

Evolutionary game analysis of green transformation decision-making in the new energy vehicle industry chain under multi-collaborative subject mechanism

Liu Mei

Guangzhou Business College, Meizhou Guangdong, 511363;

Abstract: In the context of global emphasis on environmental protection and sustainable development, the new energy vehicle industry takes on a crucial role in driving the green transformation of transportation. This paper, grounded in a multi-stakeholder framework and employing evolutionary game theory, explores the interactions and dynamic evolution among the government, enterprises, and consumers during the green transition decision-making process within the new energy vehicle supply chain. It delves into the factors shaping each stakeholder's strategy choices and their equilibrium states, offering theoretical insights and decision support to advance the green transformation of the supply chain.

Key words: new energy vehicle industry chain; multiple collaborative subjects; evolutionary game theory; green transformation

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1 Introduction

In the context of tackling climate change and the energy crisis, the new energy vehicle industry has quickly risen to prominence, serving as a pivotal force driving sustainable development within the automotive sector. New energy vehicles, which integrate a variety of cutting-edge technologies, not only contribute to reducing carbon emissions and improving the environment through the green transformation of their industrial chains but also play a significant role in driving industrial upgrading and enhancing national competitiveness on a broader scale. Evolutionary game theory, which considers the bounded rationality of actors and the dynamic nature of decision-making, aligns well with the real-world behaviors of various entities involved in the green transformation of the industrial chain, where multiple stakeholders such as governments, enterprises, and consumers have different interests that influence decision-making and pose numerous challenges to the transition. This helps to deepen our understanding of the interaction mechanisms between actors, while also providing valuable theoretical references that can be utilized for formulating more reasonable and effective policies.

2 Mechanism of multiple collaborative subjects for green transformation of the new energy vehicle industry chain

2.1 Main body composition

Government: In the green transformation of the new energy vehicle industry chain, the government plays a crucial role in guiding and regulating by introducing industrial policies, implementing fiscal subsidies and tax incentives, which encourages companies to increase R&D investment, thereby promoting technological innovation and industrial upgrading. At the same time, it enhances environmental supervision by establishing stringent emission standards and regulating corporate production practices, thereby supporting the green development of the industry chain.

Enterprises: Enterprises, including vehicle manufacturers, battery suppliers, and parts manufacturers, serve as the core participants in the industrial chain, driving cost reduction, enhancing product quality, and elevating green standards through technological innovation, optimized production processes, and effective green supply chain management to meet market demands while maximizing profitability.

Consumers: The purchasing behavior of consumers not only directly influences the market demand for new energy vehicles but also plays a crucial role in shaping the development and expansion of the entire industry chain, especially as growing environmental awareness encourages more and more consumers to prefer environmentally friendly new energy vehicles over traditional options. Consumer choices not only play a pivotal role in expanding the new energy vehicle market but also serve as a powerful motivator for companies to enhance their products and services, thereby significantly boosting their enthusiasm for embracing green transformation initiatives.

2.2 Collaborative mechanism

Synergy: The government formulates comprehensive industrial policies to guide enterprises in significantly increasing their R&D investment in green technologies specifically for new energy vehicles, while simultaneously encouraging consumers to actively purchase new energy vehicles through various incentives and awareness campaigns. For instance, granting R&D subsidies to manufacturers, providing discounts and tax exemptions for car buyers, and encouraging cooperation among upstream and downstream enterprises in the industrial chain can effectively drive a comprehensive green transformation.

Technological Innovation Collaboration: Companies engage in technical cooperation and share R&D resources to collaboratively address green technology challenges, thereby enhancing the overall technological level of the industrial chain through joint efforts. For instance, vehicle manufacturers collaborate closely with battery suppliers to develop advanced high-performance batteries, while component producers partner with vehicle manufacturers to design and produce lightweight components, ultimately enhancing the energy efficiency and environmental sustainability of vehicles.

Market Demand Synergy: The increasing consumer demand for new energy vehicles not only motivates companies to enhance their product quality and green standards but also encourages them to promote these vehicles through marketing, thereby raising consumer awareness and acceptance, which further expands market demand and ultimately drives the green transformation of the entire industrial chain.

3 the idea of evolutionary game model construction

3.1 Model Assumptions

To thoroughly investigate the decision-making behavior of each participant in the green transformation process of the new energy automotive industry chain, we propose that there are three crucial entities — government, enterprises, and consumers—within the chain, whose decisions are not entirely rational and are influenced by various factors such as their own cognition, information accessibility, and external environmental conditions.

For the government, it has two strategies: positive regulation and negative regulation, and when opting for active regulation, the government will not only strictly enforce environmental laws and regulations but also introduce detailed, forward-looking industrial support policies to promote sustainable development. For instance, create a dedicated research and development fund specifically for new energy vehicle companies to incentivize breakthroughs in green technologies, while also implementing stringent carbon and pollutant emission standards within production processes to motivate businesses to adopt more environmentally sustainable manufacturing practices. The negative regulation implies that the government has not effectively implemented environmental protection policies, and the industrial support provided is merely superficial, making it challenging to exert a substantial impact on promoting the green transformation of the new energy vehicle industry chain.

Enterprises are also confronted with two options: green transformation and non-green transformation, where green transformation necessitates that companies enhance their investment in green technology research and development, ranging from innovations in battery technology to the utilization of lightweight materials, while comprehensively optimizing production processes and establishing a robust green supply chain management system. On the contrary, non-green transformation enterprises tend to adhere to traditional production methods while neglecting the research, development, and practical application of green technologies, thus struggling to comply with the increasingly demanding environmental standards throughout their production processes.

When purchasing a car, consumers face the choice between new energy vehicles and traditional fuel vehicles, and their decisions are influenced by various factors such as vehicle price, usage costs, and environmental awareness.

3.2 Analysis of payment status

The strategic combination of different subjects will generate entirely different return outcomes. When the government actively regulates, enterprises undergo green transformation, and consumers purchase new energy vehicles, the government can achieve substantial environmental benefits, improve air quality, reduce carbon emissions, promote the upgrading of the new energy automobile industry, drive the coordinated development of upstream and downstream enterprises, and enhance national competitiveness in the new energy vehicle sector. Through green transformation, enterprises can not only secure research and development subsidies offered by the government but also enhance their market share by leveraging superior products and a positive environmental image, yet they must inevitably shoulder the transformation costs associated with green technology research and development and equipment upgrades. Consumers who choose new energy vehicles can achieve environmentally friendly travel, significantly reduce daily usage costs by saving on fuel expenses, and enjoy additional benefits such as discounted or waived parking fees.

Even if the government actively implements regulations and enterprises pursue green transformation, the environmental quality can still be improved to a certain extent when consumers prefer traditional fuel cars, yet the pace of industrial upgrading will inevitably be slowed down. Enterprises pour substantial funds into transformation costs, yet consumers fail to broaden market share, leading to revenue losses, and while they have enjoyed the driving experience of traditional fuel vehicles, they have overlooked the reduced usage costs and environmental benefits offered by new energy vehicles.

When the government implements negative regulation and enterprises opt for green transformation, even if consumers purchase new energy vehicles, the lack of substantial government support can lead to increased cost pressures from the transformation, restricted income growth, and significant challenges in achieving the government's anticipated objectives of environmental enhancement and industrial upgrading. However, if consumers opt for traditional fuel vehicles, the green transformation of the entire industrial chain will stagnate, leading to a continuous rise in environmental pressure and leaving the government with minimal impact in terms of environmental protection and industrial advancement.

4 Model result interpretation

4.1 Evolutionary stability strategy analysis

When the social benefits of proactive government regulation significantly surpass those associated with negative regulation, and the advantages of corporate green transformation are evidently greater than those of non-green transformation, while consumers experience more substantial gains from purchasing new energy vehicles compared to traditional gasoline cars, proactive government regulation, corporate green transformation, and consumer adoption of new energy vehicles will emerge as stable and strategic decisions, effectively propelling the comprehensive green transformation of the entire industrial chain. Conversely, when the social benefits of proactive government regulation are not substantial, corporate green transformation costs remain high with low returns, and consumers experience minimal gains from purchasing new energy vehicles, all parties involved will likely prefer to maintain the status quo, thereby impeding the green transformation progress of the entire industrial chain. If specific conditions are satisfied, the system might possess multiple local equilibrium points, and the evolutionary outcome is contingent upon the initial decisions and the learning adjustment speeds of all participants.

4.2 Analysis of influencing factors

Government Policy Factors: The government's regulatory efforts and industrial support policies significantly influence business and consumer decisions, as increasing subsidies for companies undergoing green transitions and raising fines for non-green transitions can enhance the benefits of green transformation, thereby encouraging businesses to adopt it. Providing more incentives for car purchases, such as tax reductions and subsidies, can significantly enhance consumers' willingness to buy new energy vehicles by making them more financially appealing and accessible.

The cost and benefit factors of enterprises, particularly the costs and benefits associated with green transformation, serve as crucial elements that significantly influence their decision-making processes. By reducing R&D costs through technological innovation, lowering production costs via optimized production processes, enhancing the market competitiveness of green transformation products, and increasing market share and revenue, enterprises can be encouraged to become more enthusiastic about pursuing green transformation initiatives.

Cognitive Factors: Enhancing environmental campaigns to boost consumer awareness can help consumers recognize the advantages of new energy vehicles, as consumers' environmental awareness and understanding of these vehicles significantly influence their purchasing decisions. At the same time, improving product quality and service levels, as well as enhancing user experience, can further increase consumer favorability towards new energy vehicles by addressing their evolving needs and expectations in a comprehensive manner.

5 Suggestions on promoting the green transformation of the new energy vehicle industry chain

5.1 Government level

To enhance the policy system, it is crucial to boost support for the new energy vehicle industry by establishing more rigorous environmental standards and industrial policies, while simultaneously increasing financial backing for green technology research and development and imposing heavier penalties on non-compliant enterprises to steer them towards green transformation.

Strengthen infrastructure construction by accelerating the layout of charging piles, battery swap stations, and other related facilities to effectively address consumers' range anxiety and offer a solid guarantee for the widespread promotion and use of new energy vehicles.

5.2 Enterprise level

Increase investment in technological innovation by continuously allocating more R&D resources to overcome challenges related to green technology, significantly reduce production costs, enhance product quality and performance, and ultimately strengthen market competitiveness.

Optimize supply chain management by establishing close cooperative relationships with upstream and downstream enterprises, promoting the construction of a green supply chain, and realizing the green development of the entire industrial chain through enhanced collaboration and sustainable practices.

5.3 Consumer level

Strengthen environmental protection publicity and education by carrying out environmental protection campaigns through various channels, such as social media, workshops, and community events, to improve consumers' awareness of environmental protection and enhance their recognition and acceptance of new energy vehicles as a sustainable transportation solution.

Enhancing the consumer experience requires enterprises and relevant departments to collaborate in elevating the after-sales service standards of new energy vehicles, thereby offering consumers a more satisfactory and seamless usage experience.

6 CONCLUSIONS

The green transformation of the new energy vehicle industry chain necessitates collaborative efforts from the government, enterprises, and consumers, and by establishing a multi-stakeholder mechanism while applying evolutionary game theory to analyze the decision-making behaviors of each party, we can provide a solid basis for formulating more effective and comprehensive policies and strategies. In the future, all parties should continue to fully leverage their respective strengths, collaborate more closely, and actively promote the sustainable and environmentally friendly green transition of the entire new energy vehicle industry chain.

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Liu Mei, Female, June 1993, Meizhou, Guangdong. Master's Degree, Lecturer, Guangzhou Business College, 511363. Green Finance and Digitalization.