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Consumer Low-Carbon Preferences on Supply Chain Decision-Making and Coordination Mechanisms

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Abstract. Customers' predilection for sustainable items is steadily promoting supply chains to undergo low-carbon transformation, making consumer low-carbon preferences a significant demand-side factor influencing supply chain decision-making mechanisms. This article focuses on consumers' low-carbon preferences, systematically sorting out their role logic in supply chain pricing, emission reduction production, and green marketing decisions, further exploring the internal causes of coordination difficulties across supply networks in decentralized decision contexts, and distinguishing the applicable boundaries and implementation effects of different coordination mechanisms. Research has found that consumers' low-carbon preferences do not necessarily lead to synchronous improvements in supply chain emissions reduction and economic benefits. Contract parameters and corporate behavioral preferences can regulate the transmission effect of demand signals. Under the coordination mechanism of cost sharing, benefit sharing, and incorporating behavioral preferences, low-carbon consumption demand can only be transformed into overall supply chain performance when specific boundary conditions are matched. This article clarifies the constraints on the transformation of low-carbon preferences into supply chain performance, which can provide a literature basis for modeling and empirical studies concerning low-carbon supply networks.

Keywords: Low-carbon preferences, supply chain decision-making, coordination mechanisms

1. Introduction

As the dual-carbon goal continues to be promoted and public environmental consciousness rises steadily, purchasers attach growing importance to products' low-carbon features in their selection process. In addition to traditional factors such as price and quality. Consumer low-carbon preferences reshape market demand from the demand side, urging supply system participants at all levels to advance low-emission renovation. This demand signal will be transmitted along the supply chain, profoundly affecting the production, pricing and other business decisions of manufacturers and retailers. Therefore, exploring the impact of consumer low-carbon preferences on supply chain behavior mechanisms is of great practical significance.

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Existing research has discussed the impact of consumer low-carbon preferences on corporate decision-making from aspects such as pricing, production emissions reduction, and marketing. Research has shown that consumers show a premium payment tendency for sustainable products, and the strengthening of low-carbon preferences will change supply chain pricing strategies. At the same time, the increase in consumer awareness of emission reduction will also drive companies to increase their investment in emission reduction. In addition, companies can also leverage carbon labels, green marketing, and other means to enhance the market advantage of low-carbon products. However, in the decentralized decision-making mode, each subject aims to maximize their own benefits, and there is a mismatch between low-carbon input costs and benefits, making it difficult to spontaneously achieve the overall optimization of the supply chain. Therefore, contracts such as cost sharing and benefit sharing, as well as behavioral factors such as fairness preferences and corporate social responsibility, are introduced into supply chain coordination research to resolve conflicts of interest among members.

It is worth noting that there is no unified conclusion on the role and effect of consumer low-carbon preferences in existing research: preference enhancement does not necessarily always bring higher emission reduction levels and supply chain benefits, and its actual effect will be regulated by multiple conditions such as centralized or decentralized decision-making models, contract types, and behavior preferences of front-end and back-end participants across the supply system. Most of the existing research independently examines the effects of green consumption preferences on firms' operational decisions or verifies the coordination effectiveness of various contracts separately [1, 2]. There is less systematic clarification on how various boundary conditions constrain the demand transmission process of consumer low-carbon preferences, and how to change the implementation effect of coordination mechanisms.

Based on this, this article takes consumer low-carbon preferences as the core, analyzes their role in supply chain pricing, emission reduction production, and green marketing, sorts out the supply chain coordination mechanisms under various contractual and behavioral factors, and proposes low-emission supply chain progression guarantee strategies from the dimensions of enterprises, supply chains, markets, and policies.

2. Impact mechanism of consumer low-carbon preference on single supply chain decision-making

2.1. Impact on supply chain pricing decisions

Once consumers develop a liking for low-carbon merchandise, it will have an impact on the operational decisions of the entire supply chain. With the increasing preference for low-carbon among consumers, environmentally conscious customers may accept a mark-up on eco-friendly items, which creates a market foundation for enterprises to implement differentiated green pricing. However, the acceptance of this premium is also constrained by practical conditions such as income level and product functional alternative. Du et al. found through constructing an emission sensitive demand function that consumers' preference for low-carbon products directly affects the inverse demand curve of the product [3]. Low carbon attributes can enhance consumer utility at the same price, thereby expanding the premium space of enterprises. Liu et al.'s study on the automotive supply chain further indicates that low-carbon preferences have a greater impact on manufacturers' pricing than retailers, and the optimal pricing of new energy vehicles exhibits a positive correlation with consumers' sustainable preference levels [4]. The change in low-carbon preference intensity not only changes the retail prices of terminals but also reorganizes the profit distribution pattern across

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all stakeholders within the supply chain through the transmission mechanism of wholesale prices, enabling upstream manufacturers to obtain more benefits in low-carbon transformation, enabling upstream manufacturers to obtain more benefits in low-carbon transformation.

2.2. Impact on emission reduction and production decisions

Low carbon preferences force companies to adjust their production strategies from the demand side, driving them to optimize their product structure, gradually phase out high carbon categories, and accelerating the iteration of green products. The evolutionary game analysis by Su et al. shows that within the moderate preference range, as consumers' awareness of carbon reduction increases, the willingness of manufacturers and retailers to produce and promote low-carbon products significantly increases [5]. Consumer low-carbon preference serves as a market demand signal transmitted to the supply chain, prompting enterprises at all nodes of the supply chain to increase their sensitivity to low-carbon product market opportunities. Du et al. pointed out that although emission reduction investment increases production costs in the short term, it can realize mutual profit benefits for all parties and environmental benefits by stimulating low-carbon demand [3]. A rise in consumers' inclination toward low-carbon options directly enhances the marginal benefits generated when firms develop emission-cutting technologies and adopt low-carbon production practices, which in turn affects their decisions on the timing of adopting green technologies and the layout of green production capacity, gradually shifting the production direction towards a low-carbon demand-oriented model.

2.3. Impact on marketing and promotion decisions

The rise of consumer preference for low-carbon products has forced companies to incorporate green and low-carbon concepts into their marketing systems, promoting various green marketing practices such as product carbon label disclosure and low-carbon scenario dissemination. Su et al. pointed out that retailers can boost the low-carbon performance of their manufactured items through advertising, such as using concrete expressions like "one kilowatt hour per night" and "six liters of oil per hundred kilometers" to increase market awareness of low-carbon products [5]. When consumers are more sensitive to promotional efforts, retailers tend to prioritize allocating promotional resources to green product channels, accelerating the market penetration of low-carbon products through discounts, bundled sales, and other means. The public disclosure of carbon labels by enterprises not only proves the compliance of low-carbon products to low-carbon preference consumers but also becomes an important marketing tool for enterprises to distinguish green products from ordinary products and shape environmental brand images, thus better adapting to the development trend of the low-carbon market.

3. Internal coordination mechanism of supply chain under consumer low-carbon preference

3.1. The motivation and goal of supply chain coordination

In the Stackelberg game of a single chain supply chain, manufacturers and retailers are independent stakeholders. Under the decentralized decision-making model, all parties pursue maximizing their own profits rather than optimizing the overall supply chain, resulting in dual marginal effects. Upstream sets higher wholesale prices, while downstream further raises terminal selling prices, thereby suppressing market demand; At the same time, influenced by certain individual cost

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constraints, enterprises will reduce their capital input in carbon reduction initiatives and recycling, resulting in a lower total profit, emission reduction efforts, and waste recycling volume in the supply chain than the centralized decision-making equilibrium, leading to a loss of low-carbon efficiency in the system. The purpose of internal coordination in the supply chain is to mitigate the efficiency losses caused by double marginal effects. Internal coordination within the supply chain requires the use of contracts. The supply chain coordination contract has two objectives: Pareto improvement and perfect coordination. Pareto improvement refers to a holistic improvement in supply network profitability where the profit of each supply chain member is not lower than that of a decentralized decision-making state, and no participant's interests are compromised; Perfect coordination means that the equilibrium result of the game under the contract is equivalent to the optimal equilibrium of centralized decision-making in the supply chain. Contracts that can achieve perfect coordination will inevitably achieve Pareto improvement, but achieving Pareto improvement does not necessarily mean achieving perfect coordination. Chen et al. studied closed-loop remanufacturing supply chains and found that reasonable contracts can simultaneously improve member benefits and manufacturer emission reduction efforts, while balancing economic and low-carbon environmental benefits [6].

3.2. Cost sharing contract

Cost sharing contracts are a commonly used coordination and cooperation mechanism within low-carbon supply chains. This contract can effectively alleviate the imbalance of emission reduction cost sharing and the heavy burden of emission reduction on manufacturers. However, the effectiveness of the contract highly depends on the sharing ratio parameter. Improper parameter settings can damage the benefits of supply chain members and fail to achieve coordination goals. Within the landscape shaped by buyers' low-emission preferences driving market green transformation, manufacturers' emission reduction and transformation, as well as retailers' low-carbon promotion, both require high investment costs. In the decentralized decision-making mode, there is a clear problem of cost sharing and benefit sharing across the entire chain for low-carbon investment, which leads to insufficient motivation for some enterprises with higher burden to invest in low-carbon. The cost sharing contract effectively alleviates the dual marginal effect by reasonably sharing the emission reduction and promotion costs between upstream and downstream, motivates members to increase their green investment efforts, and improves the system-wide low-carbon performance and economic returns for the whole supply system.

3.3. Revenue sharing and profit distribution contract

Compared to cost sharing contracts that focus on optimizing the cost side, profit sharing contracts such as revenue sharing, quantity discounts, and two-part pricing mainly ensure the overall interests of the supply chain from the revenue side. In the decentralized decision-making mode, the upstream and downstream profit sources are relatively fixed, and a single entity is difficult to engage in large-scale low-emission financial investment and green operations. Revenue sharing contracts redistribute the overall revenue of the supply chain by adjusting wholesale pricing, transferring some sales revenue, and setting tiered discounts, weakening the decision-making bias caused by individual profit seeking, and guiding manufacturers and retailers to form a cooperative consensus on collaborative emission reduction and green operation. To compensate for the limitations of a single contract, academia often adopts combination contracts to enhance coordination effectiveness. Chen et al. constructed a cost-benefit sharing combination contract for closed-loop remanufacturing supply chains, and confirmed under their model assumptions that this combination contract can

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alleviate channel conflicts, improve waste product recycling efficiency and total system revenue, and achieve Pareto improvement [6]. The study also pointed out that there are feasible intervals for profit sharing and cost sharing ratios, and imbalanced parameter settings can harm the interests of participants and cause contract coordination failure; The conclusion of this model cannot be unconditionally applied directly to ordinary open-loop low-carbon supply chains.

3.4. Coordination mechanism considering behavioral preferences

Traditional supply chain coordination mechanisms are mostly based on the assumption of complete rationality, relying solely on profit maximization as the basis for enterprise decision-making, and are difficult to adapt to the cooperative characteristics of the real low-carbon market. In reality, members within the supply chain generally exhibit behavioral characteristics such as fairness preferences, social preferences, and corporate social responsibility preferences. These irrational factors can alter a company's emission reduction, pricing, and cooperation strategies, thereby affecting the effectiveness of contract coordination [7]. Zhong et al. argue that supply chain decision-making responds differently to corporate fairness preferences under different green investment entities [8]. In a retailer dominated supply chain, when manufacturers have fairness preferences and engage in green manufacturing, this preference will increase product pricing and suppress green investment and overall supply chain benefits; If retailers engage in green marketing, fairness preference can increase manufacturers' profits, but retailers' own profits decrease. Therefore, it is necessary to find effective coordination methods to ensure the benefits of all parties involved. Zhao et al. verified through evolutionary game theory that the expansion of consumer low-carbon preferences and the increase in corporate CSR investment can jointly improve supply chain emission reduction performance and market returns [9]. The coordinated social responsibility of upstream and downstream promotes the stable development of low-carbon supply chains. From this, it can be seen that in the current market environment where consumers have a preference for low-carbon, relying solely on traditional interest contracts is difficult to ensure ideal coordination effects; Incorporating diverse bounded rationality behavioral preferences into the analysis framework can help build a low-carbon coordination mechanism that is more in line with the true decision-making logic of enterprises, but it does not mean that all supply chain scenarios must consider such behavioral factors.

4. Measures to ensure the coordinated development of the supply chain

4.1. At the enterprise level: Establish a green management philosophy and actively adapt to the trend of low-carbon consumption

Consumer low-carbon preferences can continue to affect the market environment, and supply chain enterprises need to transform traditional profit thinking, establish long-term green business concepts, and actively adapt to the market trend of low-carbon consumption. From the production perspective, enterprises should moderately increase their research and development investment in green processes and emission reduction technologies, continuously improve their carbon reduction capabilities, and enhance the quality and supply of low-carbon products. At the market operation level, enterprises can rely on consumers' low-carbon perception characteristics, implement differentiated green pricing and refined green marketing plans, and accurately tap into the potential of the low-carbon consumption market. Zhang et al. pointed out that enterprises need to flexibly choose low-carbon technology routes based on the differences in consumer low-carbon perception,

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in order to avoid resource waste caused by blind investment [10]. After further comparing the benefits of green investment, Zhong et al. found that the profit growth effect brought by manufacturers carrying out green manufacturing is better than that of retailers' green marketing investment [8]. This indicates that supply chain enterprises can prioritize investing in green manufacturing under limited resources, maximizing the return on low-carbon investment.

4.2. Supply chain level: establish a normalized low-carbon collaborative management system

To achieve stable low-carbon collaboration in a single supply chain, it is necessary to utilize normalized collaborative management mechanisms and rely on contract design, information exchange, and other methods to resolve various conflicts caused by decentralized decision-making. On the one hand, parties located at different stages across the supply chain should jointly design reasonable cost sharing and benefit sharing combination contracts, clearly define the emission reduction responsibilities and profit distribution rules of all parties, and alleviate the problems of imbalanced distribution of emission reduction costs and unequal distribution of benefits. On the other hand, building a low-carbon information sharing platform for the supply chain, connecting upstream and downstream demand, inventory, and carbon emission data, reducing low-carbon information asymmetry, lowering demand prediction bias, and improving overall collaborative efficiency. When designing contract parameters, it is wrong that the parameters are completely limited to the assumption of a completely rational person; If supply chain enterprises exhibit obvious bounded rationality characteristics such as fairness concerns and corporate social responsibility, such behavioral factors should be taken into consideration to enhance the feasibility of contracts in real-life scenarios.

4.3. Market level: cultivate a low-carbon consumption atmosphere for all citizens and stabilize green demand

At the level of market construction, relevant institutions should steadily promote the implementation of the carbon labeling system, unify and standardize the low-carbon information disclosure standards of enterprises, reduce the perceived bias of consumers on the environmental properties of merchandise, and help consumers identify real low-carbon products. At the same time, the policy level needs to take into account the cost of certification and disclosure of small and medium-sized corporations to avoid excessive operating burden brought by the system. Consumers' low-carbon preference is the underlying demand power driving the shift toward low-carbon operation across the supply chain, and a stable green consumption market can continue to stimulate enterprises' investment in emission reduction. At the same time, popularize the low-carbon concept by means of diversified green marketing and low-carbon scene publicity, continue to improve the public's low-carbon awareness level, and expand the scale of low-carbon consumer groups. Du et al. confirmed that the enhancement of consumers' low-carbon preference can simultaneously improve supply chain channel profits and enterprise emission reduction levels [3]. Su et al. proposed that within the moderate preference range, as consumers become more responsive to emission reduction, producers show greater readiness to manufacture low-carbon goods, and retailers tend to boost the marketing of low-carbon offerings, which fully shows that the construction of low-carbon consumption market can drive the reduction of carbon emissions throughout the supply chain originating at the demand end [5].

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4.4. Policy level: improve the low-carbon incentive and regulatory system

As the main body of external regulation, the government should build a low-carbon policy system that takes into account incentives and constraints. In terms of incentive policy design, relevant departments should optimize the combination of regulatory measures of carbon tax and carbon-reduction subsidies, improve regulatory constraints, and prevent the policy failure problem that the subsidy income has not really been transformed into the actual emission reduction investment after being obtained by the supply chain entities. Considering the heterogeneity of consumers' low-carbon perception, policies are formulated to build a more flexible subsidy mechanism, identify the scenarios of subsidy failure, and improve the efficiency of policy funds. At the same time, a standardized carbon emission supervision and verification system should be established to force the main bodies of the supply chain to implement the emission reduction task by relying on external constraints, so as to ensure the orderly development of the low-carbon supply chain.

5. Conclusion

This paper systematically reviews how buyers' low-emission preferences shape supply system pricing mechanisms, emission reduction production and green marketing decisions, and analyzes the internal causes of supply chain coordination dilemma when decisions are made in a decentralized manner. The research shows that the positive effect of consumers' low-carbon preference is not unconditional. Contract parameters, consumer characteristics, and corporate behavior preferences will restrict the transmission effect of demand signals. All kinds of coordination mechanisms can transform low-carbon consumption demand into the dual performance of supply chain economy and environment only if they adapt to the corresponding boundary conditions. This study clarifies the differences in the conclusions of the existing literature, which can offer theoretical guidance for subsequent research on low-carbon supply chain modeling.

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