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Research Article

Pricing Decisions in Dual-Channel Supply Chain considering Different Fairness Preferences and Low-Carbon Advertising Level

Hong Huo, Dan Luo, Zhanghua Yan, and Hao He

School of Management, Harbin University of Commerce, Harbin 150028, China

Correspondence should be addressed to Dan Luo; luodan_1998@163.com

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Countries around the world advocate low-carbon, green, and environmentally friendly lifestyles to combat climate change, which provides clear direction for enterprise decisions. This paper studies a low-carbon dual-channel supply chain based on behavioral economics, incentive theory, and optimization models to better formulate pricing decisions. This paper constructs a fair and neutral decentralized decision-making model (FNDD), a decentralized decision-making model considering Nash bargaining fairness concerns (NBFDD), a decentralized decision-making model considering absolute fairness concerns (AFDD), and a fair and neutral centralized decision-making model (FNCD) considering consumer preferences and the situations where supply chain members are fairness concerns or fairness neutrality. This paper analyzes the effect of low-carbon advertising level on pricing strategies of online retailers and offline stores and compares pricing strategies of online retailers and offline stores in four decisions. The results show that Nash bargaining fairness concerns of supply chain members could effectively reduce the retail price of low-carbon products and increase their sales volumes. Absolute fairness concerns intensify the dual marginal effect of decentralized decision-making.

1. Introduction

For businesses, pricing decisions of products affect their normal operations and development. In recent years, the low-carbon supply chain has developed rapidly, and online and offline consumption systems blend with the rise of electronic commerce. Many manufacturing enterprises such as P & G, Unilever, and GM have opened online sales channels based on original offline channels. In dual-channel supply chain, developing appropriate online and offline retail prices to promote the long-term development of the supply chain has become an important issue facing enterprises.

Companies' carbon emission reduction significantly impacts pricing decisions under the background of "double carbon." In recent years, the world climate has faced severe problems which have endangered the living environment, health, and safety of humankind. In the face of global climate change, countries urgently need to work together to reduce or control carbon dioxide emissions [1]. The United Nations Climate Change Conference produced the "Bali Roadmap" and established a clear agenda for negotiations on climate change on December 15, 2007 [2]. The European Union plans to achieve a 40 percent reduction in carbon emissions by 2030 compared with 1990. In September 2020, the Chinese government proposed reducing carbon dioxide intensity by more than 65% by 2030 compared with 2005 and achieving carbon neutrality by 2060 [3]. In order to fulfill the responsibility and obligation of low-carbon, countries worldwide have issued relevant policies to promote the sustainable development of the low-carbon economy. The concept of sustainable development in the era of the low-carbon economy guides the formation of consumers' awareness of low-carbon consumption [4].

Consumers' purchase behavior decisions consider not only the price factors but also the low-carbon factors in the process of products and services. The price and carbon emissions of low-carbon products will become the essential parts of consumer behavior decision-making, the important parts of enterprises to determine customer value needs, and the careful consideration of consumer behavior.

A group of behavioral scientists represented by Kahneman have revealed that people pay great attention to fairness in practical problems through many empirical studies. Supply chain participants should pay attention to the maximization of their interests and the fairness of income distribution in supply chain system. Therefore, we should consider the impact of supply chain members' fairness concerns on pricing decisions in low-carbon dual-channel supply chain.

Previous studies mainly focused on the impact of fairness concerns behavior of single-channel supply chain members on their decision-making. The research objects of this paper are a single supplier, a single online retailer, and a single offline store. We construct the FNDD, NBFDD, AFDD, and FNCD models considering the fairness concerns behavior of supply chain members. Meanwhile, we analyze the effect of low-carbon advertising level on pricing strategies of online retailers and offline stores and compare pricing strategies of online retailers and offline stores in four decisions. Besides, the effects of different reference points are tested in this paper. This will help understand the impact of fairness preferences on enterprises' decision-making and mechanism changes.

On the one hand, considering supply chain members' contribution differences and consumer preferences, the Nash bargaining solution is used as a fair reference point to describe supply chain members in computation. The pricing strategies considering Nash bargaining fairness concerns are studied, which is more realistic. On the other hand, we explore the impact of absolute fairness concerns behavior on pricing strategies of dual-channel supply chain members. By comparing and analyzing the difference in the impacts of Nash bargaining fairness concerns and absolute fairness concerns on supply chain members' pricing strategies, we can seek an appropriate reference point for the fairness concerns of supply chain members. In addition, this paper lays a theoretical foundation for enterprises to achieve the "double carbon" goal and help them complete the carbon emission reduction goal. The main issue discussed in this paper is the impact of Nash bargaining fairness concerns behavior and absolute fairness concerns behavior on supply chain members' decision-making, that is, how to choose partners under different fairness preferences.

The rest of the article is organized as follows. In Section 2, we review the literature relevant to this article. In Section 3, we construct four important decision models. We compare and analyze retail prices, sales volumes, and profits of online retailers and offline stores under four decision models and examine the impact of different reference points in Section 4 and Section 5. We provide our conclusions and managerial insights in Section 6.

2. Literature Review

This section reviews the related literature in two main streams: (1) pricing strategies of low-carbon supply chain and (2) fairness preference of supply chain members. Afterward, the research gaps and contributions of the current study are addressed.

2.1. Pricing Strategies of Low-Carbon Supply Chain

2.1.1. Single-Channel Low-Carbon Supply Chain. Many scholars have built low-carbon supply chains to study their pricing strategies but have not considered the impact of fairness concerns. Li et al. simulate the government's subsidy policy for low-carbon enterprises and retailers using game theory and show that the government subsidy strategy based on carbon emission reduction level can effectively drive low-carbon enterprises to further reduce carbon emissions [5]. Wei and Wang use the differential game method to study the interactive relationship between carbon emission reduction technology innovation and government intervention under decentralized decision-making and centralized decision-making. The research found that the optimal level of carbon emission reduction technology innovation under decentralized decision-making is same as that under centralized decision-making without cost-sharing [6]. Zhang et al. analyze the optimal strategy of low-carbon technology innovation in the context of government subsidies. The research found that when consumers' low-carbon preference is weak, retail prices of products are negatively correlated with subsidies [7]. The above scholars have built a single-channel low-carbon supply chain to study its pricing strategies but have not considered the condition of the dual-channel supply chain.

2.1.2. Dual-Channel Low-Carbon Supply Chain. Building dual-channel low-carbon supply chains to study supply chain decision-making problems is gradually increasing. Che et al. construct a dual-channel supply chain model and study the impact of the manufacturer's participation in carbon trading and green financial loans on the participant's profits and emission reduction decisions using the Stackelberg game. The results show that the carbon emission reduction level of the manufacturer is inversely proportional to the relevant price, and the demand and profit of two channels are proportional to the emission reduction amount under carbon trading mechanism [8]. Santanu et al. analyze a dual-channel supply chain model considering the emission-sensitive random demand under compulsory government quota, transaction supervision, and consumers' low-carbon preference. The results show that the decentralized dual-channel supply chain can be effectively coordinated and adopting a repurchase contract and emission reduction cost-sharing contract can be a win-win situation for supply chain members under emission-sensitive random demand [9]. The influence of external factors on supply chain members' pricing decisions is explored. Few scholars explore the impact of internal factors such as the behavior of supply chain members on the pricing decisions.

2.2. Fairness Preference of Supply Chain Members.

Different scholars have different research angles on the fairness of supply chain members. Li et al. construct a government incentive model for corporate carbon emission reduction and study the impact of corporate equity preference on the government's carbon emission reduction incentive strategy considering the multiobjective nature of corporate carbon emission reduction and enterprises' fairness preference. The research shows that the degree of enterprises' fairness preference directly affects enterprise effort [10]. Lu et al. establish an income distribution model considering the unfair aversion to functional logistics service providers (FLSP). The results show that the degree of unfair aversion to FLSP is negatively correlated with the proportion of income distribution [11]. Liu et al. discuss the impact of retailers' fairness on cooperative relationships in sustainable supply chains and reveal that retailers' fairness issues affect members' decision-making and cooperation in sustainable supply chain management [12]. Zhang et al. study a dual-channel supply chain consisting of a manufacturer and a retailer, where the retailer exhibits vertical and horizontal fairness concern, and reveal that the fairness concern behavior of the retailer only affects wholesale prices and online channel strategies [13].

2.2.1. Retailers' Fairness Concerns. Some scholars explore supply chain members' decision-making problems when retailers have fairness concerns. Sarkar and Bhala solved the apparent conflict between fairness and efficiency in closed-loop supply chains (CLSCs) and found that decentralized channels are effective when retailers strongly oppose disadvantageous inequality (DI) and advantageous inequality (AI) [14]. Zhou et al. study manufacturers' optimal decision-making in supply chain considering retailers' fairness behavior when demand information is asymmetric. The results show that retailers' fairness behavior and products' green degree will encourage the manufacturer to change its contract design strategy [15]. Rikuo et al. analyze a two-echelon supply chain considering the retailer's fairness concerns. The research shows that channels can be successfully coordinated in a balanced state [16]. Wang and Matsubayashi design three closed-loop supply chain models. The results show that manufacturers' corporate social responsibility behavior can effectively reduce retailers' fairness concerns behavior, but it will reduce the efficiency of government subsidies to a certain extent [17]. Zheng et al. incorporate retailers' fairness concerns into the coordination of three closed-loop supply chain (CLSC) members. The research found that different coordination mechanisms have different benefits for three CLSC members [18]. Fei and Gao study a two-stage green supply chain and compare the optimal pricing strategies under each mode. The research shows that the introduction of revenue sharing contract can effectively improve the profit of supply chain members under decentralized decision-making so that manufacturers and retailers can achieve Pareto improvement at the same time [19]. These scholars only study the impact of retailers' fairness concerns on supply chain decision-making and do not consider suppliers' fairness concerns.

Some scholars consider the impact of low-carbon advertising level and retailer fairness issues on pricing decisions. Zhang et al. study a two-echelon supply chain consisting of an advertising retailer and a consumer with environmental awareness and analyze the impact of consumer environmental awareness, the proportion of retailers sharing low-carbon costs, and the fairness concerns coefficient on supply chain enterprises. The research found that member's fair attention coefficient is negatively correlated with wholesale prices and retail prices of carbon emissions regardless of whether the retailer undertakes carbon emission reduction costs [20]. Yu et al. analyze the impact of emission reduction cost coefficient, low-carbon product advertising effort cost coefficient, and low-carbon product advertising effort cost allocation ratio on the profit of dual-channel supply chain. The research shows that retailers can use their advantages to get closer to consumers and improve the efficiency and pertinence of advertising in retail channels [21]. Zhou et al. study a low-carbon supply chain channel consisting of a manufacturer and a retailer and show how contract design can optimize low-carbon supply chain management decisions and improve supply chain performance. The research found that, regardless of whether the retailer has fairness concerns, cooperative advertising contracts cannot achieve channel synergy but can improve channel effectiveness [22]. The scholars only explore the impact of retailers' fairness concerns on pricing strategy and do not study suppliers' fairness concerns.

2.2.2. Suppliers' Fairness Concerns. Some scholars have also explored the impact of suppliers' fairness concerns on supply chain members' decisions. Wang et al. construct an online supply chain and study the optimal decisions in three cases: decentralized decision-making model without considering manufacturer fairness, decentralized decision-making model considering the manufacturer's fairness, and centralized decision-making model. Research shows that the manufacturer's fairness reduces system efficiency [23]. Jian et al. constructed a Stackelberg game model considering the fairness of the manufacturer's centralized decision-making and decentralized decision-making to study pricing decisions of products and found that when the manufacturer has fairness concerns behavior, it is not conducive to the environmental performance of green products resulting in waste of resources and forcing retailers to reduce sales and improve retail prices of products [24]. Jian et al. construct a centralized and decentralized decision-making model considering manufacturers' fairness concerns behavior to study pricing decisions of products. The results show that suppliers' fairness concerns behavior is not conducive to the environmental performance of green products [25]. Han et al. study the decision-making behavior in a low-carbon online supply chain when the supplier obtains government carbon subsidies and has fairness concerns behavior. The results show that consumers' preference for low-carbon products is beneficial to supply chain operation [26]. Wang et al. consider the fairness concerns behavior of online retailers and construct three online closed-loop supply chain decision models. The research found that the cost-sharing contract can maximize the system profit [27]. Zou et al.

Table 1: Literature review.

	Retailers have fairness concerns	Manufacturers have fairness concerns	Pricing decisions of dual-channel supply chain	Pricing decisions of dual-channel supply chain based on different fairness references
Zhang et al. [20]	√			
Jian et al. [24]		√		
Zou et al. [28]		√		
Bo et al. [29]	√	√		
Guan et al. [30]	√	√		
Ye et al. [31]	√	√		
Che et al. [8]			√	
Santanu et al. [9]			√	
Li et al.[32]		√	√	
This paper	√	√	√	√

discuss the impact of equity on sustainable low-carbon supply chain under carbon quota policy. The results show that the profit of centralized low-carbon supply chain (LCSC) is higher than that of decentralized LCSC [28]. These scholars only study the impact of suppliers' fairness concerns on supply chain decision-making and do not consider retailers' fairness concerns.

2.2.3. All Supply Chain Members Have Fairness Concerns. Many scholars have studied the optimal decisions considering the fairness concerns behavior of supply chain members. Bo et al. study the decision-making of the supply chain of fresh agricultural products considering fairness behavior. The research found that the profits of all parties under the revenue-sharing contract are more efficient [29]. Guan et al. study supply chain coordination between upstream manufacturers and downstream retailers. The results show that prominent channel members are more sensitive to fairness [30]. The members' fairness concerns behavior considering low-carbon advertising level has not been studied. Ye et al. construct a fair utility system based on Nash bargaining theory and discuss the retailer's advertising strategy under decentralized decision-making, the manufacturer's emission reduction strategy, and related strategies under centralized decision-making. The research found that the supplier's fairness concern behavior is not conducive to the development of a low-carbon economy. In contrast, the retailer's appropriate attention to fairness is conducive to the development of a low-carbon economy [31]. No scholars explored the impact of fairness concerns on supply chain pricing strategies under different fairness references.

2.3. Research Gaps and Contributions. The literature review is shown in Table 1. According to Table 1, the research gaps and contributions of this article are as follows.

Currently, most of the studies on fairness concerns behavior are aimed at a single member with fairness concerns behavior while other members are fair and neutral (e.g., [20, 24, 28]). Few scholars consider that all members have fairness concerns (e.g., [29–31]).

In addition, the research on supply chain pricing strategies is mainly for single-channel supply chains (e.g., [30, 31]), and few scholars have studied those of dual-channel supply chain members (e.g., [8, 9]). Besides, few scholars have considered the impact of fairness concerns on pricing strategies of supply chain members under different reference points (e.g., [32]).

Based on previous studies, this paper explores the impact of supply chain members' fairness concerns on the pricing strategy of dual-channel supply chain under different fairness reference points. Besides, this paper considers that all members have fairness concerns. We expect to obtain an optimal strategy to formulate the optimal pricing strategies in low-carbon supply chain.

In the existing research, the literature works that are highly related to this paper are [22, 32–34], where Hosseini-Motlagh et al. [33] make contributions to the literature on SC coordination by proposing a novel model for coordinating sustainable supply chain (SSC) under competition, supposing a manufacturer invests in reducing the carbon emissions and two retailers compete on investing in the green effort and they do not consider supply chain pricing decisions. In contrast, this paper considers the pricing decisions in supply chain. Hosseini-Motlagh et al. [34] develop a reverse supply chain model that derives optimal pricing, sustainability level, and corporate social responsibility decisions under demand disruptions. We focus on the impact of fairness concerns on pricing decisions in supply chain under different reference points in this paper. Li et al. [32] consider the case in which the manufacturer has fairness concerns behavior, but the retailer does not have. They suppose the manufacturer and the retailer adopt a cooperative advertising strategy to boost sales. This paper analyzes the impact of different fairness reference points on pricing strategies of supply chain members considering all members have fairness concerns behavior. Zhou et al. [22] consider a low-carbon single-channel supply chain consisting of a manufacturer and retailer and show how to optimize the low-carbon supply chain management decision and improve the supply chain performance through contract design, and we study pricing strategies of dual-channel supply chain members in this paper.

3. Pricing Strategies Model of Dual-Channel Supply Chain Based on Different Fairness Reference Points and Low-Carbon Advertising Level

We explore a dual channel composed of a single supplier, a single online retailer, and a single offline store, as shown in Figure 1. The paper considers a dual-channel supply chain, and low-carbon factor is an important factor to be considered in competition. We assume that the market supply and demand balance. Consumers can buy products without differences online and offline. The wholesale prices of the dual-channel retailers are the same. In order to maximize the promotion of low-carbon products, it is very necessary for retailers to carry out corresponding advertising in low-carbon supply chain. Although this will further increase products' cost, the increase of products' sales brought by advertising will lead to increase in corporate profits. In this paper, the low-carbon efforts of retailers refer to the low-carbon supply chain in which retailers promote low-carbon products and increase the sales of low-carbon products. Online retailers have low-carbon advertising costs $1/2l_1^2$, showing the advertising effort that retailers are investing in low-carbon products. Offline stores have low-carbon advertising costs $1/2l_2^2$. Referring to the basic framework of demand function in literature [35], this paper designs the demand functions of online retailers and offline stores as follows:

$$\sigma_1 = a\sigma - \beta P_1 + \gamma(l_1 - l_2), \tag{1}$$

$$\sigma_2 = (1-a)\sigma - \beta P_2 + \gamma(l_2 - l_1). \tag{2}$$

The probabilities that consumers purchase low-carbon products from online and offline channels are set to a and $(1-a)$, and the potential size of demand markets is set as σ. The price sensitivity coefficient of consumers is set as β, and the retail prices of online retailers and offline stores are set as P_1 and P_2. The transfer coefficient of consumers' demand to the difference in low-carbon advertising level is set as γ, and low-carbon advertising levels of online retailers and offline stores are set as l_1 and l_2.

This article uses the parameters shown in Table 2.

Among them, $j = d, r, a, c$ represent the fair and neutral decentralized decision-making (FNDD), the decentralized decision-making considering Nash bargaining fairness concerns (NBFDD), the decentralized decision-making considering absolute fairness concerns (AFDD), and the fair and neutral centralized decision-making (FNCD).

3.1. Decentralized Decision-Making Model with Fairness and Neutrality (Model I).

Under FNDD, the supply chain members pursue the maximization of their interests. The

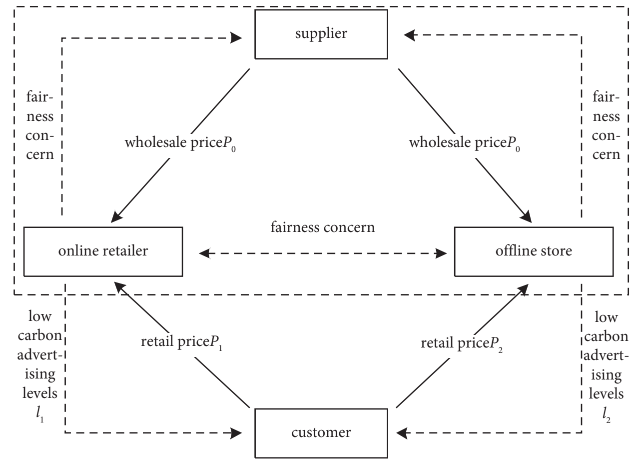

Figure 1: Decision relation of dual-channel supply chain considering fairness concerns.

revenue functions of online retailers, offline stores, suppliers, and the whole supply chain system are

$$\begin{aligned}\Pi_o^d &= (P_1 - P_0)\sigma_1 - \frac{1}{2}l_1^2 \\ &= (P_1 - P_0)(a\sigma - \beta P_1 + \gamma(l_1 - l_2)) - \frac{1}{2}l_1^2,\end{aligned} \tag{3}$$

$$\begin{aligned}\Pi_r^d &= (P_2 - P_0)\sigma_2 - \frac{1}{2}l_2^2 \\ &= (P_2 - P_0)((1-a)\sigma - \beta P_2 + \gamma(l_2 - l_1)) - \frac{1}{2}l_2^2,\end{aligned} \tag{4}$$

$$\begin{aligned}\Pi_m^d &= (P_0 - c)(\sigma_1 + \sigma_2) \\ &= (P_0 - c)(\sigma - \beta(P_1 + P_2)).\end{aligned} \tag{5}$$

3.2. Decentralized Decision-Making Model considering Nash Bargaining Fairness Concerns (Model II).

This section further considers supply chain members' Nash bargaining fairness concerns based on Model I. In this model, the goal of supply chain members is not to maximize their interests but to pursue the fairness of their interests in the supply chain and formulate corresponding pricing strategy. The profits of Nash equilibrium bargaining relative reference points of online retailers, offline stores, and suppliers are $\overline{\Pi_o}$, $\overline{\Pi_r}$, and $\overline{\Pi_m}$. The utility functions of online retailers, offline stores, and suppliers are

$$U_o^f = \Pi_o + n_1(\Pi_o - \overline{\Pi_o}), \tag{6}$$

$$U_r^f = \Pi_r + n_2(\Pi_r - \overline{\Pi_r}), \tag{7}$$

$$U_m^f = \Pi_m + n_3(\Pi_m - \overline{\Pi_m}). \tag{8}$$

Equations (6)–(8) reflect the changes in the fair utility of the supply chain members' profit relative to the fairness reference points, reflecting the characteristics of profit

Table 2: Variables and descriptions.

Variables	Descriptions
σ	Potential size of demand markets
σ_1^j, σ_2^j	Sales volumes of online retailers and offline stores under four decisions
$a, 1-a\,(0<a<1)$	The probability that consumers purchase low-carbon products online and offline
$\beta\,(0<\beta<1)$	The price sensitivity coefficient of consumers
$\gamma\,(0<\gamma<1)$	The transfer coefficient of consumers' demand to the difference in low-carbon advertising level
c	Production cost
P_0	Wholesale price
P_1^j, P_2^j	Retail prices of online retailers and offline stores under four decisions
l_1^j, l_2^j	Low-carbon advertising level of online retailers and offline stores under four decisions
$\prod_i^j\,(i=o,r,m;\ j=d)$	Profits of online retailers, offline stores, and suppliers under FNDD
$U_i^j\,(i=o,r,m;\ j=r,a)$	Utilities of online retailers, offline stores, and suppliers under NBFDD and AFDD
Π^j	Overall profits of suppliers, online retailers, and offline stores under four decisions
$n_1, n_2, n_3\,(n_1,n_2,n_3\geq 0)$	The Nash bargaining fairness concerns coefficient for online retailers, offline stores, and suppliers
$n, m\,(n,m\geq 0)$	The horizontal and vertical fairness concerns coefficient

beyond or below the fairness reference point of Nash bargaining [31].

Proposition 1. *We assume that the fairness concerns coefficients of online retailers and offline stores are equal, and there is $n_1 = n_2$, namely, $\overline{\Pi_o} = \overline{\Pi_r} = 1 + n_1/3 + 2n_1 + n_3\Pi$. The expected revenue functions of online retailers, offline stores, and suppliers are*

$$\begin{aligned}
U_o^f &= (1+n_1)\Pi_o + \frac{1+n_1}{3+2n_1+n_3}\Pi = (1+n_1)\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2\right]\\
&\quad + \frac{1+n_1}{3+2n_1+n_3}\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\right]\\
U_r^f &= (1+n_1)\Pi_r + \frac{1+n_1}{3+2n_1+n_3}\Pi = (1+n_1)\left[(P_2-P_0)(a\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2\right]\\
&\quad + \frac{1+n_1}{3+2n_1+n_3}\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\right]\\
U_m^f &= (1+n_3)\Pi_m + \frac{1+n_3}{3+2n_1+n_3}\Pi = (1+n_3)(P_0-c)(\sigma-\beta(P_1+P_2))\\
&\quad + \frac{1+n_3}{3+2n_1+n_3}\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\right].
\end{aligned} \tag{9}$$

3.3. Decentralized Decision-Making Model considering Absolute Fairness Concerns (Model III). Based on Model I, this section further considers that all supply chain members have absolute fairness concerns. In this model, the goal of supply chain members is no longer to maximize benefits but to maximize utility compared with other members' benefits and formulate corresponding pricing strategy. Assuming that there are horizontal fairness concerns between online and offline channels of the supply chain, the horizontal fairness concerns coefficient is denoted as $n\,(n>0)$, there are vertical fairness concerns between suppliers and retailers, and the vertical fairness concerns coefficient is denoted as $m\,(m>0)$. The utility functions of online retailers, offline stores, and suppliers are

$$U_o^a = \Pi_o - n(\Pi_r - \Pi_o) - m(\Pi_m - \Pi_o) = (1+m+n)\Pi_o - n\Pi_r - m\Pi_m, \tag{10}$$

$$U_r^a = \Pi_r - n(\Pi_o - \Pi_r) - m(\Pi_m - \Pi_r) = (1+m+n)\Pi_r - n\Pi_o - m\Pi_m, \tag{11}$$

$$U_m^a = \Pi_m - m(\Pi_o - \Pi_m) - m(\Pi_r - \Pi_m) = (1+2m)\Pi_m - m\Pi_o - m\Pi_r. \tag{12}$$

Equations (10)–(12) reflect the changes in the fair utility of the supply chain members' profit compared with other members' income [28].

The expected utility functions of online retailers, offline stores, and suppliers under decentralized decision-making considering the absolute fairness concerns of supply chain members are

$$\begin{aligned}
U_o^a &= (1+m+n)\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2))-\frac{1}{2}l_1^2\right] \\
&\quad - n\left[(P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1))-\frac{1}{2}l_2^2\right] - m[(P_0-c)(\sigma-\beta(P_1+P_2))] \\
U_r^a &= (1+m+n)\left[(P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1))-\frac{1}{2}l_2^2\right] \\
&\quad - n\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2))-\frac{1}{2}l_1^2\right] - m[(P_0-c)(\sigma-\beta(P_1+P_2))] \\
U_m^a &= (1+2m)[(P_0-c)(\sigma-\beta(P_1+P_2))] - m\left[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2))-\frac{1}{2}l_1^2\right] \\
&\quad - m\left[(P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1))-\frac{1}{2}l_2^2\right].
\end{aligned} \tag{13}$$

3.4. Centralized Decision-Making Model with Fairness and Neutrality (Model IV). Under FNCD, all members in the supply chain are regarded as a whole enterprise, and they cooperate to make decisions. The goal of enterprise operation is to maximize the profit of supply chain.

The overall revenue function of online retailers, offline stores, and suppliers is

$$\begin{aligned}
\Pi^c &= (P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) \\
&\quad -\frac{1}{2}l_1^2+(P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) \\
&\quad -\frac{1}{2}l_2^2+(P_0-c)(\sigma-\beta(P_1+P_2)).
\end{aligned} \tag{14}$$

Proposition 2. *Optimal pricing, sales volumes, and profits of supply chain members under four decisions are shown in Table 3.*

The optimal policies of FNDD, NBFDD, AFDD, and FNCD are solved through the converse solution method. The optimal retail prices and sales volumes of online retailers and offline stores are obtained as shown in Table 3 under four decisions. In addition, the profits of supply chain members are shown under four models.

4. Model Comparison Analysis

This section compares retail prices and sales volumes of online retailers and offline stores under four decisions and examines the impact of different reference points. At the same time, we analyze the influence of low-carbon advertising level difference on retail prices of online retailers and offline stores under four decisions. See Appendix for a specific solution process.

Proposition 3. The retail prices of online retailers and offline stores in AFDD are greater than those in FNDD, the retail prices of online retailers and offline stores in FNDD are greater than those in NBFDD, and the three are greater than those in FNCD.

The retail price of AFDD is further improved based on the dual marginal effects of FNDD among four decisions. In addition, supply chain members seek equitable interests and reduce retail prices to reduce the loss of interests caused by the dual marginal effects of decentralized decision-making in NBFDD. Supply chain members regard the whole supply chain system as a whole enterprise and pursue the maximization of enterprise interests so that the retail prices of online retailers and offline stores in NFCD are the lowest.

Proposition 4. *In FNCD, the sales volumes of online retailers and offline stores are higher than those in NBFDD, and the sales volumes in FNCD and NBFDD are higher than those in FNDD. The three are higher than those in AFDD.*

Among four decisions, the sales volumes of online retailers and offline stores in AFDD are the lowest. It will further the dual marginal effect compared with FNDD. In addition, it seeks the fairness of interests in NBFDD. Supply chain members improve their retail prices to reduce the loss of their interests caused by the dual marginal effects of decentralized decision-making. It will lead to the decrease of sales volumes. In FNCD, supply chain members regard the entire supply chain system as an enterprise, pursuing the maximization of enterprise interests. Therefore, the sales volumes of online and offline retailers in FNCD are the biggest.

Proposition 5. *In four decision models, the retail prices of online retailers are positively related to low-carbon*

Table 3: Optimal pricing, sales volumes, and profits of supply chain members under four decisions.

Fair and neutral decentralized decision-making (FNDD)	Decentralized decision-making considering Nash bargaining fairness concerns (NBFDD)	Decentralized decision-making considering absolute fairness concerns (AFDD)	Fair and neutral centralized decision-making (FNCD)
P_1, $a\sigma + \beta P_0 + r(l_1 - l_2)/2\beta$	$(4 + 2n_1 + n_3)(a\sigma + r(l_1 - l_2))/2\beta(4 + 2n_1 + n_3), + (3 + 2n_1 + n_3)\beta P_0 + \beta c/2\beta(4 + 2n_1 + n_3)$	$(1 + m + n)(a\sigma + r(l_1 - l_2))/2\beta(1 + m + n), + (1 + 2m + n)\beta P_0 - m\beta c/2\beta(1 + m + n)$	$a\sigma + \beta c + r(l_1 - l_2)/2\beta$
P_2, $(1 - a)\sigma + \beta P_0 + r(l_2 - l_1)/2\beta$	$(4 + 2n_1 + n_3)((1 - a)\sigma + r(l_2 - l_1))/2\beta(4 + 2n_1 + n_3), + (3 + 2n_1 + n_3)\beta P_0 + \beta c/2\beta(4 + 2n_1 + n_3)$	$(1 + m + n)((1 - a)\sigma + r(l_2 - l_1))/2\beta(1 + m + n),$ $+ (1 + 2m + n)\beta P_0 - m\beta c/2\beta(1 + m + n)$	$(1 - a)\sigma + \beta c + r(l_2 - l_1)/2\beta$
σ_1, $a\sigma + r(l_1 - l_2) - \beta P_0/2$	$(4 + 2n_1 + n_3)(a\sigma + r(l_1 - l_2))/2(4 + 2n_1 + n_3), - (3 + 2n_1 + n_3)\beta P_0 - \beta c/2(4 + 2n_1 + n_3)$	$(1 + m + n)(a\sigma + r(l_1 - l_2))/2(1 + m + n), - (1 + 2m + n)\beta P_0 + m\beta c/2(1 + m + n)$	$a\sigma + r(l_1 - l_2) - \beta c/2$
σ_2, $(1 - a)\sigma + r(l_2 - l_1) - \beta P_0/2$	$(4 + 2n_1 + n_3)((1 - a)\sigma + r(l_2 - l_1))/2(4 + 2n_1 + n_3), - (3 + 2n_1 + n_3)\beta P_0 - \beta c/2(4 + 2n_1 + n_3)$	$(1 + m + n)((1 - a)\sigma + r(l_2 - l_1))/2(1 + m + n),$ $- (1 + 2m + n)\beta P_0 + m\beta c/2(1 + m + n)$	$(1 - a)\sigma + r(l_2 - l_1) - \beta c/2$
Π_o, $(a\sigma + r(l_1 - l_2) - \beta P_0)^2/4\beta - \frac{1}{2}l_1^2$	$[(4 + 2n_1 + n_3)(a\sigma + r(l_1 - l_2))/2\beta(4 + 2n_1 + n_3), - (5 + 2n_1 + n_3)\beta P_0 + \beta c/2\beta(4 + 2n_1 + n_3),$ $[(4 + 2n_1 + n_3)(a\sigma + r(l_1 - l_2))/2(4 + 2n_1 + n_3), - (3 + 2n_1 + n_3)\beta P_0 - \beta c]/2(4 + 2n_1 + n_3) - \frac{1}{2}l_1^2$	$[(1 + m + n)(a\sigma + r(l_1 - l_2))/2\beta(1 + m + n), - (1 + n)\beta P_0 - m\beta c]/2\beta(1 + m + n),$ $[(1 + m + n)(a\sigma + r(l_1 - l_2))/2(1 + m + n),$ $- (1 + 2m + n)\beta P_0 + m\beta c]/2(1 + m + n) - \frac{1}{2}l_1^2$	$(a\sigma + r(l_1 - l_2) - \beta c)^2/4\beta - (1/2)l_1^2$
Π_r, $((1 - a)\sigma + r(l_2 - l_1) - \beta P_0)^2/4\beta - \frac{1}{2}l_2^2$	$(((4 + 2n_1 + n_3)((1 - a)\sigma + r(l_2 - l_1)))/(2\beta(4 + 2n_1 + n_3))),$ $((-(5 + 2n_1 + n_3)\beta P_0 + \beta c])/(2\beta(4 + 2n_1 + n_3))),$ $[(4 + 2n_1 + n_3)((1 - a)\sigma + r(l_2 - l_1))/2(4 + 2n_1 + n_3), - (3 + 2n_1 + n_3)\beta P_0 - \beta c/2(4 + 2n_1 + n_3) - \frac{1}{2}l_2^2$	$[(1 + m + n)((1 - a)\sigma + r(l_2 - l_1))/2\beta(1 + m + n),$ $- (1 + n)\beta P_0 - m\beta c]/2\beta(1 + m + n), [(1 + m + n)((1 - a)\sigma + r(l_2 - l_1))/2(1 + m + n),$ $[- (1 + 2m + n)\beta P_0 + m\beta c]/2(1 + m + n) - \frac{1}{2}l_2^2$	$((1 - a)\sigma + r(l_2 - l_1) - \beta c)^2/4\beta - \frac{1}{2}l_2^2$
Π_m, $(P_0 - c)(\sigma - 2\beta P_0)/2$	$(P_0 - c)((4 + 2n_1 + n_3)\sigma/2(4 + 2n_1 + n_3), -2(3 + 2n_1 + n_3)\beta P_0 - 2\beta c)/2(4 + 2n_1 + n_3)$	$(P_0 - c)((1 + m + n)\sigma/2(1 + m + n), -2(1 + 2m + n)\beta P_0 + 2m\beta c)/2(1 + m + n)$	$(P_0 - c)(\sigma - 2\beta c)/2$

Table 4: Parameter assignment.

Parameter	σ	a	P_0	c	r	β	l_1	l_2
Value	100	0.4	50	40	0.5	0.6	3	5

Table 5: Optimal decision values and profit values of four decisions.

	P_1	P_2	σ_1	σ_2	Π_o	Π_r	Π_m	Π
FNDD	57.5	74.2	4.5	15.5	29.3	362.1	200.0	591.4
NBFDD	56.7	73.4	5.0	16.0	28.9	360.9	209.4	599.2
AFDD	59.0	75.7	3.6	13.6	27.8	336.5	171.5	535.8
FNCD	52.5	69.2	7.5	18.5	14.3	342.1	260	616.4

advertising level difference of online retailers and offline stores. As the ratio of the transfer coefficient of consumers' demand to the difference in low-carbon advertising level and the price sensitivity coefficient of consumers increases, the retail prices of online retailers increase. The retail prices of offline stores are the opposite.

In four decision models, online retailers increase their retail prices to decrease their low-carbon advertising costs and obtain more profits with the increase of low-carbon advertising level difference of online retailers and offline stores. Meanwhile, the offline stores decrease their retail prices to obtain market competitiveness with the increase of low-carbon advertising level difference of online retailers and offline stores. When the transfer coefficient of consumers' demand to the difference in low-carbon advertising level is bigger than the price sensitivity coefficient of consumers, the low-carbon level mainly affects consumer decisions. When the low-carbon level of online retailers is higher than that of offline stores, consumers choose more online channels, and online retailers raise prices to reduce the loss of benefits. The retail prices of offline stores are the opposite.

Proposition 6. *The profit of the supply chain system under FNCD is more significant than that under FNDD.*

In FNCD, supply chain members work together to set the prices of products, pursue profit maximization, and create a win-win situation for the whole system. In order to maximize their profits, online retailers and offline stores increase their sales prices, leading to a decline in sales volumes in FNDD. Suppliers pursue profit maximization and increase wholesale prices, eventually leading to profits for online and offline stores and the entire supply chain system. Therefore, the profit of the supply chain system under the centralized decision-making is more significant compared with that under the decentralized decision-making.

5. Numerical Simulation

In the previous part, we used the Stackelberg game to study the pricing decisions of supply chain members under FNDD, NBFDD, AFDD, and FNCD models and analyzed the influence of low-carbon advertising level difference of online retailers and offline stores on the optimal decisions of different models. This section compares the optimal decisions and profit values under four decisions by numerical simulation. In order to better verify the above propositions, this section verifies and analyzes the above propositions through MATLAB software. The parameter distribution is shown in Table 4.

The optimal decisions and profit values under four decisions are shown in Table 5. The Nash bargaining fairness concerns coefficient of online retailers, offline stores, and suppliers in Model II is 0.8, and the horizontal and vertical fairness concerns coefficient in Model III is 0.8.

It can be seen from Table 5 that the retail prices of online retailers and offline stores under AFDD are higher than those under FNDD, and those under NBFDD are higher than those under FNCD. Proposition 3 is proven. Considering that the sales volumes of online retailers and offline stores in FNCD are higher than those in FNCD, both are higher than those in FNDD. The three are higher than the sales volumes in AFDD and Proposition 4 is proven.

In short, Nash bargaining fairness concerns behavior among supply chain members can reduce the marginal effect of the dual-channel supply chain. At the same time, online retailers and offline stores reduce retail prices to a certain extent and improve consumer satisfaction and loyalty. It will further strengthen the dual marginal utility of decentralized decision-making, improve retail prices, and reduce sales volumes in AFDD. Therefore, supply chain members should take their profits as the reference point and pay attention to the distribution fairness of their profits in supply chain system.

In addition, Table 5 shows that the profit of the supply chain system under FNCD and the sales volumes of online retailers and offline stores are the highest. This is because dual-channel supply chain members maximize the system's overall benefits as the goal under FNCD. Proposition 6 is further verified.

6. Conclusion and Managerial Insights

6.1. Conclusion. This paper discusses the influence mechanism of pricing decisions in the dual-channel supply chain under different fairness reference points and finds a possible behavior induction path. Meanwhile, this paper studies pricing strategies of dual-channel supply chain members considering different fairness reference points and consumer price sensitivity coefficient among supply chain members and analyzes the impact of changes in the fairness reference points of supply chain members on pricing strategies. Besides, this paper explores the relationship between the low-carbon advertising level difference and retail prices of online retailers and offline stores. This paper draws the following conclusions:

(1) Under four decisions, the retail prices of online retailers are positively related to low-carbon advertising level difference of online retailers and offline stores, and the retail prices of offline stores are the opposite.

(2) Supply chain members' attention to Nash bargaining fairness reduces the price of low-carbon products to a certain extent and improves the sales volumes. At the same time, the absolute fairness concerns behavior of supply chain members aggravates the marginal effect of the dual-channel supply chain. The sales volumes of online retailers and offline stores in NBFDD are higher than those in FNCD. They are all higher than the sales volumes under FNDD, and all three are higher than the sales volumes under AFDD. Retail prices are the opposite.

In this paper, we analyze the impact of different fairness preferences on supply chain pricing decisions when online and offline retailers' Nash bargaining fairness concerns coefficients are the same. The Nash bargaining fairness problem with entirely different fairness concerns of members could be considered in the dual-channel supply chain, and its impact on supply chain pricing decisions could be analyzed in the future.

6.2. Managerial Insights. In this section, some helpful management insights are generated through the numerical simulation analysis of this study.

6.2.1. Supply Chain Members' Approach to Fairness Concerns. Supply chain members should continuously deepen the concept of Nash bargaining fairness in corporate culture and create a fair system and cultural atmosphere. When choosing partners, suppliers and retail enterprises should choose enterprises with their profits as reference points, reduce retail prices, improve sales volumes, and reduce the marginal effect in the dual-channel supply chain to some extent.

6.2.2. Supply Chain Members' Approach to Improving Low-Carbon Advertising Level. Retail enterprises should increase investment in low-carbon advertising, improve quality green products for consumers, improve consumer satisfaction, improve consumer low-carbon sensitivity coefficient, and promote the sustainable development of the low-carbon industry. Online and offline retailers should organize carbon emission reduction activities to improve consumers' awareness of low-carbon environmental protection and promote the sustainable development of low-carbon products.

Appendix

A Proof of Proposition 1

Referencing the model construction of literature [31], we can obtain $\Pi_o + \Pi_r + \Pi_m = \Pi$ and $\overline{\Pi_o} + \overline{\Pi_r} + \overline{\Pi_m} = \Pi$.

According to the axiomatic definition of the Nash bargaining game solution, the Nash bargaining fairness reference points are the solution of the following Nash bargaining game model:

$$\begin{cases} \max_{\Pi, U_o^f, U_r^f} U_o^f U_r^f U_m^f \\ s.t. \Pi_o + \Pi_r + \Pi_m = \Pi \\ \overline{\Pi_o} + \overline{\Pi_r} + \overline{\Pi_m} = \Pi \\ U_o^f \geq 0, U_r^f \geq 0, U_m^f \geq 0 \end{cases} \tag{A.1}$$

Equation (A.1) can be expressed as

$$\begin{cases} \max_{\Pi, U_o^f, U_r^f} \left[(1+n_1)\Pi_o - n_1\overline{\Pi_o}\right]\left[(1+n_2)\Pi_r - n_2\overline{\Pi_r}\right]\left[(1+n_3)(\Pi - \Pi_o - \Pi_r) - n_3(\Pi - \overline{\Pi_o} - \overline{\Pi_r})\right], \\ U_o^f \geq 0, U_r^f \geq 0, U_m^f \geq 0. \end{cases} \tag{A.2}$$

For the second derivative Π_o, we can get $\partial^2 (U_o^f U_r^f U_m^f)/\partial \Pi_o^2 = -2(1+n_1)(1+n_3)[(1+n_2)\Pi_r - \overline{\Pi_r}] < 0$ and $\partial^2 (U_o^f U_r^f U_m^f)/\partial \Pi_r^2 = -2(1+n_2)(1+n_3)[(1+n_1)\Pi_o - \overline{\Pi_o}] < 0$. It is shown that Nash equilibrium bargaining has a unique optimal solution. Making $\partial (U_o^f U_r^f U_m^f)/\partial \Pi_o = 0$ and $\partial (U_o^f U_r^f U_m^f)/\partial \Pi_r = 0$, the optimal solutions of Nash equilibrium bargaining are $\Pi_o = \overline{\Pi_o}$ and $\Pi_r = \overline{\Pi_r}$. Bringing in $\partial(U_o^f U_r^f U_m^f)/\partial\Pi_o = 0$ and $\partial(U_o^f U_r^f U_m^f)/\partial\Pi_r = 0$, we can get $\overline{\Pi_o}$ and $\overline{\Pi_r}$. From $\overline{\Pi_m} = \Pi - \overline{\Pi_o} - \overline{\Pi_r}$, we can get $\overline{\Pi_m}$. That is, $\overline{\Pi_o} = 1 + n_1/3 + n_1 + n_2 + n_3\Pi$, $\overline{\Pi_r} = 1 + n_2/3 + n_1 + n_2 + n_3\Pi$, and $\overline{\Pi_m} = 1 + n_3/3 + n_1 + n_2 + n_3\Pi$.

The expected revenue functions of online retailers, offline stores, and suppliers are

$$
\begin{aligned}
U_o^f & \\
&+ \frac{1+n_1}{3+2n_1+n_3}\Big[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\Big],\\
U_r^f &= (1+n_1)\Pi_r + \frac{1+n_1}{3+2n_1+n_3}\Pi = (1+n_1)\Big[(P_2-P_0)(a\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2\Big]\\
&+ \frac{1+n_1}{3+2n_1+n_3}\Big[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\Big],\\
U_m^f &= (1+n_3)\Pi_m + \frac{1+n_3}{3+2n_1+n_3}\Pi = (1+n_3)(P_0-c)(\sigma-\beta(P_1+P_2))\\
&+ \frac{1+n_3}{3+2n_1+n_3}\Big[(P_1-P_0)(a\sigma-\beta P_1+\gamma(l_1-l_2)) - \frac{1}{2}l_1^2 + (P_2-P_0)((1-a)\sigma-\beta P_2+\gamma(l_2-l_1)) - \frac{1}{2}l_2^2 + (P_0-c)(\sigma-\beta(P_1+P_2))\Big].
\end{aligned}
\tag{A.3}
$$

B Proof of Proposition 2

For the retail prices, sales volumes, and profits of online retailers and offline stores under FNDD, through the reverse induction method, the second-order partial derivatives of Π_o^d on P_1 are first obtained and $\partial^2\Pi_o^d/\partial P_1^2 < 0$ is known, so there is a unique optimal solution on P_1. Making $\partial\Pi_o^d/\partial P_1 = 0$, we can obtain retail prices of the online retailers as

$$P_1^d = \frac{a\sigma + \beta P_0 + \gamma(l_1 - l_2)}{2\beta}. \tag{B.1}$$

The second-order partial derivatives of Π_r^d on P_2 are first obtained and $\partial^2\Pi_r^d/\partial P_2^2 < 0$ is known, so there is a unique optimal solution on P_2. Making $\partial\Pi_r^d/\partial P_2 = 0$, we can get retail prices for offline stores as

$$P_2^d = \frac{(1-a)\sigma + \beta P_0 + \gamma(l_2 - l_1)}{2\beta}. \tag{B.2}$$

Substituting P_1^d and P_2^d in equations (1) and (2), we can get online retailers and offline store sales volumes as

$$\sigma_1^d = \frac{a\sigma + \gamma(l_1 - l_2) - \beta P_0}{2}, \sigma_2^d = \frac{(1-a)\sigma + \gamma(l_2 - l_1) - \beta P_0}{2}. \tag{B.3}$$

Substituting P_1^d, P_2^d, σ_1^d, and σ_2^d in equations (3)–(5), we can get the sales volumes of online retailers and offline stores as

$$
\begin{aligned}
\Pi_o^d & \\
&= \frac{((1-a)\sigma + \gamma(l_2 - l_1) - \beta P_0)^2}{4\beta} - \frac{1}{2}l_2^2\Pi_m^d \\
&= \frac{(P_0 - c)(\sigma - 2\beta P_0)}{2}.
\end{aligned}
\tag{B.4}
$$

The proofs of Model II, Model III, Model IV, and Model I are similar, so they are omitted.

C Proof of Proposition 3

$$
\begin{aligned}
P_1^a - P_1^d & \\
&= \frac{(P_0 - c)(3 + 2n_1 + n_3)}{2(4 + 2n_1 + n_3)}.
\end{aligned}
\tag{C.1}
$$

It is easy to know that $P_1^a > P_1^d$, $P_1^d > P_1^f$, and $P_1^f > P_1^c$, so $P_1^a > P_1^d > P_1^f > P_1^c$.

The proofs of offline stores' retail prices are similar to those of online retailers, so they are omitted.

D Proof of Proposition 4

$$\sigma_1^c - \sigma_1^f = \frac{m\beta(P_0 - c)}{2(1 + m + n)}. \quad \text{(D.1)}$$

It is easy to know that $\sigma_1^c > \sigma_1^f$, $\sigma_1^f > \sigma_1^d$, and $\sigma_1^d > \sigma_1^a$, so $\sigma_1^c > \sigma_1^f > \sigma_1^d > \sigma_1^a$.

The proofs of offline stores' sales volumes are similar to those of online retailers, so they are omitted.

E Proof of Proposition 5

It is easy to know that $\partial P_1^d/\partial(l_1 - l_2) = r/2\beta > 0$ and $\partial P_2^d/\partial(l_1 - l_2) = -r/2\beta < 0$.

The proofs of Model II, Model III, and Model IV are similar to that of Model I, so they are omitted.

F Proof of Proposition 6

It is easy to know that $P_0 > c$ and $\sigma > 2\beta c$, so there is

$$\Pi^c - \Pi^d - \left(\frac{(a\sigma + \gamma(l_1 - l_2) - \beta P_0)^2}{4\beta} - \frac{1}{2}l_1^2 + \frac{((1-a)\sigma + \gamma(l_2 - l_1) - \beta P_0)^2}{4\beta} - \frac{1}{2}l_2^2 + \frac{(P_0 - c)(\sigma - 2\beta P_0)}{2}\right) = \frac{(\sigma - 2\beta c)(P_0 - c)}{2} > 0. \quad \text{(F.1)}$$

Data Availability

The data used to support the results of this study are available from the corresponding author.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

Hong Huo and Dan Luo conceived and designed the study, contributed significantly to the analysis and manuscript preparation, performed the model analyses, and wrote the manuscript. Zhanghua Yan and Hao He performed the analysis by reviewing and editing. All authors have agreed on the published version of the manuscript.

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