes Zhangjiagang new energy automobile industry cluster as an empirical object, analyzes the practical dilemma of supply chain digital collaboration driven by chain owner orders, and constructs a collaborative mechanism empowered by digital intelligence technology. It is found that although the chain leader enterprises represented by Beam Automobile have formed a preliminary synergy pattern, the four pain points of ' data island ', ' limited synergy radius ', ' resilience and fragility ' and ' rigid relationship between the whole and the parts ' are intertwined and constitute the core obstacle. Digital intelligence technology empowerment needs to be promoted from three dimensions: data penetration, intelligent decision-making and ecological embedding. Based on the three-dimensional model of ' chain leader leading-technical support-mechanism guarantee ', the gradual evolution from pilot to ecology is realized. The effective operation of the collaborative mechanism also requires the government, the chain leader enterprise and the supplier to form a joint force in terms of policies, platforms, capabilities, talents and so on. This study introduces the theory of platform supply chain and dynamic capability into the new energy automobile industry cluster, expands the industrial boundary of supply chain collaboration research, and reveals the evolution law of the role of chain enterprises in the transformation of digital intelligence. The practical enlightenment is that Zhangjiagang and other clusters should be based on the main advantages of the chain, with orders as the traction, technology as the means, and ecological co-construction as the goal, so as to avoid fragmented transformation. The limitations of the research are the lack of single case analysis and quantitative evaluation. In the future, multi-case comparison can be introduced and a collaborative effectiveness evaluation system can be developed.

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