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Competitiveness Dynamics of the New Energy Vehicle Innovation Ecosystem: A Functional–Structural Analysis under New-Generation Productive Forces

Baole Sun*

School of Management, Xi'an Polytechnic University, Xi'an 710048, Shaanxi, China
*Corresponding author: Baole Sun, 478956169@qq.com

Abstract: In the context of a global shift toward green, intelligent, and high-end development, this study examines how New-Generation Productive Forces (NGPF) drive the competitiveness of the New Energy Vehicle (NEV) industrial innovation ecosystem. We develop a comprehensive evaluation framework integrating functional (innovation inputs, outputs, and performance) and structural (collaboration network characteristics) dimensions. Using a hierarchical entropy weighting method and TOPSIS, we measure the competitiveness of Xi'an's NEV innovation ecosystem from 2016 to 2023 and analyze its evolution across distinct phases. The results show that overall competitiveness steadily increased, with notable acceleration after 2020. In early stages, improvements were driven primarily by innovation inputs and outputs, whereas in later stages the strengthening of network structure (increasing density, clustering, and core stability) played an increasingly critical role. Functional performance and network structure demonstrated a complementary, co-evolving relationship: continuous innovation investment built the foundation for competitiveness, while an optimized collaboration network amplified and sustained those gains. The findings highlight the enabling role of NGPF—through technological breakthroughs, factor reconfiguration, and network synergy—in transforming the NEV ecosystem from being factor-driven to system-driven. This study contributes a dual-dimensional evaluation approach for industrial innovation ecosystems and provides empirical insights for policymakers to enhance both the "hard" innovation capacity and the "soft" collaborative linkages in strategic emerging industries.

Keywords: New-Generation Productive Forces; Industrial Innovation Ecosystem; New Energy Vehicle (NEV); Competitiveness Evaluation; Evolutionary Analysis

1.Introduction

1.1 Research Background

Under the background of accelerating the transformation of the global industrial system to green, intelligent and high-end, the new energy vehicle industry has become an important carrier of a new round of technological revolution and industrial competition. The new energy vehicle industry is highly integrated with the new generation of information technology, new energy technology and new material technology, showing significant systematic and complex characteristics in the industrial organization mode, innovation paradigm and value creation mode. As technology development path and industry boundaries, a single enterprise or isolated subject has been difficult to support the new energy automotive industry innovation and

continuous competitive advantage, the formation of industrial innovation is increasingly embedded by multivariate main body participation, the co-evolution of industrial innovation ecosystem in [1] [2] [3].

As an important organizational form of innovation activities, the industrial innovation ecosystem emphasizes the interaction and coordination among multiple subjects such as enterprises, universities and research institutions, government departments, financial capital and users, and realizes the improvement of the overall innovation ability and industrial competitiveness of the system through knowledge flow, technology diffusion and resource reorganization [4][5][6]. However, in the process of rapid development of the new energy vehicle industry, there are still some problems, such as insufficient coordination among innovation subjects, low factor allocation efficiency and fragile network structure, which restrict the continuous improvement of the competitiveness of the industrial innovation ecosystem. How to scientifically describe the operation state of the innovation ecosystem of the new energy vehicle industry from a system perspective and systematically evaluate its competitiveness level has become an important theoretical and practical problem that needs to be answered urgently.

At the same time, to the formation of new mass productivity to accelerate scientific and technological innovation as the leading factor, for the new energy automotive industry innovation ecosystem evolution provides a new source of power. New mass productivity depends on the key core technology and disruptive technology breakthrough, with high-tech, high performance and high quality and other significant characteristics, not only to promote industrial technology path transition, and reconstruction, the platform can assign and network elements together, profoundly affected industry innovation ecosystem structure form and operating mechanism of [3] [7]. In this context, it is of great research value to systematically evaluate the competitiveness of the innovation ecosystem of the new energy vehicle industry from the perspective of new quality productivity, which can reveal its evolution law, identify development bottlenecks and put forward targeted management and policy implications.

1.2 Literature Review

Scholars at home and abroad have carried out systematic research on the connotation, structure and operation mechanism of innovation ecosystem. Related research is generally believed that is a kind of innovation ecosystem by multivariate innovation main body and its system, market and technology environment constitute open complex system, its core is to subject the interactions between collaborative and value creating [1][4]. On this basis, some studies further introduce the perspective of ecosystem into the industrial level, and propose the concept of industrial innovation ecosystem to explain the systematic characteristics of cross-subject collaboration, knowledge diffusion and technology evolution in industrial innovation activities [2][5][6].

In terms of competitiveness evaluation, existing studies mostly construct evaluation index systems from functional dimensions such as innovation input, innovation output and industrial performance to measure regional or industrial innovation capacity [8][9]. This kind of research has certain value in revealing the input-output efficiency of innovation activities, but it often ignores the structural relationship between innovation subjects and its role in amplifying or constraining the competitiveness of the system. In recent years, as a complex network method in the application of innovative research, some scholars begin to pay close attention to the structure of the innovation network characteristics, such as network density, centrality and aggregation, etc. [10], but the related research stay in structure description level, has not yet been systematically structure indexes into comprehensive competitiveness evaluation framework.

On the other hand, new quality productivity, as an important theoretical proposition proposed in recent years, has been discussed in the academia from the aspects of theoretical logic, formation mechanism and action path for high-quality development [3][7][9]. Existing research from the new macro analysis productivity impact on regional economic or industrial system upgrade, there will be a new quality and productivity and industrial competitiveness innovation ecosystem evaluation with the combination of empirical research is still relatively limited, especially lack of for new energy vehicles such as systems analysis of strategic emerging industries.

In conclusion, the existing research is still the following deficiencies: first, the new energy automotive industry innovation ecosystem competitiveness evaluation system is mainly functional index, the system structure dimension system characterization; Second, the perspective of new quality productivity has not been effectively embedded in the evaluation and evolution

analysis of the competitiveness of the industrial innovation ecosystem; Third, related research is static measure more, stage characteristics of competitive evolution and insufficient attention. The above deficiencies constitute the entry point of further research in this paper.

1.3 Research Objectives and Contributions

Based on the above research background and literature review, this paper takes the innovation ecosystem of the new energy vehicle industry as the research object, introduces the perspective of new quality productivity, constructs a comprehensive competitiveness evaluation index system covering both functional and structural dimensions, and conducts an empirical analysis on the competitiveness level and its evolution characteristics of the system. Specific research goals include: first, build can reflect the characteristics of the new mass productivity can assign the new energy automotive industry innovation competitiveness evaluation index system of ecological system; Second, based on the entropy weight method and TOPSIS method, the competitiveness of the innovation ecosystem of the new energy vehicle industry is comprehensively measured; Thirdly, the evolution trajectory of system competitiveness is described from the time dimension, and the dominant factors and their structural characteristics in different stages are identified.

The main contribution of this paper is reflected in the following three aspects: first, it expands the research framework of industrial innovation ecosystem competitiveness from the perspective of new quality productivity, and organically combines functional performance with structural characteristics; Secondly, the method of stratification of entropy is introduced in - TOPSIS comprehensive evaluation method, improve the competitiveness of science and the explanatory power of the measure, Thirdly, with the new energy automotive industry as the empirical object, reveals the dynamic evolution law of industrial competitiveness innovation ecosystem, for the industry management practice and provides empirical reference for policy making.

2.Conceptual Framework and Theoretical Basis

2.1 New-Generation Productive Forces and the NEV Innovation Ecosystem

New-generation productive forces refer to the advanced forms of productivity with high-tech, high efficiency and high quality characteristics, which are dominated by scientific and technological innovation, relying on key and core technologies and disruptive technological breakthroughs [3][7]. Compared with traditional productivity, new quality productivity has achieved a systematic transition in technology-driven mode, factor structure and industrial organization form, and its essence is to continuously improve the level of total factor productivity through higher-order allocation and collaborative reorganization of innovation factors [3].

The innovation ecosystem of the new energy vehicle industry is an important carrier for the embedding and playing of the new quality productivity. In this paper, the innovation ecosystem of the new energy vehicle industry is defined as an open and complex system composed of multiple innovation subjects such as enterprises in the new energy vehicle industry chain, universities and research institutions, government departments, financial capital and users within the boundaries of the new energy vehicle industry. This system promotes the flow and reorganization of innovation elements such as knowledge, technology, capital and data in the system through the joint action of system, market and technological environment, so as to realize the improvement of industrial innovation ability and overall competitiveness [2][4][5].

2.2 Enabling Mechanisms of New-Generation Productive Forces

In the innovation ecosystem of new-energy vehicle industry, new-quality productive forces play an enabling role through the following three mechanisms.

The first is the mechanism of technological transition and knowledge spillover. Disruptive technological breakthroughs represented by new-generation information technology, new energy technology and new material technology have brought new technological paradigms and innovation paths to the new-energy vehicle industry. New quality productivity promotes the leapfrog development of key and core technologies, and accelerates the diffusion of knowledge within the ecosystem through industry-university-research cooperation, patent sharing and technology transfer, and improves the overall innovation efficiency of the system [3][7].

Second, factor reconstruction and intelligent penetration mechanism. New quality productivity takes data as the key fulcrum,

and promotes the intelligent reorganization of traditional factors such as capital, technology and talent. Through platforming collaboration and digital technology penetration, the innovation ecosystem of the new energy vehicle industry can break through organizational boundaries and achieve simultaneous improvement of resource allocation efficiency and industrial structure quality [3].

Thirdly, network collaboration and structural optimization mechanism. New quality productivity promotes the formation of closer and more diverse collaborative networks among innovators and strengthens the strength and stability of internal connections. By optimizing the network structure and strengthening the bridge role of key nodes, the innovation ecosystem of the new energy vehicle industry can maintain strong adaptability and resilience in the uncertain environment, and provide structural support for the improvement of competitiveness [9][10].

2.3 Analytical Framework of Competitiveness Evaluation

Based on the above theoretical analysis, this paper constructs an analytical framework of competitiveness evaluation of the innovation ecosystem of the new energy vehicle industry driven by new quality productivity. The framework focuses on the dual dimensions of function and structure: the functional dimension focuses on describing the direct performance of innovation investment, knowledge output and achievement transformation, while the structural dimension focuses on the network relationship, coordination degree and system stability characteristics among innovation subjects. The two dimensions interact and jointly determine the comprehensive competitiveness level of the innovation ecosystem of the new energy vehicle industry.

Under this analytical framework, the subsequent research will further build a specific competitiveness evaluation index system, and carry out quantitative measurement and evolution analysis on the competitiveness of the innovation ecosystem of the new energy vehicle industry combined with empirical data, so as to provide empirical support for revealing the enabling effect of new quality productivity.

3.Construction of the Competitiveness Evaluation Index System

Based on the aforementioned new quality productivity enabling mechanism and analysis framework, this paper further constructs the evaluation index system of the comprehensive competitiveness of the innovation ecosystem of the new energy vehicle industry. This index system describes the system competitiveness from two aspects of functional dimension and structural dimension, aiming to comprehensively reflect the operational performance and structural characteristics of the innovation ecosystem of the new energy vehicle industry driven by the new quality productivity.

The functional dimension index focuses on describing the direct performance of the innovation ecosystem in terms of innovation investment, knowledge and technology output, and achievement transformation, reflecting "what the system has done and to what extent". Structural dimension indicators focus on the network structure characteristics and collaborative relationship among innovation subjects, reflecting "how the system is organized and coordinated". Through the organic integration of functional and structural indicators, the comprehensive competitiveness level of the innovation ecosystem of the new energy vehicle industry can be comprehensively evaluated, which not only focuses on the "hard power" of innovation activities, but also takes into account the "soft connection" of innovation network collaboration [9][10].

3.1 Functional Dimension Indicators

Combined with the theoretical analysis of "technology transition and knowledge spillover mechanism" and "factor reconstruction and intelligent penetration mechanism" in Chapter 3, this paper selects functional dimension indicators from three levels of innovation investment, knowledge and technology output, and industrial structure and market performance, and constructs a functional dimension evaluation sub-system composed of 10 indicators, as shown in the table. In general, the indicators of innovation input and knowledge output mainly correspond to the enabling effect of new quality productivity on technological progress and knowledge diffusion, while the indicators of industrial structure and market performance reflect the improvement effect of new quality productivity on industrial operation quality and market performance through factor reconstruction [3][7].

3.1.1 Innovation Input

Innovation input is the basic condition for the continuous evolution of the innovation ecosystem of the new energy vehicle

industry, and also an important prerequisite for the formation and release of new quality productivity. This paper selects the following indicators to describe the level of innovation investment.

(1) R&D intensity (city). This indicator is measured by the proportion of regional R&D expenditure in regional GDP, reflecting the overall level of regional innovation resource input, and is an important basic indicator to measure the implementation effect of innovation-driven development strategy [8]. In the innovation ecosystem of the new energy vehicle industry, this index reflects the macro R&D investment environment on which the formation of new quality productivity depends.

(2) Industry R&D intensity. This index reflects the intensity of R&D investment of enterprises in the new energy vehicle industry relative to the main business income, and is used to describe the willingness and ability of innovation investment at the industry level. High industrial R&D intensity usually means that industrial subjects pay more attention to technological innovation, which is an important supporting condition for technological transition.

(3) Coverage rate of R&D activities. This index is measured by the proportion of new energy vehicles-related enterprises carrying out R&D activities in the total number of enterprises in the industry, reflecting the popularity of innovation activities within the industry. A high coverage rate helps to enhance the overall activity of the innovation ecosystem and the ability of knowledge diffusion.

(4) The proportion of fiscal expenditure on science and technology. This indicator is expressed as the proportion of local fiscal expenditure on science and technology in total fiscal expenditure, reflecting the government's support in scientific and technological innovation and industrial innovation. Government investment plays an important role in guiding and amplifying the innovation ecosystem of the new energy vehicle industry, which helps to reduce the risk of enterprise innovation and promote the agglomeration of new quality productivity factors.

3.1.2 Knowledge and Technology Output

Knowledge and technology output is an important embodiment of the transformation of innovation input into actual innovation ability, and also a key dimension to measure the innovation performance of the innovation ecosystem of the new energy vehicle industry. This paper selects the following indicators to describe the innovation performance.

(5) Number of invention patents granted per 10,000 people. This index reflects the knowledge output level of regional innovation activities, and is one of the important indicators to measure the technological innovation ability and innovation quality [8]. In the context of the new energy vehicle industry, this index can reflect the breakthrough of core technology and the degree of knowledge accumulation.

(6) The proportion of industrial invention patents. This index is measured by the proportion of the number of invention patents in the new energy vehicle industry to the total number of industrial patent applications, reflecting the proportion of high-value technological achievements in industrial innovation achievements. A high proportion of invention patents usually means that the quality of industrial technological innovation is high, which is conducive to the formation of sustainable competitive advantages.

(7) Technology contract intensity. This index is measured by the proportion of the transaction amount of technology contracts in the regional GDP, which is used to describe the transformation activity of technological achievements in the market. The higher the intensity of technology contracts is, the smoother the operation of knowledge spillover and technology transfer mechanism is, which is conducive to the diffusion and application of new quality productivity in the industrial innovation ecosystem.

3.1.3 Industrial Structure and Market Performance

Driven by the new quality productivity, the innovation ecosystem of the new energy vehicle industry is not only reflected in the improvement of technological innovation ability, but also reflected in the optimization of industrial structure and the improvement of market performance. This paper selects the following indicators to describe this dimension.

(8) New product sales rate (industry). This index is measured by the proportion of new energy vehicle product sales revenue in the main business revenue of the industry, reflecting the market transformation ability of innovation achievements and the innovation vitality of the industry. A high sales rate of new products usually means that innovation activities can be effectively

transformed into market competitive advantages.

(9) Proportion of high-tech industries (income). This index reflects the proportion of high-tech related businesses in the industrial income structure of the new energy vehicle industry, which is used to describe the technology-intensive degree of the industrial structure. The higher the index is, the more advanced the industry is towards high-end and high value-added.

(10) VC intensity of the industry. This index is measured by the proportion of the venture capital amount of the new energy vehicle industry in the main business income of the industry, reflecting the degree of recognition of the capital market to the prospect of industrial innovation. Venture capital not only provides financial support in the innovation ecosystem of the new energy vehicle industry, but also promotes innovation efficiency through governance and resource integration mechanism.

3.2 Structural Dimension Indicators

In addition to functional performance, the competitiveness of the innovation ecosystem of the new energy vehicle industry also depends on the organizational structure and collaborative network characteristics among the innovation subjects. Based on the complex network theory, this paper selects structural dimension indicators from the aspects of overall connectivity, local aggregation, core bridge role and network stability to describe the network structure characteristics of the industrial innovation ecosystem [3][9][10].

(1) Network density. Network density is measured by the proportion of the actual number of connections to the maximum possible number of connections, which is used to reflect the overall degree of collaboration among innovators. High network density means frequent interaction between innovation subjects, which is conducive to knowledge diffusion and collaborative innovation.

(2) Average clustering coefficient. This index describes the degree of interconnection in the local network of the innovation subject, and reflects the ability to form a stable collaborative group within the system. High clustering coefficient helps to promote professional collaboration and knowledge sharing.

(3) Degree centrality (mean). This index reflects the average connection degree of nodes in the network, which is used to measure the distribution of innovation resources in the system. A moderate level of centrality is conducive to improving collaborative efficiency, while excessive concentration may bring about the risk of structural vulnerability.

(4) Intermediary centrality (mean). This index is used to measure the degree to which nodes play the role of "bridge" in the network, reflecting the ability of key actors to control the knowledge flow and collaborative path. Too high mediation centrality may cause the system to rely on a few nodes, thus increasing the risk of breakage.

(5) Modularity Q. Modularity is used to measure the community structure characteristics of the network and reflect the degree of differentiation among different innovation groups in the system. Reasonable modular structure is conducive to the formation of a clear division of labor, collaborative and efficient innovation network.

(6) k-core thickness. This index is used to describe the stability of the network core layer, and is an important index to measure the stability and anti-impact ability of the system structure. High k-core thickness means that the innovation ecosystem has a stable core body group, which provides a solid structural foundation for the improvement of competitiveness.

3.3 Integrated Index System

On the basis of the above analysis, this paper integrates the indicators of functional dimension and structural dimension, and constructs the comprehensive competitiveness evaluation index system of the innovation ecosystem of the new energy vehicle industry. The system follows the principles of comprehensiveness, scientificity and operability, covering the main aspects of the operation of the industrial innovation ecosystem driven by new quality productivity, and ensuring that the index data can be obtained and quantified.

Table 1. Competitiveness Evaluation Index System of the NEV Innovation Ecosystem.

Code	Indicator	Definition
F1	City-level R&D Intensity	Intramural R&D expenditure of the city divided by gross domestic product (GDP)
F2	Industry R&D Intensity	Intramural R&D expenditure of the automobile manufacturing industry divided by its main business revenue

Code	Indicator	Definition
F3	R&D Activity Coverage Rate	Number of automobile manufacturing firms engaged in R&D activities divided by the total number of firms in the industry
F4	Share of Fiscal Expenditure on Science and Technology	Fiscal expenditure on science and technology divided by total general public budget expenditure
F5	5. Invention patent Granted per 10,000 Residents	Number of invention patents granted divided by year-end permanent resident population multiplied by 10,000
F6	Share of Invention Patent Applications (Industry)	Number of invention patent applications in the automobile manufacturing industry divided by total patent applications in the industry
F7	Technology Contract Intensity	Transaction value of technology contracts divided by GDP
F8	New Product Sales Ratio (Industry)	Sales revenue of new products in the automobile manufacturing industry divided by its main business revenue
F9	Revenue Share of High-tech Industries	Main business revenue of above-scale high-tech industrial enterprises divided by operating revenue of all above-scale industrial enterprises
F10	Industry Venture Capital (VC) Intensity	Amount of venture capital investment in the industry divided by main business revenue of the automobile manufacturing industry
S1	Network Density	Ratio of the number of observed edges to the maximum possible number of edges in the network
S2	Average Clustering Coefficient	Mean value of clustering coefficients across all nodes in the network
S3	Average Degree Centrality	Mean value of degree centrality across all nodes in the network
S4	Average Betweenness Centrality	Mean value of betweenness centrality across all nodes in the network
S5	Modularity (Q)	Degree of community structure in the network based on modularity optimization (e.g., Louvain or Leiden algorithm)
S6	k-core Thickness	Maximum k-shell index of the network

Through the combination of function and structure indicators, the evaluation system constructed in this paper can reflect the competitiveness level of the innovation ecosystem of the new energy vehicle industry from a multi-dimensional perspective, and lay a foundation for the subsequent weight determination, comprehensive evaluation and evolution analysis.

4.Data and Methodology

4.1 Data Sources and Research Design

This paper takes the innovation ecosystem of new energy vehicle industry in Xi 'an as the research object, selects 2016-2023 as the research interval, and conducts empirical evaluation and evolutionary analysis on the competitiveness of the industrial innovation ecosystem driven by new quality productivity. The new energy vehicle industry in Xi 'an is selected as the research object, on the one hand, the new energy vehicle industry, as a strategic emerging industry, has the typical characteristics of new quality productivity driving; On the other hand, the scale and innovation activity of the new energy vehicle industry in Xi 'an have been significantly improved in recent years, which has strong representativeness and research value. In particular, the annual output of new energy vehicles in Xi 'an will reach 1,015,500 units in 2022, marking that its industrial innovation ecosystem has entered a stage of accelerated evolution.

In terms of research design, this paper takes the innovation ecosystem of the new energy vehicle industry as the analysis unit, and constructs a comprehensive competitiveness evaluation framework based on the dual dimensions of function and structure. Through the quantitative measurement of functional indicators and structural indicators, combined with time series data, this paper systematically analyzes the competitiveness level and evolution characteristics of the industrial innovation ecosystem.

4.2 Data Sources and Preprocessing

4.2.1 Functional Dimension Data

Functional dimension data mainly come from government departments and authoritative statistical data, including Xi 'an

Statistical Yearbook, China Statistical Yearbook on Science and Technology, annual technology market reports issued by science and technology authorities, and industrial and high-tech industry statistics. Indicators related to enterprise innovation activities, such as R&D investment, innovation output and market performance, are sorted out through official statistics to ensure the reliability and comparability of data. Patent-related indicators rely on the patent database of the State Intellectual Property Office to screen and count the patents related to new energy vehicles by region and industry.

4.2.2 Structural Dimension Data

The structural dimension data is obtained by constructing the innovation cooperation network of the new energy vehicle industry. This paper takes vehicle enterprises, parts enterprises, universities and research institutions, government departments, financial capital and other innovation subjects as network nodes, and comprehensively uses multi-source information to identify collaborative relationships. Specifically, this paper obtains the relationship data of equity investment and cross-tenure of senior executives through the enterprise information platform, identifies the relationship between joint application and joint right holder through the patent database, and constructs a multi-source cross-verified collaborative relationship dataset based on the information of industrial alliances, joint laboratories and industry-university-research cooperation projects published on the official websites of government departments and universities.

In order to describe the dynamic evolution characteristics of the industrial innovation ecosystem, this paper divides the collaborative relationship from 2016 to 2023 into four time slices (2016-2017, 2018-2019, 2020-2021, and 2022-2023). In each time slice, the network structure is assumed to be relatively stable, and the corresponding collaborative network is constructed accordingly to represent the structural state of the innovation ecosystem of the new energy vehicle industry in different stages [3][9][10].

4.3 Indicator Standardization and Weight Determination

4.3.1 Data Standardization

Due to the significant differences in dimension and value range between functional dimension and structural dimension indicators, it is necessary to carry out dimensionless processing of original data before comprehensive evaluation. In this paper, the range standardization method is used to convert the index values to the interval of $[0,1][0,1][0,1]$. For the positive indicators (the higher the value is, the higher the competitiveness is), the corresponding standardization formula is used to ensure the comparability between different indicators.

4.3.2 Entropy Weight Method and Its Limitations

In terms of index weight determination, this paper firstly adopts entropy weight method to objectively calculate the weight of each index. The entropy weight method can determine the relative importance of index data in comprehensive evaluation by reflecting the dispersion degree of index data, which can avoid the deviation caused by subjective weighting to a certain extent.

However, in the preliminary calculation, it is found that if the entropy weight method is uniformly adopted for the two types of indexes, the sum of entropy weight of the indexes of the structural dimension is significantly higher than that of the indexes of the functional dimension. This result shows that the structural indicators fluctuate greatly during the sample period, but it is different from the previous theoretical analysis that functional performance is a direct reflection of the competitiveness of the industrial innovation ecosystem, while structural characteristics play a more supporting and amplifying role.

4.3.3 Hierarchical Entropy Weighting Approach

Based on the above problems, this article on reservation of entropy method of objective weight is determined in the group "advantage, on the basis of introduction of layered ideas of entropy method to adjust weight calculation. Specifically, firstly, the entropy weight method is used to determine the relative weight of each index in the functional dimension and the structural dimension respectively. Then, in the comprehensive evaluation of phase function and structure of two subsystem gives reasonable system weight, in order to reflect the leading function, structural support evaluation logic. This method not only takes into account the objectivity of data, but also better fits the theoretical connotation of the competitiveness of the innovation ecosystem of the new energy vehicle industry [9][10].

4.4 Comprehensive Evaluation Method: TOPSIS

After completing the standardization of indicators and weight determination, this paper adopts the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to comprehensively evaluate the competitiveness of the innovation ecosystem of the new energy vehicle industry. By constructing positive and negative ideal solutions, the TOPSIS method calculates the relative proximity between each evaluation object and the ideal solution, so as to rank its comprehensive competitiveness level.

Compared with single index evaluation method, TOPSIS to consider more index information, avoid the extreme value and cause individual index evaluation results deviate from the actual situation, apply to the multidimensional comprehensive competitiveness evaluation. In this paper, TOPSIS method is applied to measure the competitiveness of the innovation ecosystem of the new energy vehicle industry in different time slices, which provides a quantitative basis for the subsequent evolution analysis.

5.Results and Evolutionary Analysis

5.1 Overall Competitiveness Evaluation Results

Based on the hierarchical entropy weight-TOPSIS method, this paper measures the comprehensive competitiveness level of the innovation ecosystem of the new energy vehicle industry in Xi 'an from 2016 to 2023. The results show that the comprehensive competitiveness of the innovation ecosystem of the new energy vehicle industry in Xi 'an during the study period shows a steady upward trend, but there are obvious differences in the improvement range in different stages.

*Figure 1. Evolution of Overall Competitiveness of the NEV Innovation Ecosystem (2016-2023)*
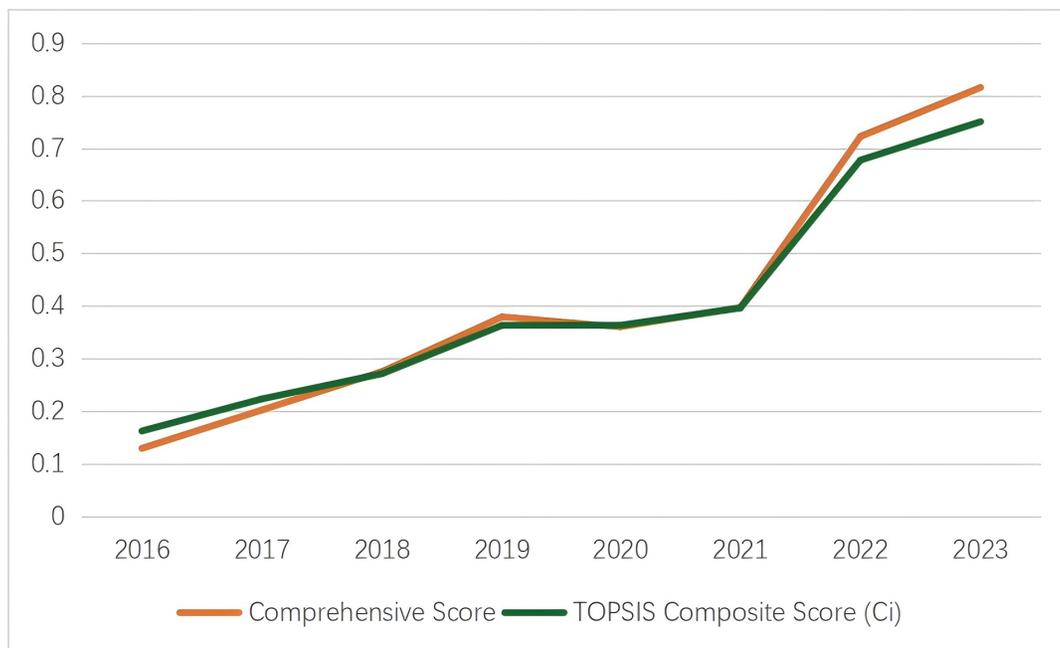
From the perspective of the time evolution stage in 2016-2017 comprehensive competitiveness level is relatively low, the industrial innovation ecosystem is in a stage of cultivation and accumulation; From 2018 to 2019, the competitiveness level began to significantly improve, and the innovation investment and technology output increased significantly. In 2020-21, the growth rate of competitiveness slowed down under the impact of external environment, but the resilience of the system gradually emerged; In 2022-2023, the comprehensive competitiveness level has significantly jumped, marking that the innovation ecosystem of the new energy vehicle industry has entered a stage of accelerated development.

5.2 Evolution of Functional and Structural Subsystems

Further analysis of the evolution characteristics of functional and structural subsystems shows that there are significant differences in their contributions to comprehensive competitiveness in different stages. Score function subsystem present the rising trend in the study period, indicates that new mass productivity through innovation investment increase, improve technology output and achievements transformation is accelerated, has directly on the new energy automotive industry competitiveness.

Figure 2. Evolution of Functional and Structural Subsystems
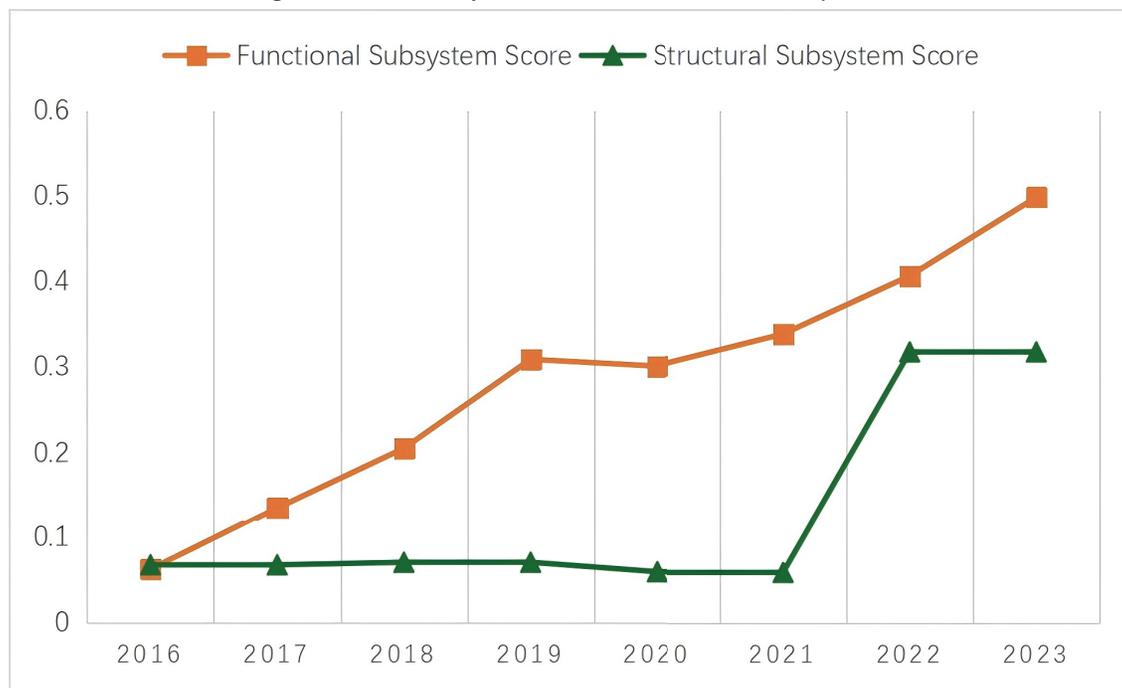
Although the overall score of structural and structural subsystems is lower than that of functional subsystems, its growth trend is more stable. With the gradual improvement of the collaborative network of innovation subjects, the network density, the clustering coefficient and the stability of the core layer continue to improve, and the supporting role of the structural dimension in the comprehensive competitiveness is gradually enhanced. The co-evolution of functional and structural subsystems has become an important internal mechanism for the improvement of the competitiveness of the innovation ecosystem of the new energy vehicle industry.

5.3 Dynamic Changes of Key Indicators

From the evolution of key indicators, there are differences in the factors leading to the improvement of the competitiveness of the innovation ecosystem of the new energy vehicle industry in different stages. In the early stage, innovation input indicators such as R&D investment intensity and coverage rate of innovation activities play a leading role in improving competitiveness. As the industrial development enters the middle and later stages, the importance of achievement transformation indicators such as the proportion of invention patents, the sales rate of new products and the intensity of technology contracts gradually increases.

In terms of structural dimension, network density and average clustering coefficient play a basic supporting role in the system cultivation period, while in the subsequent stage, intermediary centrality and k-core thickness gradually become the key factors affecting the stability and anti-impact ability of the system. This shows that the improvement of the competitiveness of the innovation ecosystem of the new energy vehicle industry is not driven by a single factor, but the result of the dynamic evolution of multiple factors.

5.4 Structural Stability and Vulnerability Analysis

Based on the complex network perspective, this paper further analyzes the innovation ecosystem of the new energy vehicle industry from the perspective of structural stability and vulnerability. The results show that the k-core thickness of the system improves overall during the study period, indicating that the core innovation subject group gradually forms and tends to be stable, which provides a structural guarantee for the long-term competitiveness of the system.

However, the analysis of intermediary centrality shows that some key nodes play a higher role as Bridges in the collaborative network, and the system still has certain dependence on a few core subjects. Once these key nodes fail, it may lead to the risk of network breakage. Therefore, in the process of enhancing the competitiveness of the innovation ecosystem of the new energy vehicle industry, it is necessary to reduce the vulnerability of the system structure and enhance the overall resilience through multiple collaboration and network structure optimization [9][10].

6.Discussion

Based on the comprehensive evaluation results of hierarchical entropy weight-TOPSIS method, this paper systematically describes the evolution characteristics of the innovation ecosystem competitiveness of the new energy vehicle industry driven by new quality productivity. Compared with only to present the evaluation results, and further to explain the result of the above from the perspective of theory and management, help to deepen the understanding of the operation mechanism of industrial innovation ecosystem.

6.1 Functional and Structural Dimensions: A Complementary Perspective

The results show that in the evolution process of the innovation ecosystem competitiveness of the new energy vehicle industry, the functional and structural dimensions are not substitutes for each other, but show an obvious complementary relationship. The indicators of functional dimension mainly reflect the direct performance of innovation investment, knowledge output and achievement transformation, which is the "explicit foundation" of competitiveness improvement. The structural dimension index supports and amplifies the functional performance through the collaborative network among innovation subjects.

In the early stage of the research, the competitiveness improvement of the innovation ecosystem of the new energy vehicle industry mainly depends on the R&D investment intensity, the coverage rate of innovation activities and other functional indicators. This phenomenon shows that when the new quality productivity is still in the cultivation stage, the continuous investment of innovation resources is still the key factor to promote the accumulation of industrial innovation capacity. However, it is difficult to support the long-term improvement of competitiveness only by relying on functional input. With the expansion of industrial scale and the increase of the number of innovation subjects, the collaborative efficiency among innovation subjects has gradually become an important factor restricting the operation of the system.

As the industrial development enters the middle and late stage, the influence of structural dimension indicators on comprehensive competitiveness gradually increases. The improvement of network density, clustering coefficient and stability degree of core layer indicate that a stable collaborative network structure has gradually formed within the innovation ecosystem of the new energy vehicle industry. This structural optimization not only helps to reduce the innovation cost, but also improves the efficiency of knowledge diffusion, so that the new quality productivity factors can be more efficiently allocated within the system. The result of the dual-dimensional co-evolution of function and structure is the transformation of the competitiveness of the innovation ecosystem of the new energy vehicle industry from "factor-driven" to "system-driven".

6.2 New-Generation Productive Forces as a Dynamic Enabler

From the perspective of new quality productivity, the evolution of the competitiveness of the innovation ecosystem of the new energy vehicle industry is not the result of a single technological breakthrough, but the reflection of the joint action of multiple enabling mechanisms. The new quality productivity continues to reshape the operation logic of the industrial innovation ecosystem through technological transition, factor reconstruction and network coordination.

First of all, technology transition and knowledge spillover mechanism play a leading role in the early improvement of competitiveness. Disruptive innovation, represented by key technologies of new energy vehicles, has injected new growth momentum into the industrial innovation ecosystem, accelerated knowledge diffusion through industry-university-research collaboration, and enabled innovation achievements to be transformed and applied in a wider range. Secondly, elements of refactoring and intelligent penetration mechanism to promote the effective integration of capital, data and technology factors, make the new energy automotive industry innovation along with the increase of the ecological system in the structure complexity, still can keep high efficiency.

More importantly, the new quality productivity strengthens the network collaboration relationship among the innovation subjects, and gradually evolves the ecosystem from loose connection to a collaborative network with core structure. This process not only improve the overall competitiveness of the system, and also enhance its adaptability to external shocks and toughness.

6.3 Structural Stability and Potential Vulnerabilities

Although the research results show that the overall stability of the innovation ecosystem of the new energy vehicle industry

is enhanced, the analysis of the structural dimension also reveals the potential systemic risks. The index of intermediary centrality shows that some core players assume a high bridge function in the collaborative network, and the system is highly dependent on them. This structural feature not only improves the efficiency of collaboration, but also brings the potential risk of "key node failure".

From the management perspective, the results indicate the new energy automotive industry innovation ecosystem in the process of continuous expansion, should pay attention to the diversification of the network structure and redundancy design, through cultivating multilevel cooperative relations, reduce the degree of dependence on a single core subject system. Only by maintaining a balance between the stability and flexibility of the structure, can the competitiveness of the innovation ecosystem achieve sustainable improvement.

6.4 Implications for Innovation Ecosystem Research

The results of this paper have some implications for innovation ecosystem research. Existing research from the perspective of the static evaluation more industry innovation ability, and in this paper, by introducing a function - double dimension evaluation framework structure, reveals the competitiveness of the different elements in the evolution process of periodic function. This shows that the understanding of industrial innovation ecosystem should not be limited to a single dimension, and we should start from the whole system, focus on the characteristics of structure long-term impact on the functional performance.

At the same time, the new qualitative research into industrial innovation ecosystem productivity, helps to explain a new round of technological revolution under the background of the internal mechanism of industrial competitiveness rapidly restore. The empirical results of the new energy vehicle industry show that the new quality productivity not only improves the innovation performance, but also promotes the evolution of the industrial innovation ecosystem to a higher level through the optimization of the system structure.

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