

Collaborative Innovation Factor Analysis Based on Grounded Theory - A Case Study of the New Energy Vehicle Industry

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Abstract: The new energy vehicle industry is one of the emerging strategic industries, and innovation is crucial for the survival and healthy development of new energy vehicle enterprises. Currently, factors such as internal enterprise innovation, collaboration between upstream and downstream companies, government support, environmental regulations, and changes in market demand affect the collaborative innovation in the new energy vehicle industry. This article, based on grounded theory, aims to clarify the elements and interrelationships of collaborative innovation in the new energy vehicle industry and construct a collaborative innovation mechanism model. Using the three-stage coding of grounded theory, four main categories are identified: enterprise innovation and management, competition and cooperation in the industry chain, knowledge creation and technology sharing, and external environment. These four main categories constitute the foundation, key, core, and support of collaborative innovation in the new energy vehicle industry. The interactions between and within the main categories are analyzed, elucidating the innovation process of "communication-coordination-cooperation-collaboration" and the mechanism of transitioning from disorder to order in collaborative innovation in the new energy vehicle industry.

Keywords: The new energy vehicle industry; grounded theory; and collaborative innovation mechanism.

1. Introduction

In the current world's major changes, the global industrial and supply chains are facing reshaping, resulting in increased instability and uncertainty. Technological innovation has become a focal point in international strategic competition. Since 2009, the new energy vehicle industry has been regarded as one of the seven strategic emerging industries. The "Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries" emphasized the need to enhance independent innovation capabilities and establish an innovation system that is enterprise-centered and market-oriented. Later, the concept of multi-party collaboration in scientific research, industry, and academia was proposed as a technological innovation system, becoming an important theme for the industry's development.

The "Development Plan for the New Energy Vehicle Industry (2021-2035)" advocates strengthening the "three verticals and three horizontals" research and development layout to enhance technological innovation capabilities. The "three verticals" include pure electric vehicles, plug-in hybrid vehicles, and fuel cell vehicles, while the "three horizontals" refer to power battery and management systems, drive motors and power electronics, and network connectivity and intelligent technologies. Currently, efforts are being made to construct a key component technology supply system. Based on the characteristics of new energy vehicle products, various automobile manufacturers are investing heavily in technological innovation and software and hardware development. Due to the impact of trade relations, there is a shortage of critical upstream components, and research institutions are also involved in research and development. With the continuous iteration of new energy vehicle technology, its advantages in intelligence, with increased energy density of power batteries and significantly improved

driving range, have largely addressed consumer range anxiety, leading to changes in the demand market for new energy vehicles. Additionally, regulatory support from environmental policies and a further liberalized financial environment also have significant influences on innovation in the new energy vehicle industry.

Therefore, collaborative innovation in the industry involves multiple stakeholders and various influencing factors, making it a complex process. Understanding the mechanism of collaborative innovation in the new energy vehicle industry is of practical significance. In light of this, this paper utilizes grounded theory to study the collaborative innovation mechanism and constructs a collaborative innovation mechanism model for the new energy vehicle industry, providing a basis for the innovation and development of technology-intensive industries.

2. Literature References

Researchers in the fields of management science and engineering, business management, and economics related to innovation have begun to pay attention to the issue of collaborative innovation. The concept of collaborative innovation originated from the disciplines of synergy and innovation. In 1912, economist Joseph Schumpeter first proposed the theory of innovation, viewing it as a process of developing new technologies, products, processes, and exploring new markets, and considered it as a key factor in economic growth. In 1971, physicist Hermann Haken introduced the concept of synergetics and defined "synergy" in 1976 as the collaboration of different parts of a system that results in the formation of new structures and characteristics [1]. Later, scholars [2] defined collaborative innovation as heterogeneous innovation subjects based on a collective vision, utilizing social relationship networks, cooperating and

exchanging ideas and information, achieving knowledge complementarity, sharing benefits, and sharing risks, thereby promoting the development of innovation. Currently, there are different dimensions of research on collaborative innovation.

The existing research can be summarized from the following three aspects:

(1) In terms of research objects, current research can be divided into different levels such as industry [4,5], enterprises [7,8], and different granularities such as international alliances [9,10], countries, regions [11], and provinces and cities [12].

(2) In terms of research content, current research focuses on the measurement and evaluation of collaborative innovation effects [13,14,15], network system evolution analysis [16,17], and the driving forces and mechanisms of collaborative innovation [18].

(3) In the process of researching collaborative innovation, methods such as complex network analysis [13], compound system synergy model [2][5][15], text analysis [19], game theory [3], qualitative grounded analysis method [1][20][21] are used.

The new energy automobile industry, as a technology-intensive industry, is one of China's strategic emerging industries. It has many innovation elements, and different production subjects such as government, universities, and enterprises have put forward many innovation encouragement policies, innovative technologies, and innovative business models. However, the current academic achievements lack the mechanism analysis of many innovation elements from the industrial dimension, and also lack the sorting and mechanism analysis of the innovation elements of the new energy automobile industry, an emerging industry. The future development relies on mechanism research, reusing past experience while clarifying the innovation path.

3. Research Design

3.1. Research Subjects

This study takes the new energy vehicle industry as the research object, and based on the division of enterprises in the upstream, midstream and downstream of the new energy vehicle industry, it explores the competition and cooperation relationship between enterprises and studies the elements of synergistic innovation within the industry, forming a mechanism for synergistic innovation in the new energy vehicle industry.

3.2. Research Method

3.2.1. Grounded Theory

Glaser and Strauss proposed a qualitative analysis method in the 1960s that is completed in three steps: open coding, axial coding, and selective coding [22]. The characteristic of this method is that after qualitative grounded analysis, under the premise that the researcher ensures sufficient objectivity, a general theoretical system can be established after multiple integrations, comparative analysis, coding induction, and refining abstraction through evidence verification [23].

3.2.2. Case Study Method

This paper uses industry reports and interview materials from the new energy vehicle industry as original materials. Based on the open coding of qualitative grounded theory, it uncovers the innovation characteristics of the new energy

vehicle industry and the changing characteristics of the current industry environment. The logic of the main categories and subcategories is determined, and the conceptual sorting of the original material is combined to determine the storyline of selective coding, linking all elements of industry collaborative innovation, and analyzing its connotation and the mechanism in the collaborative process.

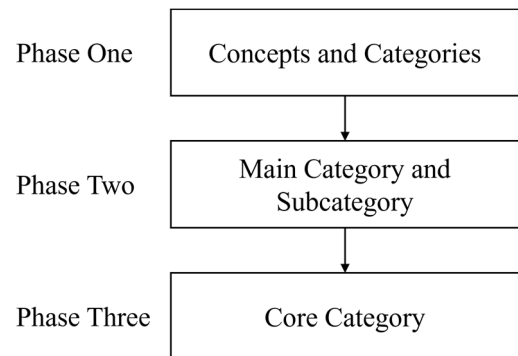


Figure 1. Grounded theory analysis process

3.3. Data Collecting

Using qualitative research methods and grounded theory to systematically study the mechanism of synergistic innovation in the new energy vehicle industry, clarifying the parameters of synergistic innovation can better study the evolution process of industry synergistic innovation from a disordered state to an ordered state, and draw the internal mechanism of the formation of industry synergistic innovation relationships. Taking the policy and layout planning, industry ecology, market supply and demand, enterprise research, and core technology and manufacturing process related to the synergistic innovation of new energy vehicles as the entry point, select 37 materials from research reports and consulting interviews to study the synergistic innovation mechanism of the new energy vehicle industry; the materials come from major consulting companies, securities companies, and Internet companies, totaling more than 300,000 words.

4. Research on the Intrinsic Mechanism of Synergistic Innovation

4.1. Determining the Sequence Parameters

By collecting 37 original materials, 8 of them (about 20%) were randomly selected as the basis for theoretical saturation test and re-verification of the identification and summarization results using grounded theory. Based on the set sample size and related literature theory, following the standard extraction process of grounded theory, it is ensured that the main and core categories are consistent with the literature and theoretical foundation, showing a high degree of matching and adaptability.

After the encoding of the first and second stages, based on the specific situation of the new energy vehicle industry, there is a potential logical connection among the 14 categories generated in open coding. These connections are revealed through exploring the characteristics and intrinsic relationships of the categories, allowing for the reclassification and connection of the categories. Four main categories and their corresponding subcategories are determined, including knowledge creation and technology

sharing, cooperation and industrial chain, enterprise innovation and management (in this context, "enterprise" refers to midstream enterprises according to the theoretical

research in Phase 2), and external environment, as shown in the table.

Table 1. Main Axis Encoding Results

Main Category	Subcategory	Connotation of the Category
Knowledge Creation and Technology Sharing	Intelligent Technology	Intelligent tech application fosters tech sharing in production and research
	Software Development	Software, key in new energy vehicles, applies knowledge
	Hardware Development	Hardware, supporting software, relies on tech innovation
	Manufacturing Process	Vehicle function innovation relies on manufacturing processes
Cooperation and Industrial Chain	Supply Chain	Connecting supply chain is key for cooperative ecosystems
	Cooperative Relationships	Integration of upstream, midstream, and downstream facilitates the industrial chain
Enterprise Innovation and Management	Product Strategy	Product innovation is the core of enterprise collaborative innovation
	Risk Management	Innovation brings safety, data, and financial risks to products
	Business Model	Innovation requires iterative business and profit models
	Organizational Management	Enterprise innovation needs follow-up in structure, operations, and planning
External Environment	Regulation and Support	Regulation drives positive development, and policy tools promote innovation
	Financial Support	Financial support aids in transforming tech and fostering cooperation
	Market Demand	Widespread demand and stable supply are vital for industry collaboration

Selective encoding is the process in the axial coding stage where a core category is identified. This category serves as a key link to connect other categories and is utilized for analyzing other main categories. This process is presented by

constructing a "storyline," complemented by auxiliary categories and original data to enhance incomplete categories. Once the "storyline" is completed, the new substantive theoretical framework is constructed. In this study, the typical relationship structure and connotations of the main categories are presented in Table 2.

Table 2. Selective Encoding Results

Typical Structural Relationships	Connotations of Structural Relationships
External environment contributes to knowledge creation and tech sharing	External environment is a key driver for knowledge creation and tech sharing.
External environment supports cooperation and industrial chain	External environment is a primary driver for cooperation and industrial chain
External environment aids enterprise innovation and management.	External environment is a key driver for enterprise innovation and management
Knowledge creation and tech sharing enhance collaborative innovation	They are key drivers for improving innovation performance
Cooperation and industrial chain enhance collaborative innovation.	They are key drivers for better innovation performance
Factors flow among knowledge creation, tech sharing, and innovation.	The synergy of knowledge creation, tech sharing, and innovation management is a key driver for enhanced innovation performance

This study conducted a theoretical saturation test using the reserved eight sets of original materials. The results indicate that the categories in the model have been developed extensively. For the four main categories of collaborative innovation mechanisms in the new energy vehicle industry (knowledge creation and technology sharing, cooperation and industrial chain, enterprise innovation and management, and external environment), no new important categories or relationships were discovered, and no new elements were found within the four main categories. Therefore, it can be considered that the mechanism research mentioned above has reached theoretical saturation.

4.2. Collaborative Innovation Mechanism Model Construction

Through repeated iterations of open coding, axial coding, selective coding, and theoretical model saturation testing on

interview data, we derived collaborative innovation parameters based on the innovation network. Specifically, it is mainly divided into four main categories, also referred to as main sequence parameters, namely knowledge creation and technology sharing, cooperation and industrial chain, enterprise innovation and management, and external environment.

According to the definition of mechanisms in theoretical research 2, mechanisms mainly consist of two parts: forming elements and the relationships between forming elements. They represent a series of related activities or processes involving or leading to certain behaviors, reflecting natural phenomena, etc. For the analysis of collaborative innovation mechanisms, it mainly includes the sequence parameters influencing the transition from disorder to order in collaborative innovation, energy exchange within and between subsystems, and the self-organizing evolution

process under the influence of sequence parameters and energy exchange.

Therefore, based on the definitions of sequence parameters and main sequence parameters, the forming elements of mechanisms in this study are main sequence parameters and sequence parameters, namely main categories and

subcategories. The relationships between forming elements include the relationships between main sequence parameters, the relationships between main sequence parameters and sequence parameters, and the relationships between sequence parameters, forming the collaborative innovation mechanism model in the new energy vehicle industry as shown in Fig 2.

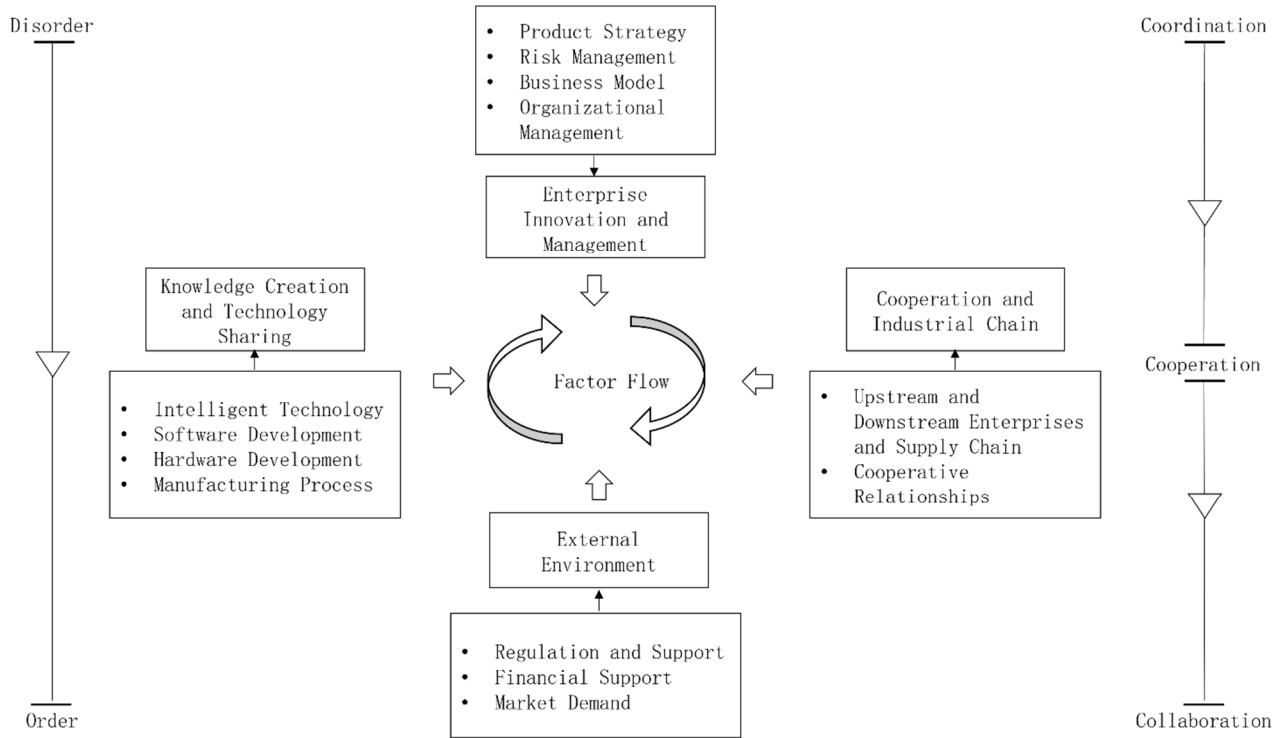


Figure 2. Collaborative Innovation Mechanism Model for the New Energy Vehicle Industry

4.3. Collaborative Innovation Mechanism Analysis

4.3.1. Collaborative Innovation Mechanism Elements Analysis

The main sequence parameter "Enterprise Innovation and Management" includes four sub-parameters: Product Strategy, Risk Management, Business Model, and Organizational Management. Enterprise innovation serves as the driving force for corporate development, and innovative management involves restructuring production and operational elements to achieve higher social, economic, and ecological benefits. Enterprise innovation and management integrate innovative management concepts into operational activities, and strategic adjustments are made to adapt to continuous changes in market demands, technological innovations, and industry environments. Enterprise innovation and management are essential conditions for a company's survival and development, making this main sequence parameter the foundation of collaborative innovation in the new energy vehicle industry.

The main sequence parameter "Competition and Industrial Chain" consists of two sub-parameters: Upstream and Downstream Enterprises with Supply Chain, and Cooperative Relationships. Current challenges, such as shortages in chip supply and dependence on imported resources like lithium, have led some downstream companies to establish industrial parks. Through strategies such as complementary, strengthened, and extended supply chains, they gradually expand coverage in the new energy industry, forming a

complete supply network. The increasing digitization shortens the supply chain, and the establishment of procurement platforms enhances supply chain transparency, reducing dependency on a single supplier for original equipment manufacturers (OEMs). This enhances supply chain flexibility, promoting the interconnectedness and efficient operation of resource elements and infrastructure. This process generates numerous upstream-downstream relationships and value exchanges, such as the transfer of products or services and information feedback. Upstream, midstream, and downstream enterprises thus form a material circulation supply chain, a spatial chain with a relatively concentrated layout, and economically and technically interdependent enterprise and value chains. The industry chain, comprising value chains, enterprise chains, supply and demand chains, and spatial chains, helps create an innovative atmosphere and provides a digital collaborative innovation environment.

The main sequence parameter "Knowledge Creation and Technology Sharing" includes four sub-parameters: Intelligent Technology, Software Development, Hardware Development, and Manufacturing Processes. Companies, in pursuit of technological innovation, seek suitable academic and research institutions for collaborative innovation. The demand for knowledge conversion from academic and research institutions prompts consensus-building with enterprises. The stronger the network connection between enterprises and academic institutions, the more significant the promotion of collaborative innovation capabilities, facilitating the collaborative management of knowledge and

technology both internally and externally in the new energy vehicle industry. Due to the high-risk nature of technological innovation and the multi-party participation characteristic of collaborative innovation, different innovation entities assume different risks, significantly mitigating the risks associated with independent innovation. Knowledge creation and technology sharing are central to the collaborative innovation process.

The main sequence parameter "External Environment" includes four sub-parameters: Government Policies, Environmental Regulations, Market Demand, and Financial Support. The participating entities for these four sub-parameters are primarily government bodies, financial institutions, regulatory agencies, etc. These entities foster cooperation and communication between industry, academia, and research, providing financial support and policy subsidies for enterprise innovation. Simultaneously, they support collaboration and innovation within the new energy vehicle industry. These factors not only act as participating entities in collaborative innovation but are also major elements in the innovation environment of the new energy vehicle industry, forming an ecosystem for collaborative innovation.

4.3.2. Collaborative Innovation Mechanism Elements Relationship Analysis

From the perspective of participating entities, the collaborative innovation process involves three main categories: enterprises, academic research institutions, and government/financial institutions. Enterprises play a crucial role as the primary participants in collaborative innovation, while academic research institutions serve as active contributors to the creation of new ideas, products, and technologies[23]. Together, these two constitute the core entities driving innovation. The government, financial institutions, and technology intermediaries act as external supporters and guarantors, forming the supportive entities of collaborative innovation. From the viewpoint of enterprises, innovation and collaboration are essential for obtaining economic benefits and ensuring survival. This process requires support from the government and relies on the active involvement of enterprises, as well as the participation of higher education institutions and research organizations. This implies the need to reallocate resources and promote collaborative innovation among enterprises, universities, and research institutions to achieve a low input, high output, and significant value for enterprises. This, in turn, propels innovative enterprises towards continuous development in the direction of globalization and networking[24]. The main sequence parameters of knowledge creation and technology sharing involve the participation of both enterprises and academic research institutions, constituting a combination of internal and external entities within the industry, as defined in theoretical research[2]. The main sequence parameters of enterprise innovation and management and cooperation within the industrial chain involve the participation of midstream automotive manufacturers and upstream/downstream enterprises, forming internal entities within the industry. Finally, the external environment is comprised of external entities such as the government and financial institutions.

5. Conclusion

This article, based on the theories of self-organization and collaboration, defines the entities involved in the new energy

vehicle industry and collaborative innovation in the new energy vehicle industry. It employs grounded theory research methods to analyze and identify relevant subordinate parameters and main parameters in the collaborative innovation process. The study explores the operational rules governing the development of collaborative innovation, proposes relevant mechanisms, and ensures the rational and scientific design of the collaborative innovation mechanism. The following conclusions are drawn:

(1) The mechanism of collaborative innovation in the new energy vehicle industry consists of four main categories: knowledge creation and technology sharing, cooperation and industrial chain, enterprise innovation and management, and external environment. Among them, enterprise innovation and management form the foundation of collaborative innovation in the industry, cooperation and industrial chain are crucial, knowledge creation and technology sharing are core components, and the external environment provides support throughout the collaborative innovation process. These main parameters constitute the essential elements of the collaborative innovation mechanism in the new energy vehicle industry. Simultaneously, they represent the process of seeking collaborative innovation from internal to external sectors of the industry. The mutually reinforcing relationships and mechanism elements formed among the main parameters together constitute the collaborative innovation mechanism in the new energy vehicle industry, realizing development from cooperation to collaboration and transitioning from disorder to order.

(2) The collaborative innovation mechanism in the new energy vehicle industry has certain reference value for other industries engaged in collaborative innovation. Particularly in technology-intensive industries where technological innovation is the primary focus, there is potential to draw insights from the development process of the new energy vehicle industry. This includes learning from the industry chain, which involves core midstream enterprises, the overall enterprise chain, the integration of value transfer and supply network, and the integration of industry, academia, and research. By understanding the interactive development process of the external environment, it can help other industries achieve the transition from disorder to order in collaborative innovation.

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