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Research Status and Frontier of Closed-Loop Supply Chain Pricing for New Energy Vehicles

-- A Visual Analysis Based on CiteSpace

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Abstract: With the explosive growth of the new energy vehicle industry and the continuous advancement of the global "dual carbon" goal, pricing in the closed-loop supply chain of new energy vehicles, as a core issue of resource recycling, has become a focused research hotspot in academia. To grasp the research status of closed-loop supply chain pricing for new energy vehicles, this paper conducts a visual analysis of relevant literature from the CNKI database between 2015 and 2025 based on the bibliometric tool CiteSpace, in terms of publication trends, highly cited papers, and various knowledge maps. The study shows that relevant research in the past decade has undergone three stages: the initial exploration stage (2015–2018), the policy-driven development stage (2018–2022), and the in-depth technology integration stage (2022–2025). Research hotspots have evolved from traditional static pricing models to dynamic decision-making systems and multi-party game coordination mechanisms empowered by technology. Although certain achievements have been made in current research, a unified theoretical framework has not yet been established. Future research should further focus on interdisciplinary integration and empirical research, continuously improve the relevant theoretical system, and promote practical innovation in this field.

Keywords: New energy vehicles; Closed-loop supply chain; Pricing decision; CiteSpace; Visual analysis.

1. Introduction

Against the background of the continuous advancement of the global "dual carbon" goal and the explosive growth of the new energy vehicle industry, the closed-loop operation of the supply chain and the recycling of retired power batteries have become key issues for the sustainable development of the industry [1].As a core carrier connecting production, consumption, recycling and reuse, the pricing strategy of the closed-loop supply chain for new energy vehicles affects the collaborative optimization of multiple benefits and the efficiency of resource recycling [2]. The pricing of the closed-loop supply chain for new energy vehicles focuses on power battery recycling and capacity-related subsidies. Its rational design directly affects the recovery rate and the profits of various supply chain entities, and provides critical support for government policy optimization and enterprise operational decision-making [3]. Compared with traditional models, closed-loop supply chain pricing needs to take into account external interventions such as government deposits, recycling and echelon utilization subsidies, conform to consumers' traceability preferences and environmental awareness, and cope with new variables including blockchain traceability, technology investment and channel diversification, which significantly increases the complexity and systematicness of the supply chain [4].

With the implementation of the Extended Producer Responsibility (EPR) system and the deep integration of digital technologies into the supply chain, the research boundary in this field has been continuously expanded, forming a multidisciplinary interdisciplinary pattern [5]. However, there is still a lack of systematic review and integration on the research status, core hotspots and future trends. To fully understand the research status and development trends of closed-loop supply chain pricing for new energy vehicles, this paper conducts quantitative analysis and visual presentation of relevant literature in the past decade based on the bibliometric tool CiteSpace. By generating highly cited literature lists, co-occurrence maps, time-series diagrams and other knowledge maps, this paper systematically reveals the research status, core topics and frontier dynamics in this field, so as to provide a knowledge map reference for subsequent theoretical research, and offer decision-making support for policy formulation, mechanism design and operation optimization in industrial practice.

2. Research Methods and Data

2.1. Methods and Data

CiteSpace is an information visualization software developed using Java. It has powerful data processing capabilities and can analyze the potential dynamic mechanism of disciplinary evolution and detect the frontier of disciplinary development by drawing a series of visual maps [6]. This study adopts CiteSpace version 6.3.1.0 to conduct visual analysis. The literature screened from the CNKI database is exported in a specified format and converted into a software-compatible data format. By adjusting various parameters, the knowledge maps required for the research are generated.

2.2. Data Source and Processing

This paper takes the CNKI database as the source for literature retrieval. In the first step, an initial search is performed using the subject terms new energy vehicles and supply chain, yielding a total of 2251 documents. In the second step, the publication time is restricted to the period from 2015 to 2025 through time filtering. In the third step, to ensure the quantity and academic quality of the analyzed literature, the source categories are limited to core journals such as Peking University Core, CSSCI, and EI, while doctoral and master's dissertations from key universities are

also included. In the fourth step, strict manual screening and content review are conducted on the retrieval results according to the three core dimensions: new energy vehicles/power batteries, closed-loop supply chain/recycling and remanufacturing, and pricing/decision-making/coordination, so as to ensure high relevance between the literature and the research topic. Finally, documents that do not match the research object (e.g., traditional fuel vehicles, general electronic products), miss key research links (e.g., only involving forward supply chain links such as sales, charging, and battery swapping), or lack specific pricing decision models (e.g., pure technical or policy reviews) are excluded. After systematic multi-step screening and deduplication, 235 valid documents are finally determined, which serve as a reliable data foundation for this CiteSpace visual analysis.

3. Results and Analysis

3.1. Publication Trend of Research on Closed-Loop Supply Chain Pricing for New Energy Vehicles

Based on the annual publication volume data from the CNKI database, the academic attention to closed-loop supply chain pricing for new energy vehicles shows a clear trajectory of "embryonic stage – accelerated growth – explosive growth – in-depth development", which is highly consistent with the advancement of China's new energy vehicle industrial policies and the evolution of core issues. The specific publication trend is shown in Figure 1.

The number of relevant publications remained low and stable from 2015 to 2017. During this period, research on closed-loop supply chain pricing for new energy vehicles was still in the embryonic stage, and national industrial policies were in the initial layout phase. For example, the State Council issued Made in China 2025 in 2015. Although new energy vehicles were listed as a key development area, no specific policies targeting power battery recycling and closed-loop supply chain pricing had been introduced. The academic attention to this field was relatively low, so the annual publication volume remained at a low level of only 1–2 papers from 2015 to 2017.

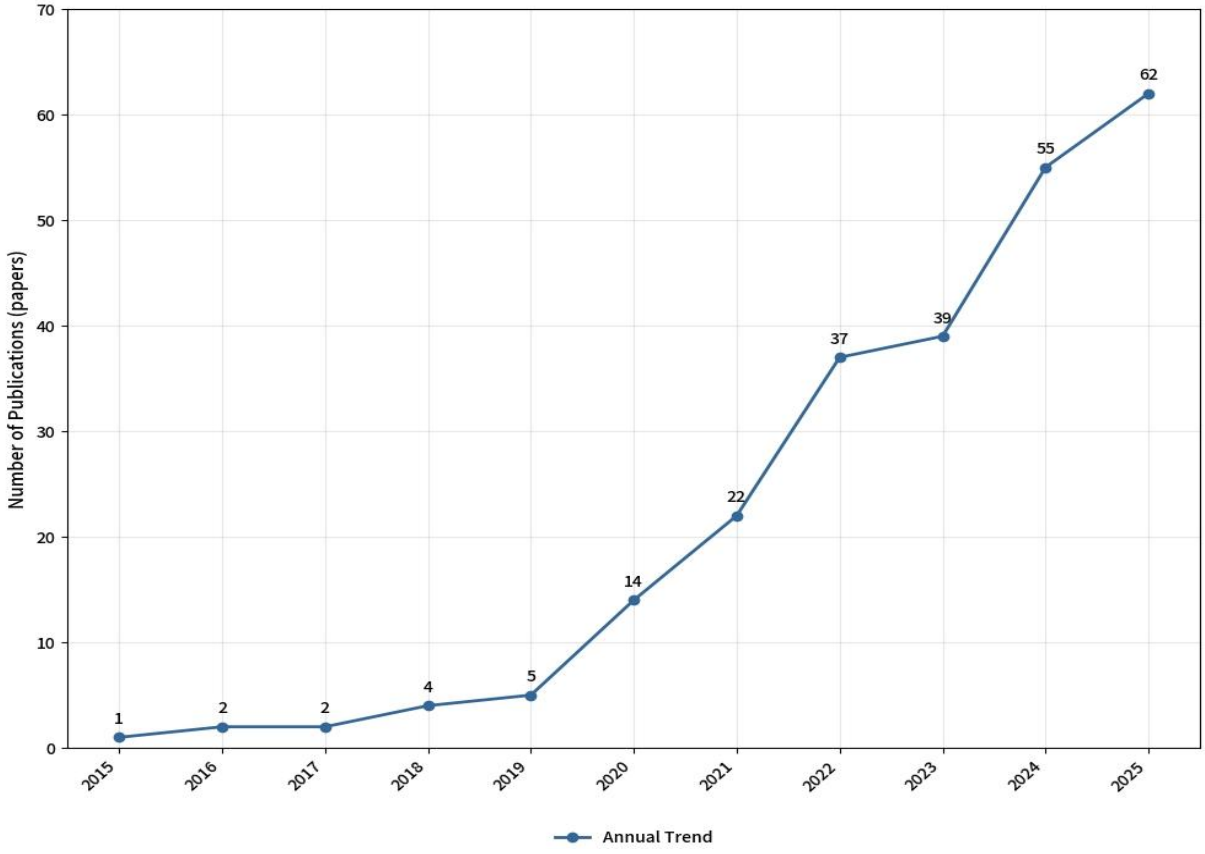


Figure 1. Annual publication volume

From 2018 to 2020, the number of relevant publications showed a gradual upward trend, which was closely related to the implementation of national special policies. For example, in February 2018, seven ministries including the Ministry of Industry and Information Technology jointly issued the Interim Measures for the Administration of Recycling and Utilization of Power Batteries for New Energy Vehicles, which for the first time clarified the responsible entities and process specifications for power battery recycling, providing policy guidance for research on closed-loop supply chain pricing. The Interim Provisions on the Traceability Management of Recycling and Utilization of Power Batteries for New Energy Vehicles, implemented in June 2019, further refined the requirements for information tracking in the recycling process. The gradual improvement of policies promoted the academic community to focus on basic issues such as "recycling pricing" and "impacts of policy tools". As a result, the number of publications increased from 4 in 2018 to 14 in 2020.

From 2021 to 2025, the number of relevant publications entered a stage of rapid growth, driven mainly by the intensive introduction of national policies for high-quality

industrial development. For instance, the State Council issued the New Energy Vehicle Industry Development Plan (2021–2035) in 2020, which proposed improving the power battery recycling system and perfecting incentive policies for recycling and utilization. In July 2021, the National Development and Reform Commission and other departments issued the 14th Five-Year Plan for the Development of Circular Economy, which clearly listed "promoting the industrialization of echelon utilization of power batteries" as a key task of circular economy in the new energy vehicle sector. In December 2023, the Ministry of Industry and Information Technology released the Administrative Measures for the Comprehensive Utilization of Power Batteries for New Energy Vehicles (Draft for Comment), strengthening the requirements for value distribution and digital traceability in the recycling process. The continuous deepening of these policies has prompted scholars to further explore topics such as "echelon utilization pricing" and "multi-agent game pricing". Consequently, the number of publications reached 23 in 2021 and further increased to 62 in 2025.

3.2. Analysis of Highly Cited Literature

Based on the CNKI database, this study takes citation frequency and average annual citation frequency as core indicators, and screens 8 highly cited papers in this field, as shown in Table 1.

Table 1. Analysis of Highly Cited Papers

Document Name	Authors	Publication Date	Document Source	Total Citations	Average Annual Citations
Pricing Strategy and Coordination Mechanism of Closed-loop Supply Chain under Cost Difference of Dual-channel Recycling	ZHU Xiaodong; WU Bingbing; WANG Zhe	2018	Chinese Journal of Management Science	241	30.125
Decision Optimization of Multi-level Contracts for New Energy Vehicle Closed-loop Supply Chain	XIE Jiaping; LI Jing; YANG Feifan; LIANG Ling	2019	Journal of Industrial Engineering and Engineering Management	203	29
Research on Recycling Pricing and Coordination Mechanism of Power Battery Closed-loop Supply Chain	LI Xin; MU Dong	2018	Soft Science	138	17.25
Automotive Supply Chain Coordination Considering Price, Emission Reduction and Range under the "Dual-Credit" Policy	LU Chao; WANG Qianqian; CHEN Qiang	2021	Systems Engineering — Theory & Practice	135	27
Research on Operational Decisions of New Energy Vehicle Power Battery Closed-loop Supply Chain under Different Recycling Subsidy Policies	LOU Gaoxiang; LEI Peng; MA Haicheng; WAN Ning	2023	Chinese Journal of Management Science	132	44
Research on Competitive Pricing and Emission Reduction Strategies of Automobile Manufacturers under the "Dual-Credit" Policy	LU Chao; WANG Qianqian; ZHAO Mengyuan; YAN Junlin	2021	Chinese Journal of Management Science	131	26.2
Design of Dual-channel Battery Recycling Contract for New Energy Vehicles from the Perspective of Closed-loop Supply Chain	MA Ke; LIU Yujie; ZHU Hao	2021	Science and Technology Management Research	104	20.8
Research on Reverse Subsidy Mechanism of Power Battery Closed-loop Supply Chain Considering Echelon Utilization	LIU Juanjuan; MA Junlong	2020	Industrial Engineering and Management	102	17

Following the logic of basic framework construction – policy adaptation analysis – core carrier deepening, these highly cited studies fully cover the core topics in this field, provide theoretical and methodological support for enterprise pricing optimization and government policy-making, and promote the systematization of research in this domain. They can be divided into three major research directions:

First, focusing on basic pricing and contract coordination in closed-loop supply chains to build a general analytical framework. Zhu et al. [2] constructed a Stackelberg game model for a dual-channel recycling chain and designed a revenue-cost sharing contract to alleviate efficiency loss under decentralized decision-making. Xie et al. [7] proposed a "combined revenue-sharing contract" for multi-echelon supply chains and revealed the impacts of channel competition and cost structure on recycling pricing. Ma et al. [8] clarified the selection conditions of enterprise cost and responsibility allocation modes through the comparison of dual-channel recycling contracts. Such studies laid the theoretical foundation for pricing and coordination in this field.

Second, focusing on the adaptability between industrial policies and enterprise pricing to quantify the policy transmission mechanism. Lu's team conducted a series of studies on the "Dual-Credit" policy, analyzing its impacts on vehicle manufacturers' pricing and emission reduction

decisions from the perspective of supply chain coordination [9], and identifying the linkage between credit indicators and market preferences from the perspective of manufacturer competition [10]; Lou et al. [3] compared the effects of different recycling subsidy models and provided a quantitative basis for the government to select subsidy schemes that improve recycling rate and social welfare, realizing the precise connection between macro policies and micro decisions.

Third, focusing on full life-cycle pricing of power batteries to deepen industrial scenario research. Li et al. [11] proposed a dual-track policy of "mandatory regulation + financial subsidies" based on a three-echelon supply chain model to improve the recycling rate of power batteries. Liu et al. [12] introduced the echelon utilization scenario, constructed a phased dynamic subsidy strategy, optimized the full life-cycle value flow and benefit distribution, and promoted the deep integration of theory into industrial practice.

3.3. Analysis of Authors and Institutions in CNKI

3.3.1. Knowledge Map of Author Co-occurrence

To explore the close cooperative relationships among authors, CiteSpace was used to construct the knowledge map of the author co-occurrence network, as shown in Figure 2.



Figure 2. Author co-occurrence knowledge graph

It can be seen from the figure that a certain number of cooperative networks have been formed among authors, but the overall network still presents the obvious characteristics of "prominent cores, scattered overall". Specifically, there are cooperative networks formed by scholars such as Hou Qiang and Tang Cancan, collaborative groups composed of Liu Zhi and Tang Juan, and other connected networks built by representative authors including Liu Lingli, Zhang Chuan and Zhu Junjie. However, the map also shows that a considerable number of scholar nodes remain relatively isolated or loosely connected, and a tight cross-team academic collaboration network has not yet been formed. The current situation indicates that the overall collaboration level in this field has great potential for improvement. In the future, it is necessary to further integrate high-quality research resources and build a more efficient author collaboration network.

3.3.2. Knowledge Map of Institutional Co-occurrence

To investigate the cooperation and communication among research institutions, CiteSpace was employed to construct the knowledge map of institutional co-occurrence network, as shown in Figure 3.

It can be observed from the figure that research in this field presents a distinct multi-center structure, among which core institutions such as China University of Mining and Technology, Chongqing University, Beijing Jiaotong University, Chongqing Jiaotong University, and Donghua University are the most prominent nodes. Nevertheless, the map also reveals that cooperation between most institutions remains sparse, and a wide-ranging collaborative innovation network has not yet been formed. Existing cooperation fails to effectively integrate multi-party resources, as most studies are confined within the same institution or specific research groups.

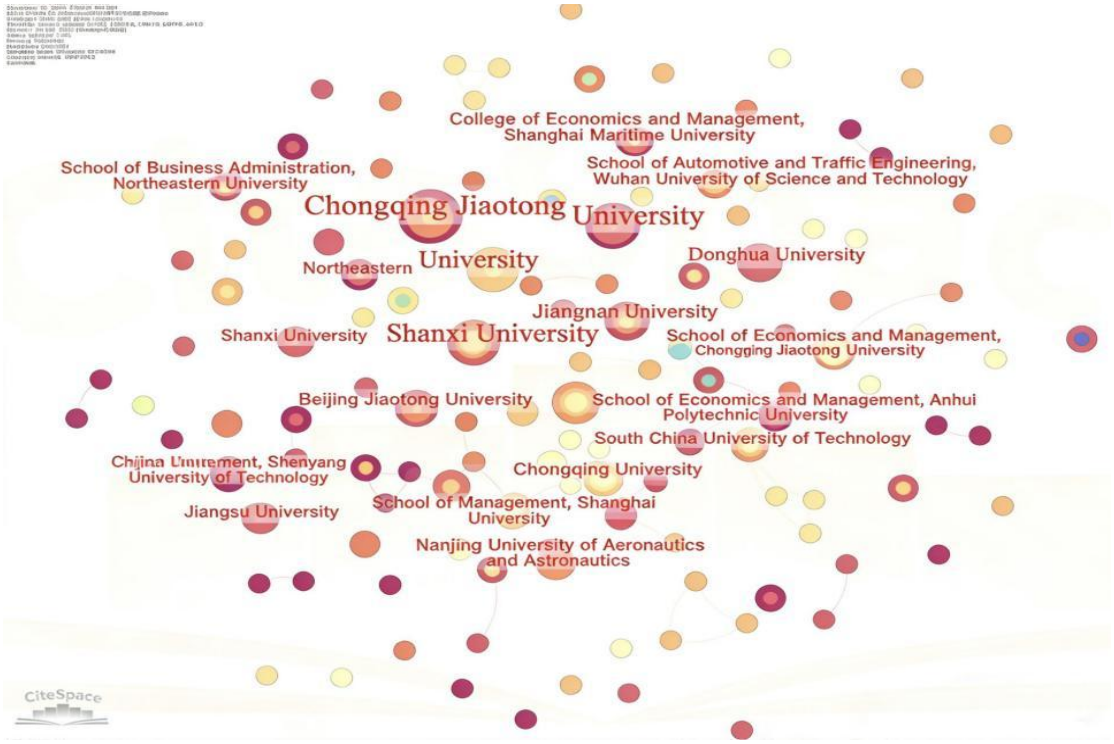


Figure 3. Institutional co-occurrence knowledge graph

Such a relatively fragmented cooperation pattern may restrict the interdisciplinary integration of theories and methods, and is not conducive to systematically solving various complex problems in practice. In the future, it is necessary to establish cross-institutional cooperation platforms, promote the open sharing of data, models and other resources, gradually form a more efficient research community, enhance research and innovation capabilities, and improve the efficiency of achievement transformation.

3.4. Research Hotspot Analysis

To present the research hotspots in the field of closed-loop supply chain pricing for new energy vehicles in China, CiteSpace was used to construct a keyword co-occurrence map, as shown in Figure 4.

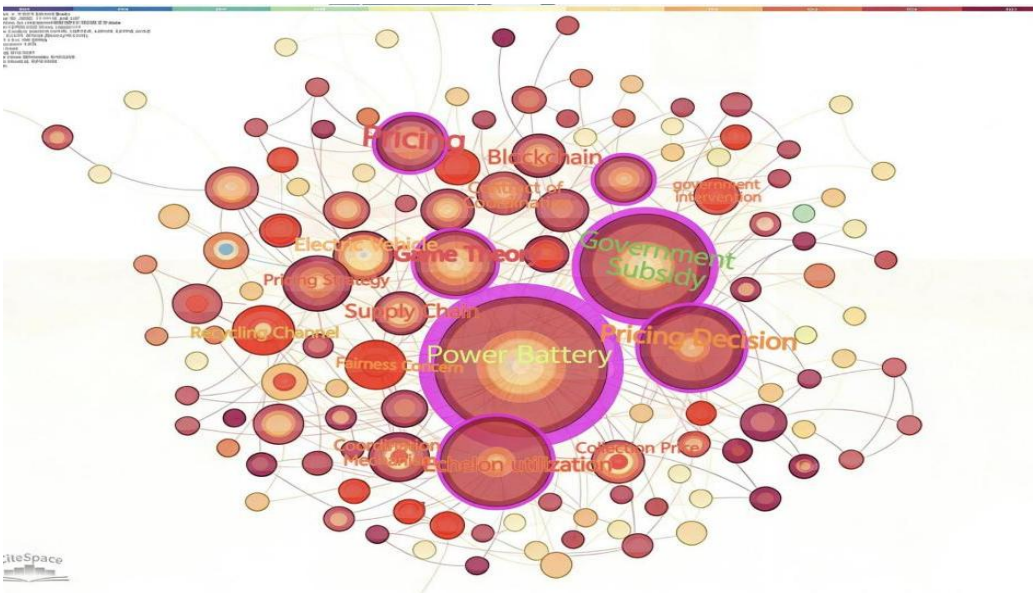


Figure 4. Keyword co-occurrence graph

It can be seen from the figure that keywords such as power battery, government subsidy, pricing decision, echelon utilization, and game theory exhibit high frequency and high centrality in the research on closed-loop supply chain pricing for new energy vehicles. Among them, power battery is an absolute core topic, reflecting its core attribute as the research carrier. The pricing mechanism, recycling subsidy, resource reuse and other links in this field all revolve around power batteries, which are not only the core hub connecting vehicle enterprises, recyclers, the government and other stakeholders, but also the basic logical starting point of research in this field. The high centrality of keywords such as government subsidy and government intervention directly reflects the key regulatory role of policies. Most existing studies focus on the guiding mechanism of policy tools (e.g., government subsidies, trade-in, carbon tax) on supply chain pricing strategies, as well as the impact of policy instruments on pricing decisions and participation behaviors of market players.

As the core focus of research, the high-frequency co-

occurrence of pricing decision and pricing strategy reflects that the key of current research lies in the design of pricing mechanisms for each closed-loop link. Relevant studies mainly focus on multi-agent pricing logic, interest balance and pricing optimization paths. The high-frequency correlation of keywords such as echelon utilization and recycling not only reflects the full life-cycle characteristics of closed-loop supply chain (forward production and reverse recycling), but also indicates that pricing research should incorporate back-end links such as recycling costs and resource recycling benefits to jointly build a full-chain pricing system. The clustering of keywords such as game theory and evolutionary game shows that the mainstream research method in this field is to deduce pricing equilibrium and cooperation mechanisms in multi-agent interest conflicts and coordination through game models. The co-occurrence of keywords such as supply chain coordination and contract coordination reflects the in-depth development trend of research, that is, on the basis of pricing, further exploring multi-agent interest coordination and overall benefit optimization.

In summary, current research in this field is forming a logical framework with power batteries as the core carrier, policy tools as the guiding mechanism, multi-agent game coordination, and full-chain pricing optimization. The research dimension has evolved from single-link pricing to systematic pricing of the full closed-loop life cycle.

3.5. Research Trend and Frontier Analysis

3.5.1. Research Trend

To reveal the dynamic evolution path of research hotspots in the field of closed-loop supply chain pricing for new energy vehicles, CiteSpace was used to construct a keyword time-zone map, as shown in Figure 5.

Specifically, the research on closed-loop supply chain pricing for new energy vehicles is divided into three stages:

The first stage is the initial exploration stage from 2015 to 2018. During this period, research on closed-loop supply chain pricing for new energy vehicles gradually started in China, with a relatively limited number of relevant publications, but the research topics had been initially expanded. Macro industrial issues such as electric vehicles and social welfare received early attention, while core topics including power batteries and pricing decision also began to emerge in this period.

The second stage is the policy-driven development stage from 2018 to 2022. In this period, policies such as industrial subsidies and the dual-credit policy were intensively implemented in China's new energy vehicle industry, promoting the rapid development of research in this field. The number of relevant publications increased sharply, and both the depth and breadth of research were significantly improved. The emergence of high-frequency keywords such as government subsidy and game theory not only reflects the key guiding role of policy tools in closed-loop supply chain pricing, but also indicates that pricing strategies under multi-agent interest game became the core research direction in this period.

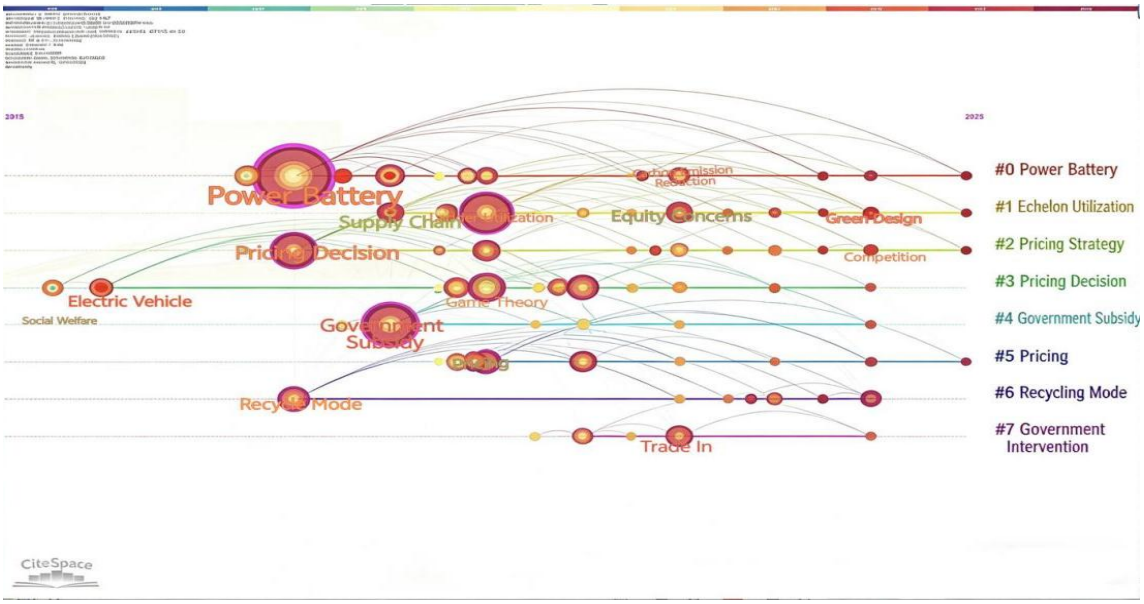


Figure 5. Keyword Timeline Graph

The third stage is the technology-integrated deepening stage from 2022 to 2025. During this period, the new energy vehicle industry transformed toward high-quality development, and the research focus shifted from a single pricing link to the systematic optimization of the whole chain. The connections between keywords such as echelon utilization, green design, information sharing and the core topics became increasingly dense, indicating that the research focus has turned to the full life-cycle pricing of power batteries and technology-enabled information collaboration. Relevant practical applications not only focus on the implementation of industrial scenario pricing such as the superposition of carbon trading mechanism and dual-credit policy, but also begin to explore the impact of international policy differences on the pricing of transnational supply chains.

3.5.2. Frontier Analysis

To identify the latest research trends and predict the development direction in the field of closed-loop supply chain pricing for new energy vehicles, CiteSpace was used to construct a keyword burst map, as shown in Figure 6.

It can be seen from the figure that the research hotspots of closed-loop supply chain pricing for new energy vehicles

show obvious phased evolution characteristics.

From 2018 to 2019, high-burst keywords such as subsidy policy, recycling pricing and coordination mechanism constituted the early core hotspots in this field. Among them, "subsidy policy" was the core policy variable, "recycling pricing" focused on the core issue of economic feasibility of power battery recycling, and "coordination mechanism" paid attention to multi-agent interest coordination, which laid the research tone of policy orientation and basic pricing.

From 2019 to 2021, supply chain, echelon utilization and evolutionary game became high-burst keywords. Among them, "supply chain" had the largest growth in popularity in this stage, indicating that research expanded from single-link pricing to the overall closed-loop dimension. "Echelon utilization" reflected the pricing logic of power battery resource recycling, connecting forward and reverse value chains. The emergence of "evolutionary game" promoted the adoption of quantitative models to analyze multi-agent dynamic pricing decisions, realizing the refinement of research methods.

Keywords	Year	Strength	Begin	End	2015 - 2025
Subsidy Policy	2018	1.23 **2018**	2019	2019	
Recycling Pricing	2018	1.03 **2018**	2020	2020	
Coordination Mechanism	2018	1.08 **2018**	2020	2020	
Supply Chain	2017	1.65 **2018**	2029	2020	
Graded Utilization	2019	1.85 **2019**	2021	2021	
Responsibility Sharing	2020	0.89 **2020**	2021	2021	
Recycling Decision	2020	0.80 **2020**	2020	2023	
Recycling Subsidy	2020	0.61 **2020**	2023	2023	
Evcycling Subsidy	2020	0.69 **2020**	2022	2023	
Evolutionary Game	2021	0.83 **2021**	2022	2023	
Dynamic Game	2021	0.83 **2021**	2022	2023	
Dismantling	2021	0.83 **2021**	2022	2023	
Information Sharing	2021	1.35 **2021**	2023	2023	
Goward-Punishment Mechanism	2023	0.69 **2022**	2025	2023	
Fairness Concern	2023	0.63 **2022**	2025	2023	
Recycling Channel	2019	0.49 **2023**	2025	2025	
Differential Game	2023	0.47 **2023**	2025	2023	

Figure 6. Keyword bursting map

Since 2022, fairness concerns, recycling channels and differential game have remained active until 2025, becoming the core frontiers of current research. Among them, "fairness concerns" makes up for the shortcoming of early research that emphasized efficiency over fairness, focusing on the fairness of benefit distribution; "recycling channels" focuses on the impact of reverse channel optimization on pricing; "differential game" makes research methods more dynamic and accurate, improving the explanatory power of models for complex reality.

Combined with the temporal characteristics, research in this field presents a clear evolution path: from external policy-driven to internal mechanism design, from static pricing analysis to dynamic game modeling, and from single-agent decision-making to multi-agent collaborative optimization. Current hotspots focus on pricing fairness, recycling channel optimization and precise modeling.

4. Conclusions

Based on a comprehensive investigation of publication trends, author and institutional cooperation networks, keyword co-occurrence, time-series evolution, and burst maps, the main conclusions are as follows:

(1) Research on closed-loop supply chain pricing for new energy vehicles in China since 2015 can be clearly divided into three stages: the initial exploration stage, the policy-driven development stage, and the technology-integrated deepening stage. The core research content has expanded from single-link pricing guided by policy tools, to the overall dimension of closed-loop supply chains and quantitative analysis methods, and then deepened to pricing fairness, channel optimization, and accurate dynamic modeling.

(2) The visual analysis clearly shows that the current research has formed a stable research paradigm with power batteries as the physical and value core carrier, government subsidies/intervention as the key external driving factor, game theory (evolutionary game, differential game, etc.) as the core research method, and supply chain coordination/contract design as the systematic optimization goal.

(3) According to the research frontier and the actual demand of industrial development, the current research focuses on three core directions: pricing fairness, recycling channel optimization, and dynamic and accurate modeling. Relevant research results not only provide theoretical support for solving practical problems such as uneven benefit distribution and low channel efficiency, but also meet the realistic demand for the industrialization of power battery recycling and large-scale echelon utilization, promoting the transformation of pricing research from theoretical modeling to industrial practice.

5. Deficiencies and Future Development

Although certain research achievements have been accumulated and a relatively stable theoretical framework has been established in the field of closed-loop supply chain pricing for new energy vehicles, there are still many theoretical bottlenecks and practical challenges in the context of industrialization, refinement, and globalization.

First, the theoretical system is not yet fully mature, and a unified theoretical framework that can systematically integrate interdisciplinary elements is lacking. In the future, interdisciplinary theoretical integration should be further deepened to construct a unified multi-agent dynamic pricing analysis framework.

Second, most existing studies focus on theoretical modeling, with few targeted studies on complex real-world scenarios. Future research should improve the adaptability of empirical research to industrial scenarios and narrow the gap between theoretical research and practice.

Third, the integration of digital technology and pricing models is still in the initial stage, and a practical intelligent decision-making system has not yet been formed. In the future, the integration of digital technology and pricing models should be accelerated, the application of technologies such as blockchain and artificial intelligence should be promoted, and practical intelligent decision-making tools should be developed.

Fourth, existing studies mostly focus on single domestic policy tools, with insufficient attention to issues such as international policy differences and transnational supply chain pricing coordination. Future research should expand the policy and global research perspective, strengthen the comparison of domestic and foreign policies, and explore the coordination mechanism of transnational supply chain pricing.

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