

Research Article

Designing Buy-Online-and-Pick-Up-in-Store (BOPS) Contract of Dual-Channel Low-Carbon Supply Chain considering Consumers' Low-Carbon Preference

Yang Zhang ¹, Jingyi Li,² and Bing Xu³

¹School of Finance, Jiangxi Normal University, Nanchang 330022, China

²School of Commerce, Jiangxi Institute of Fashion Technology, Nanchang 330201, China

³School of Management, Nanchang University, Nanchang 330031, China

Correspondence should be addressed to Yang Zhang; fuhanzhang@jxnu.edu.cn

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Nowadays, buy-online-and-pick-up-in-store (BOPS) is a popular sales project to promote product sales. Implementing BOPS in the dual-channel low-carbon supply chain (DLSC) can not only improve low-carbon manufacturers' profit but also reduce energy consumption in it. This paper focuses on how to design the contract which can ensure the implementation of BOPS in the DLSC consisting of one manufacturer and one retailer considering consumers' low-carbon preference. Based on the analysis of game theory, two kinds of BOPS contract (MW contract with the dominant manufacturer making decision on wholesale price and RW contract with the dominant retailer making decision on wholesale price) with fixed compensation are designed and compared to obtain the better contract which is more effective on the implementation of BOPS. The findings show that MW contract is better than RW contract for the DLSC to implement BOPS. When consumers' low-carbon preference and BOPS preference and the anti-cross-price elasticity are high enough, the DLSC can implement BOPS under the MW contract because it has Pareto efficiency on the profit of the original DLSC. We further find the sales price is decreasing in consumers' low-carbon preference and anti-cross-price elasticity, while the wholesale price is increasing in consumers' low-carbon preference. Finally, the results are verified by numerical examples.

1. Introduction

The Special Report on the Ocean and Cryosphere in a Changing Climate recently published by The Intergovernmental Panel on Climate Change's has brought global warming to the world's attention once again. The report claims that global warming has led to widespread shrinking of the cryosphere, with mass loss from ice sheets and glaciers, and increased permafrost temperature over the last decades [1]. The report also calls for urgent and ambitious emission reductions coupled with coordinated, sustained, and increasingly ambitious adaptation actions. Several legislations have been issued by many countries to reduce carbon emissions, such as carbon subsidy, cap-and-trade scheme, and carbon tax policy. Meanwhile, consumers gradually realize that buying low-carbon and environmental

protection products would contribute to the sustainable development of their homes. As a result, they have a preference for low-carbon products. In the US, 67% of consumers consider environmental benefit an important factor when shopping, and 51% are prepared to buy low-carbon products at a high price [2]. As a result, manufactures began to shift their focus to low-carbon products in order to obtain profits and fulfill social responsibilities. Following the introduction of central air conditioning with haze removal rate of more than 99.8% and energy-saving effect in 2015, Haier launched the maglev central air conditioning with intelligent energy-saving and smart cloud platform in 2018.

Since the rise of e-commerce, low-carbon manufacturers have sold low-carbon products not only through their online store directly but also through offline retailers who have brick-and-mortar stores, which is called dual-channel low-

carbon supply chain (DLSC). Rigby put forward the concept of “omnichannel retailing” in Harvard Business Review, that is, “retailers will be able to interact with customers through countless channels and integrate disparate channels into a single seamless omnichannel experience” [3]. To reflect this trend, many retailers have integrated their existing channels. Buy-online-and-pick-up-in-store (BOPS) is a primary type of omnichannel retailing, which allows consumers to pay for their orders online and pick up purchasing items in a near brick-and-mortar store.

Many consumers would rather purchase in the BOPS channel because BOPS allows them to reap the benefits of each channel (e.g., ability to search merchandise information online and instant pick-up) while avoiding their inherent costs (e.g., traveling costs to pick up, shipping fee, and psychological cost of waiting). Best Buy, the US-based transnational electronics retailer, announced that, for approximately 40% of its online purchases, consumers opted to pick up their purchasing items in store [4]. Furthermore, this cross-channel fulfillment strategy also helps manufacturers/retailers move store inventory fast and saves sale losses to increase their profits [5]. UNIQLO and Zara achieved breakthrough sales results by implementing BOPS on the basis of dual-channel on the Tmall Double 11 Shopping Festival in 2016, which is hosted by Alibaba Group, a famous e-commerce company in China. Retailers across different categories, such as Macy’s, The Home Depot, and Apple, have been providing the BOPS service to their customers, as a strategic business model to improve retail sales. The above observations indicate that the implementation of BOPS by DLSCs will help manufacturers and retailers to get higher profits which can increase their investment and enthusiasm in low-carbon energy conservation.

In addition, the implementation of BOPS by supply chains is also a low-carbon sales project. Compared with online purchases, BOPS can coordinate online and offline inventory and cut the operating cost of offline retailers’ inventory and additional transshipment from online manufacturers’ inventory (e.g., wastage, lighting, packaging, and transportation) [5], which would reduce energy consumption accordingly. A report surveyed by Forrester Research showed that 46% of retailers consider “to reduce store markdowns by routing online orders to stores with slow item turnover or excessive inventory risk” as the major reason to decide to invest in BOPS program, 18% consider “to lower our distribution center inventory carrying costs,” and 11% consider “to increase inventory turnover in our stores” [6]. In addition, BOPS allows consumers to pick up or return/exchange their purchasing items in store like offline shopping, thus reducing the consumer return rate which would result in carbon emissions. According to David Sobie, co-founder and CEO of Happy Returns, about 5–10 percent of in-store purchases are returned, but that rises to 15–40 percent for online purchases [7]. Above all, the implementation of BOPS by DLSCs will not only help it to higher profits but also help consumers to meet their low-carbon consumption needs and the society to cut carbon emissions. Nowadays, many low-carbon manufacturers and retailers cooperate to implement BOPS in their DLSC (e.g., GIANT,

the world’s largest bicycle brand advocating low-carbon travel, cooperates with its local retailers to implement BOPS).

However, it is interesting to observe a few low-carbon manufacturers and retailers do not cooperate to implement BOPS from the perspective of supply chain in some countries, making more room for the increase in their profits and low-carbon development level. For example, many famous low-carbon manufacturers in China (e.g., Haier and Gree, the famous low-carbon household appliances manufacturers) failed to cooperate with large brick-and-mortar retailers (e.g., Gome and Suning, the leading retailers) to implement BOPS, which allows consumers to pick up the purchases bought from manufacturers’ online flagship stores. According to Suning/Gome’s BOPS service, consumers nowadays can only pick up the purchases bought from their own online stores. In addition, Tesla, a famous low-carbon electric vehicle manufacturer, has been promoting the O2O model from last year but has not yet cooperated with local retailers to implement BOPS in China. How to overcome channel coordination problems and promote low-carbon manufacturers and retailers to cooperate to implement BOPS is a very significant theoretical and practical issue to low-carbon economy and society.

Manufacturers and retailers that do not belong to each other can ensure their close cooperation and the implementation of BOPS only by signing and abiding by the BOPS contract which needs to meet the Pareto efficiency principle, that is, to improve the profits of both manufacturers and retailers in a DLSC. We observe that Linsy Furniture gives extra remunerations to offline store salespersons who cater to online-to-offline consumers. This contract is similar to two-part tariff contract with fixed compensation. We investigate the following key questions under the DLSC consisting of one online low-carbon manufacturer and one offline retailer:

- (i) Under what conditions can the DLSC implement BOPS, that is, realize BOPS cooperation between the manufacturer and the retailer based on the Pareto efficiency principle?
- (ii) Which BOPS contract (MW contract or RW contract) based on pricing structure is more effective on the implementation of BOPS under the question (i)’s conditions?
- (iii) How consumers’ low-carbon preference can pose effect on the question (i)’s conditions?

The rest of the article is structured as follows: Section 2 reviews the related literature; Section 3 defines the DLSC model and BOPS supply chain model in which DLSC has implemented BOPS; Section 4 solves the price decision model of DLSC; Section 5 analyzes the price decision of BOPS supply chain under different contracts (MW contract and RW contract); Section 6 makes a static comparison between the two contracts and obtains the better contract; Section 7 further discusses the better contract and answers the above questions; Section 8 makes numerical experimentation to demonstrate the effectiveness of the presented

method; and Section 9 summarizes the conclusions and some future research directions.

2. Related Literature

This study is closely related to the literature on BOPS, dual-channel supply chain coordination with contracts and dual-channel low-carbon/green supply chain. We present a review below.

2.1. BOPS. The most relevant research area of this paper is BOPS. An important consequence of e-commerce development is that many retailers currently operate physical and online channels to fulfill consumers who demand a smooth transition between these channels. This omnichannel product fulfillment strategies include the options of BOPS; buy-online, ship-to-store [8]; buy-online, ship-from-store [9]; and building offline showrooms [10–13]. A review of e-fulfillment and distribution in omnichannel retailing is presented by Melacini et al. [14]. At present, BOPS has been studied in three different streams.

First, empirical data have been collected to analyze the impact of BOPS on various aspects of retailing. Gallino and Moreno [15] analyze the mechanism of BOPS influencing retail channels by using empirical interview data. Kim et al. [16] discuss the factors influencing the formation of BOPS sales mode.

The second stream of literature constructs the theoretical models to study operational decisions on BOPS and the impact of opening BOPS on a retailer where the online channel and offline channel belong to a single retailer. In this stream, some omnichannel inventory models are studied to obtain inventory decisions on BOPS. Gao and Su [5] first construct an omnichannel inventory model of retailers with online stores and physical stores and analyze the conditions for opening BOPS. Jin et al. [17] further discuss the entity Salop scope of the store when opening the online BOPS channel based on inventory models. By contrast, some scholars utilize pricing models to study the problems in this stream. Cao et al. [18] first characterize the demand allocation among the BOPS channel and construct pricing model using consumer utility theory to study the effectiveness of BOPS based on dual channel. Furthermore, by taking account of traffic congestion in offline stores, Niu et al. [19] construct pricing models to explore BOPS's introduction and its impact on traffic congestion and retailers' profit. In the above two papers, they only consider one monopoly retailer. However, in the case of introducing retailer competition, Zhang et al. [20] find that not all products are suited for the BOPS mode under a competition case. Since consumer return strategies are important marketing tool and consumers have different return performances in different channels, Shi et al. [21], Zhang et al. [22], He et al. [23], and Jin et al. [24] studies return strategies in the BOPS channel.

The third stream of literature studies operational decisions on BOPS where the online channel and the offline channel belong to different firms within a supply chain.

Fan et al. [25] design revenue sharing, service subsidy, and inventory subsidy contracts among the coordinating BOPS supply chain partners given the extra revenue generated from additional sales by BOPS customers who purchase additional products at the offline outlet. Furthermore, Jiang et al. [26] and Li et al. [27] calculate optimal pricing decisions on BOPS, respectively, considering the retailer providing service and cooperative advertising based on a BOPS supply chain. The above two literature study the impact of opening BOPS without contracts.

2.2. Dual-Channel Supply Chain Coordination with Contracts. Designing contract is an effective way to improve the operational efficiency of supply chains [28]. Literature [29, 30] proved that many effective contracts in traditional supply chains lose their function in dual-channel and multichannel supply chains. Various contracts are studied to coordinate the conflicts among channels more effectively. Two-part tariff contracts, revenue sharing contracts, cost subsidy contracts, and buy-back contracts are most commonly used to coordinate the dual-channel supply chain.

Two-part tariff contract provides a contract with the whole price and fixed fee. Based on the contract, the retailer needs to buy the manufacturer's products at the agreed wholesale price, and the manufacturer also gives the retailer a fixed fee. Chen et al. [29] illustrate how a two-part tariff contract with a complementary agreement can coordinate the dual-channel supply chain. Li et al. [31] use a simple two-part tariff contract to coordinate the dual-channel green supply chain. Revenue sharing contract refers to one member sharing its benefits (revenue) with another member. Xu et al. [32] propose the two-way revenue sharing contract to coordinate the dual-channel supply chain with risk-averse. Cai [33] shows that a revenue sharing contract and a pricing scheme can fully coordinate the dual-channel supply chain.

Cost subsidy contract refers to one member needs to subsidize/share the other member's costs or services. Wang et al. [34] show that the manufacturer and platform sharing the service cost can coordinate the dual-channel supply chain under capital constraints. Chen et al. [35] demonstrate that a subsidy contract can achieve the channel coordination in the dual-channel that consists of a telecommunication service operator and a mobile phone manufacture. With a buy-back contract, the supplier charges the retailer w per unit purchased but pays the retailer b per unit remaining at the end of the season. Ji et al. [36] illustrated that the buy-back contract can coordinate the dual-channel supply chain with false failure returns.

2.3. Dual-Channel Low-Carbon/Green Supply Chain. The growth of e-commerce enables manufacturers to sell low-carbon/green products directly on the Internet, which deeply transforms the structure, price, profit, and coordination of the low-carbon/green supply chain. As a result, DLSC has become a research hotspot. Nowadays, the DLSC consisting of one low-carbon product manufacturer and one retailer is mostly studied, and few researchers study the other structures of DLSC (e.g., two dual-channel green supply

chains [37] and three-tier dual-channel green supply chain [38]). Because the closed-loop supply chain is not relevant to the core of this paper, we do not review it. These studies can be divided in three different streams.

The first stream is to analyze the conditions for the manufacturer to open direct online channel in a focused manner. Li et al. [31] obtain that when the degree of customer loyalty to the retail channel and the greening cost satisfy certain conditions, the manufacturer does open a direct channel. Considering the influence of the low-carbon policy like cap-and-trade regulation, Ji et al. [39] further suggest that when the degree of consumers' low-carbon sensitivity satisfies certain conditions, the introduction of the online channel is profitable for the manufacturer. Xin et al. [40] further model consumers' channel preferences due to channel mismatch in the DLSC to show the conditions for dual-channel selling.

The second stream is to design various contracts to coordinate DLSC. Zhou and Ye [41] discuss how the cooperative advertising contract and the cooperative advertising and emission reduction cost sharing contract affect coordination of dual-channel supply chains. Xu et al. [42] design an improved revenue sharing contract to effectively coordinate DLSC considering cap-and-trade regulation. Wang and Sun [43] introduce the transfer payment contract to a win-win outcome for both members in DLSC. Zhang et al. [44] design and compare the revenue sharing contract and the fixed fee contract and then study the interrelationship between a platform's contract choice and a manufacturer's product quality decision.

The third stream is to analyze the factors influencing manufacturers' decision on low-carbon/green and retailers' decision on promoting products, like joint emission reduction strategy [39, 45], consumers' low-carbon/green preference [39, 46], different cap-and-trade regulations on low-carbon emission and high-carbon emission firms [46], cap-and-trade regulation [42, 47], and customers' loyalty to the retailer channel [40, 48].

2.4. Literature Summary and Our Theoretical Contribution.

The third stream of literature in BOPS is more related to our paper. But they all study the general supply chain. In addition, a common feature of literature [25, 27] is that they assume that the manufacturer and the retailer cooperate with each other to implement BOPS by default, while ignore comparison between BOPS and dual-channel supply chain which operate in the online and offline channels at the same time and how BOPS is derived from the dual-channel supply chain. Literature [26] is the most related to our paper, but it studies the impact of opening BOPS without contracts and assumes that the online and offline prices are inconsistently contrary to most examples in reality. Our study will fill the gaps in literature [25–27] and develop this stream. Different from those studies, we discuss the implementation of BOPS on the basis of DLSC rather than assuming that it exists by default; that is to say, the condition of implementing BOPS is that it should improve the profits of both the manufacturer and the retailer in original DLSC. We also assume that the

online and offline prices are consistent. In addition, two BOPS contracts are designed and compared to coordinate the DLSC and ensure successful implementation of BOPS.

The two-part tariff contract with fixed compensation that our model considers has been addressed several times before, but our research question bridges the gap regarding the incorporation of the BOPS model with these models. This paper is different from the existing DLSC papers. They lack discussion on the conditions of BOPS and BOPS contract, which is essential to realize BOPS, while our study fills these gaps. In this paper, we design two kinds of BOPS contracts with fixed compensation which is also known as two-part tariff contract in the supply chain management (MW contract with the dominant manufacturer making decision on wholesale price and RW contract with the dominant retailer making decision on wholesale price) and study which contract is more effective on the implementation of BOPS.

Above all, the main theoretical contributions of this paper are the following: (i) we extend the implementation of BOPS in the supply chain model to the DLSC model where consumers' low-carbon preference has a unique impact on the decisions; (ii) we study the conditions under which the DLSC can realize BOPS cooperation between the manufacturer and the retailer based on the Pareto efficiency principle and extend the model of literature [26] by assuming the same price in any channel; and (iii) we design the contract with fixed compensation which can ensure the implementation of BOPS in the DLSC and discuss the impact of consumers' low-carbon preference on the sales price and whole price.

3. Basic Models

3.1. Dual-Channel Low-Carbon Supply Chain Model.

Consider a DLSC consisting of one manufacturer with a direct channel and one retailer. In addition to the offline retail channel, the manufacturer sells only one kind of low-carbon product through his online channel directly. The retailer is allowed to buy the low-carbon product at wholesale price and only sells it in his brick-and-mortar store. The demand function in the online channel d_e^{dou} and offline channel d_b^{dou} is as follows: $d_e^{\text{dou}} = a_e - n_1 p_e + n_2 p_b$ and $d_b^{\text{dou}} = a_b - n_1 p_b + n_2 p_e$.

In the above formula, p_e and p_b are the sales prices of the low-carbon product in the online channel and offline channel, respectively. a_e and a_b represent the potential market demand in the online channel and offline channel, respectively. Without loss of generality, we assume $a_e = a_b = a$ in this model to simplify the analysis, such as studies [49, 50]. n_1 is the marginal channel demand per respective channel price, and n_2 is the cross-price sensitivity, which means the demand shift between the two channels with respect to the prices, whereas $n_1 > n_2$ indicates that one channel's own price effect is greater than the cross-price effect [31]. For ease of exposition and without loss of generality, we assume $n_1 = 1$ and $n_2 = 1 - n$ ($0 < n < 1$), in which n is the anti-cross-price elasticity [11]. The smaller the

value of n , the fiercer the price competition between the two channels.

Under the above assumptions, we can get the following:

$$d_e^{\text{dou}} = a - p_e + (1 - n)p_b, \quad (1)$$

$$d_b^{\text{dou}} = a - p_b + (1 - n)p_e. \quad (2)$$

In order to focus on the effect of implementing BOPS, we let the operating costs for both the manufacturer and the retailer equal to zero. In this case, the manufacturer's profit π_e^{dou} and the retailer's profit π_b^{dou} are as follows:

$$\pi_e^{\text{dou}} = (p_e + m_e)d_e^{\text{dou}} + wd_b^{\text{dou}}, \quad (3)$$

$$\pi_b^{\text{dou}} = (p_b - w + m_b)d_b^{\text{dou}}. \quad (4)$$

Among them, w denotes the wholesale price. Parameter m_e denotes the manufacturer's additional profit brought by a unit demand in the online channel, and m_b denotes the retailer's additional profit brought by a unit demand in the offline channel. We assume $m_e \leq m_b$, which can be explained as follows. Low-carbon products would be better experienced and examined by low-carbon consumers physically in brick-and-mortar stores compared with online store [18, 51], which indicates they have better perceived value in brick-and-mortar stores. Given consumers would buy more other kinds of products and help themselves trust the retailer when they have higher perceived value in stores [52, 53], and we can say that $m_e \leq m_b$.

In order to simplify the analysis, it is assumed that $m_b = m \geq 0$, and the manufacturer's additional profits from a unit demand in the online channel (that is, m_e) is standardized to 0 [5]. The higher the consumers' low-carbon preferences, the higher the consumer perceived value in stores [53], and the higher the retailer's additional profit. This means m is proportional to consumers' low-carbon preference. We assume $m \leq 2a/n$ which indicates the retailer will lose more than the additional profit they gain by deliberately pushing down prices. The problem structure of the DLSC is shown in Figure 1, which is helpful to understand the DLSC.

There is a price game between the manufacturer and retailer in the DLSC. We can assume that both manufacturer and retailer are risk-neutral and fully rational, making decisions with the goal of maximizing profits. Given the manufacturer occupies a dominant position in the market generally [51], it is assumed that the manufacturer and the retailer in the DLSC play a Stackelberg game with complete information as follows: the manufacturer makes decisions on the wholesale price w and direct selling price p_e , and then the retailer makes decisions on retail price p_b . It is shown in Figure 2. In order to avoid channel cross-selling, the direct selling price must meet the condition: $p_e \geq w$. Otherwise, the retailer would purchase products from the online channel rather than the manufacturer.

3.2. BOPS Supply Chain Model. After the manufacturer establishes the BOPS channel, some potential consumers

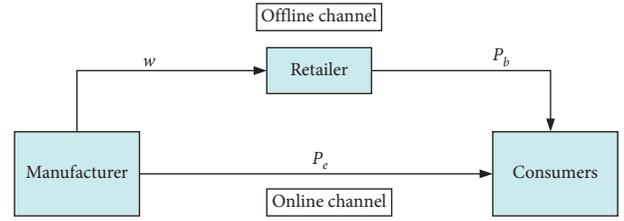


FIGURE 1: Problem structure of the DLSC.

who prefer the online channel can place orders in the manufacturer's online store and pick up the purchases in the retailer's brick-and-mortar store. In this situation, we assume that λ of potential consumers who originally prefer the online channel will transfer to the BOPS channel for purchase [26]. This λ can characterize the potential online consumers' BOPS preference. Considering that BOPS is a new channel far from perfect, consumer acceptance is lower than the traditional online channel [4]. For example, Best Buy, the US-based transnational electronics retailer, announced that, for approximately 40% of its online purchases, consumers opted to pick up their purchasing items in store [5]. According to 2019 Omnichannel Report published by Digital Commerce 360, 40% of J.C. Penney online orders are picked up in store by consumers [54]. It can be seen that nowadays, the demand in the BOPS channel accounts for less than half of the total demand for online orders, so we assume $0 \leq \lambda \leq 1/2$.

BOPS integrates the online and offline channels, but the policy of separately pricing in different channels will lead to the dilemma of channel management and coordination [5, 17]. Thus, many retailers that had implemented BOPS channel have chosen the same price strategy, such as UNIQLO and Zara. In this case, we assume that the manufacturer and the retailer adopt a unified pricing strategy, that is, $p_e = p_b = p$ [5, 17, 20]. The problem structure of the BOPS supply chain can be shown in Figure 3. From equations (1) and (2) and consumers' BOPS preference, it can be seen that the market demand functions in the online channel (d_e^{bp}), in the BOPS channel ($d_{\text{bops}}^{\text{bp}}$), and in the offline channel (d_b^{bp}) are as follows, respectively:

$$\begin{aligned} d_e^{\text{bp}} &= (1 - \lambda)a - np, \\ d_{\text{bops}}^{\text{bp}} &= \lambda a - np, \\ d_b^{\text{bp}} &= a - np. \end{aligned} \quad (5)$$

All notations used in the models are summarized in Table 1.

Among them, $i = e/\text{bops}/b$ represents the online/BOPS/offline channel, respectively, and $j = \text{dou}/\text{mw}/\text{rw}$ represents the DLSC/MW contract/RW contract model, respectively.

4. Price Decision Model of DLSC

In the DLSC, the manufacturer and the retailer play a manufacturer-led Stackelberg game with complete information. The equilibrium price p_e and p_b and wholesale price



FIGURE 2: Game sequence in the DLSC model.

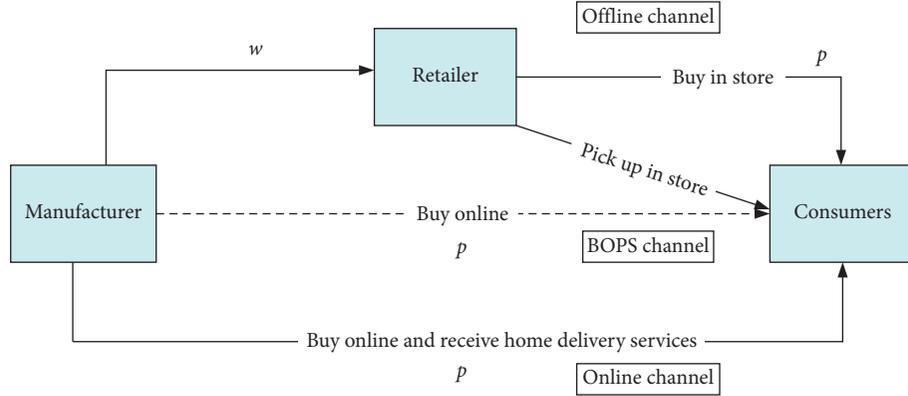


FIGURE 3: Problem structure of the BOPS supply chain.

TABLE 1: Notations of parameters and variables.

Parameters	Notations
d_i^j	Market demand in i in model j
π_e^j	Manufacturer's market profit in model j
π_r^j	Retailer's market profit in model j
p_i	Selling price of i in DLSC model
p^j	Unified selling price in model j
w^j	Wholesale price in model j
a	The potential market demand in the online (offline) channel
n	Anti-cross-price elasticity
m	Retailer's additional profit brought by a unit demand in the offline channel (be proportional to consumers' low-carbon preference)
λ	Consumers' BOPS preference
T^j	Fixed compensation given by the manufacturer to the retailer in model j

w can be solved by backward induction. Given p_e and w , the retailer's decision-making can be expressed as

$$\max_{p_b} \pi_b^{\text{dou}} = (p_b - w + m)[a - p_b + (1 - n)p_e]. \quad (6)$$

Given $(d^2 \pi_b^{\text{dou}} / d^2 p_b) = -2 < 0$, π_r^{dou} is a differentiable concave function. Then, we solve the first-order condition which is $d\pi_b^{\text{dou}} / dp_b = 0$ and get

$$p_b = 0.5(a + w - m + hp_e), \quad (7)$$

where $h = 1 - n$. Substituting equation (7) into equation (3) can obtain the profit function of the manufacturer. The solution to the following equation (8) is the optimal decision of the manufacturer:

$$\begin{cases} \max_{p_e, w} \pi_e^{\text{dou}} = (0.5h^2 - 1)p_e^2 + hwp_e - 0.5w^2 + [a + 0.5h(a - m)]p_e + 0.5(a + m)w \\ \text{s.t. } p_e \geq w \end{cases} \quad (8)$$

The sequential principal subexpression of $\begin{bmatrix} h^2 - 2 & h \\ h & -1 \end{bmatrix}$, which is the Hessian matrix of π_e^{dou} , is $h^2 - 2 < 0$ and $2(1 - h^2) > 0$, respectively. Thus, it is a negative definite matrix

and π_e^{dou} has the maximum value. Using the KKT method to solve equation (8), we can get the following proposition (the solution process is omitted due to space limitations).

Lemma 1. *The optimal online price, offline price, and wholesale price decision in the DLSC is p_e^{dou} , p_b^{dou} , and w^{dou} , and the expression is as follows:*

$$\begin{aligned} p_e^{\text{dou}} = w^{\text{dou}} &= \frac{a}{2n} + \frac{m}{2(4-n)}, \\ p_b^{\text{dou}} &= \frac{(2+n)a}{4n} - \frac{(6-n)m}{4(4-n)}. \end{aligned} \quad (9)$$

Proposition 1. *In the DLSC, (i) the optimal direct selling price is increasing in m , (ii) the wholesale price is increasing in m , and (iii) the optimal offline price is decreasing in m .*

Proposition 1 indicates that when consumers' low-carbon preference increases, the retailer will lower price in the offline channel to attract more low-carbon consumers to his brick-and-mortar store. The manufacturer, on the one hand, increases direct selling price to sacrifice online demand in order to increase offline demand and, on the other hand, increases the wholesale price to share more profits from offline demand. The higher consumers' low-carbon preference has given the manufacturer more incentives to shift online demand to offline demand by charging a higher direct selling price, to earn more profit by charging higher wholesale price.

5. Price Decision Model of BOPS Supply Chain under the MW Contract and the RW Contract

There is price and demand competition between the manufacturer and the retailer in online and offline channels. However, in order to implement BOPS, they need to cooperate with each other. For example, the retailer needs to prepare stocks and distribute purchases in time for consumers who choose the BOPS channel to shop. Therefore, a BOPS contract needs to be signed between the manufacturer and the retailer, and BOPS transactions are guaranteed in accordance with the contract. In order to reduce conflicts between channels, manufacturers often use fixed compensation contracts to promote cooperation with retailers and improve the overall revenue of the supply chain [28]. In this section, we design two kinds of fixed compensation contracts to implement BOPS and solve the price equilibrium under different contracts.

5.1. Price Decision Model of BOPS Supply Chain with the Manufacturer Deciding Wholesale Price (MW Contract Model). The first fixed compensation contract (p , w , and T) named as "MW contract" means all members should follow the decision sequence below, which is shown in Figure 4. Firstly, the manufacturer decides the wholesale price w . Then, the retailer determines the unified price p in all channels. Finally, the manufacturer gives the retailer a fixed compensation T for BOPS services according to the contract.

Because consumers always pay at online store, we can assume that the manufacturer obtains all the profits of the BOPS channel. The retailer can only buy the low-carbon

product from the manufacturer at wholesale price and sell it offline but does not bear the cost to meet the demand in the BOPS channel. Under the MW contract, the manufacturer's profit π_e^{mw} and the retailer's profit π_b^{mw} are as follows:

$$\begin{aligned} \pi_e^{\text{mw}} &= \hat{\pi}_e^{\text{mw}} - T^{\text{mw}} = p \left(d_e^{\text{bp}} + d_{\text{bops}}^{\text{bp}} \right) + w d_b^{\text{bp}} - T^{\text{mw}}, \\ \pi_b^{\text{mw}} &= \hat{\pi}_b^{\text{mw}} + T^{\text{mw}} = m d_{\text{bops}}^{\text{bp}} + (p - w + m) d_b^{\text{bp}} + T^{\text{mw}}. \end{aligned} \quad (10)$$

We use backward induction to solve the Stackelberg game between the manufacturer and the retailer. Given the manufacturer's decision on w , the retailer's decision-making can be expressed as

$$\begin{cases} \max_p & \pi_b^{\text{mw}} = (p - w + m)(a - np) + m(\lambda a - np) + T \\ \text{s.t.} & \lambda a - np > 0. \end{cases} \quad (11)$$

The constraints in equation (11) ensure that BOPS exists. Using the KKT method to solve equation (13), we get

$$p^{\text{mw}} = \begin{cases} 0, & \text{if } w < 2m - \frac{a}{n}, \\ \frac{a + nw - 2mn}{2n}, & \text{if } 2m - \frac{a}{n} \leq w < 2m - \frac{(1-2\lambda)a}{n}, \\ \left(\frac{\lambda a}{n} \right)^-, & \text{if } w \geq 2m - \frac{(1-2\lambda)a}{n}. \end{cases} \quad (12)$$

Substituting equation (12) into equation (3), the profit function of the manufacturer is obtained. The solution to the following equation (13) is the optimal decision of the manufacturer:

$$\max_w \pi_e^{\text{mw}} = p^{\text{mw}}(a - 2np^{\text{mw}}) + w(a - np^{\text{mw}}) - T. \quad (13)$$

The objective function of equation (13) is a piecewise function. After piecewise calculation and comparison, we obtain the following proposition.

Lemma 2. *Under the MW contract where the manufacturer decides the wholesale price, the optimal price and wholesale price decision (p^{mw} , w^{mw}) of BOPS supply chain is*

$$p^{\text{mw}} = \begin{cases} \left(\frac{\lambda a}{n} \right)^-, & \text{if } m \leq \frac{(2-4\lambda)a}{n}, \\ \frac{2a - mn}{4n}, & \text{if } m > \frac{(2-4\lambda)a}{n}, \end{cases} \quad (14)$$

$$w^{\text{mw}} = \begin{cases} 2m - \frac{(1-2\lambda)a}{n}, & \text{if } m \leq \frac{(2-4\lambda)a}{n}, \\ \frac{3}{2}m, & \text{if } m > \frac{(2-4\lambda)a}{n}. \end{cases} \quad (15)$$

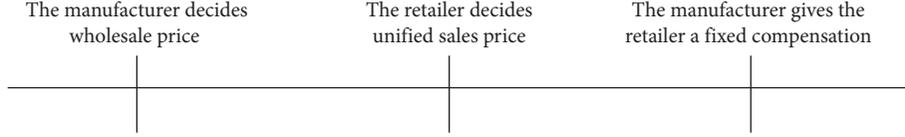


FIGURE 4: Game sequence in the MW contract model.

5.2. Price Decision Model of BOPS Supply Chain with the Retailer Deciding Wholesale Price (RW Contract Model).

In reality, some large retailers, for instance, Wal-Mart, Tesco, and Best Buy, are able to dictate the wholesale price and dominate the competition with manufacturers. Many researchers call them “dominant retailers” [55, 56]. Taking into account this scenario, we can design a contract under which the retailer decides the wholesale price. At this time, the low-carbon manufacturer follows it and should be authorized to decide the unified sales price. Otherwise, the manufacturer’s profit would be completely squeezed, and there is no motivation for him to participate in the implementation of BOPS. Thus, we design the second fixed compensation contract (p , w , and T) named as “RW contract.” It means all members should follow the decision sequence shown in Figure 5. First, the retailer decides the product wholesale price w . Then, the manufacturer determines the unified price p in all channels. Finally, the manufacturer gives the retailer a fixed compensation T for BOPS services according to the contract.

Under the RW contract, the manufacturer’s profit π_e^{rw} and the retailer’s profit π_b^{rw} are

$$\pi_e^{rw} = \hat{\pi}_e^{rw} - T^{rw} = p(d_e^{bp} + d_{bops}^{bp}) + wd_b^{bp} - T^{rw}, \quad (16)$$

$$\pi_b^{rw} = \hat{\pi}_b^{rw} + T^{rw} = md_{bops}^{bp} + (p - w + m)d_b^{bp} + T^{rw}.$$

We use backward induction to solve the Stackelberg game between the manufacturer and the retailer. Given the retailer’s decision on w , the manufacturer’s decision-making can be expressed as

$$\begin{cases} \max_p & \pi_e^{rw} = p(a - 2np) + w(a - np) - T \\ \text{s.t.} & \lambda a - np > 0 \end{cases}. \quad (17)$$

The constraints in equation (17) ensure that BOPS exists. Using the KKT method to solve equation (17), we get

$$p^{rw} = \begin{cases} \left(\frac{\lambda a}{n}\right)^-, & \text{if } w < \frac{(1-4\lambda)a}{n}, \\ \frac{a - mw}{4n}, & \text{if } \frac{(1-4\lambda)a}{n} \leq w < \frac{a}{n}, \\ 0, & \text{if } w \geq \frac{a}{n}. \end{cases} \quad (18)$$

Substituting equation (18) into equation (4), the profit function of the retailer is obtained. The solution to the following equation (19) is the optimal decision of the retailer:

$$\max_w \pi_b^{rw} = (p^{rw} - w + m)(a - np^{rw}) + m(\lambda a - np^{rw}) + T. \quad (19)$$

The objective function of equation (19) is a piecewise function. After piecewise calculation and comparison, we obtain the following proposition.

Lemma 3. Under the RW contract where the retailer decides the wholesale price, the optimal price and wholesale price decision (p^{rw} and w^{rw}) of BOPS supply chain is

$$p^{rw} = \begin{cases} \left(\frac{\lambda a}{n}\right)^-, & \text{if } m \leq \frac{(3-5\lambda)a}{n}, \\ \frac{3a - mn}{5n}, & \text{if } m > \frac{(3-5\lambda)a}{n}, \end{cases} \quad (20)$$

$$w^{rw} = \begin{cases} \frac{(1-4\lambda)a}{n}, & \text{if } m \leq \frac{(3-5\lambda)a}{n}, \\ \frac{4mn - 7a}{5n}, & \text{if } m > \frac{(3-5\lambda)a}{n}. \end{cases} \quad (21)$$

Proposition 2. Under the RW contract, when $A_{rw} \equiv mn - (3 - 5\lambda)a \leq 0$, that is, consumers’ low-carbon preference and BOPS preference are low, the demand in the BOPS channel tends to 0.

Proposition 3. Under the MW contract, when $A_{rw} \equiv mn - (3 - 5\lambda)a \leq 0$, we can get the following: (i) the demand in the BOPS channel is significantly greater than zero; (ii) the sales price p^{rw} is decreasing in m ; (iii) the wholesale price w^{rw} is increasing in m ; (iv) the sales price p^{rw} is decreasing in n ; and (v) the wholesale price w^{rw} is increasing in n .

According to equation (19), the manufacturer’s price decision depends on the wholesale price and consumers’ BOPS preference. When they are low, the manufacturer gets few profits from the increase in the demand in the offline channel (d_b^{bp}) and tend to set high price to profit from the demand in the online channel. When they are high, the manufacturer will lower the price to get more revenue from the increase in the demand in the offline channel. After anticipating the manufacturer’s decision, the retailer will determine the wholesale price based on consumers’ low-carbon preference and BOPS preference. When they are low, the retailer does not make much profit from the demand in the BOPS and offline channel and hopes that the manufacturer would set a high price to ensure its profit. Thus, the retailer only sets a low wholesale price. At this time, the demand in the BOPS channel tends to 0. When consumers’

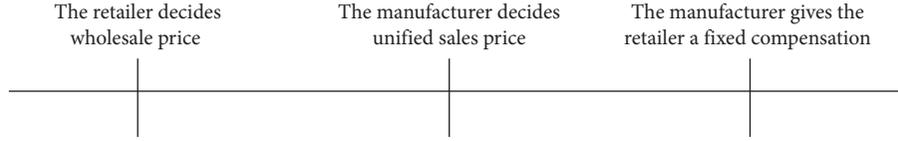


FIGURE 5: Game sequence in RW contract model.

low-carbon preference and BOPS preference are large, the retailer hopes that the manufacturer could set a low price to increase the demand in the BOPS channel and accordingly sets a high wholesale price. At this time, the demand in the BOPS channel is significantly greater than zero.

6. Comparative Static Analysis

The previous section discussed price decision of BOPS supply chain under the MW and the RW contracts. In order to further analyze the effectiveness of the two contracts, it is necessary to discuss whether they have Pareto improvement on the manufacturer's and the retailer's profit in the DLSC. From the nature of two-part tariff contract, when the total profit of the BOPS supply chain is greater than the total profit of the original DLSC, there always exists $T \in [\underline{T}, \bar{T}]$, and it satisfies that $\underline{T} = \pi_b^{\text{dou}} - \hat{\pi}_b^{\text{mw}}$ and $\bar{T} = \hat{\pi}_e^{\text{mw}} - \pi_e^{\text{dou}}$, which makes the fixed compensation contract not only realize the Pareto improvement on the total profit of the DLSC but also increase both the manufacturer's and the retailer's profit. To this end, we first compare the total profit of the BOPS supply chain under the MW contract with the RW contract to analyze which contract has the better total profit. And then, we further compare the total profit of the BOPS supply chain with the DLSC under the better contract to design a reasonable BOPS contract in the next part.

Proposition 4. *The total profit of the BOPS supply chain under the MW contract is not lower than that under the RW contract.*

Proof. According to Propositions 2 and 3, the total profit of the BOPS supply chain under the two contracts is

$$\pi^{\text{mw}} = \begin{cases} (1-\lambda)ma + (2\lambda - 3\lambda^2)\frac{a^2}{n}, & \text{if } m \leq \frac{(2-4\lambda)a}{n}, \\ \frac{5m^2n^2 + 4mna + 4a^2 + 16\lambda mna}{16n}, & \text{if } m > \frac{(2-4\lambda)a}{n}, \end{cases} \quad (22)$$

$$\pi^{\text{rw}} = \begin{cases} (1-\lambda)ma + (2\lambda - 3\lambda^2)\frac{a^2}{n}, & \text{if } m \leq \frac{(3-5\lambda)a}{n}, \\ \frac{7m^2n^2 + 3mna + 3a^2 + 25\lambda mna}{25n}, & \text{if } m > \frac{(3-5\lambda)a}{n}. \end{cases} \quad (23)$$

Comparing equation (22) with equation (23), we find that when $m \leq (2-4\lambda)a/n$, there is $\pi^{\text{mw}} = \pi^{\text{rw}}$, and when $m > (2-4\lambda)a/n$, $\pi^{\text{mw}} > \pi^{\text{rw}}$. From this, the proposition is proved.

Proposition 4 indicates that the MW contract is superior to the RW contract and reflects that the situation when the manufacturer dominates the market and can independently decide on the wholesale price makes it easier for DLSC to realize BOPS. This implication is in line with some realities like GIANT. We can analyze the reason why Proposition 4 holds and the implications as follows.

Comparing equation (14) with equation (20), when $p^{\text{mw}} \leq p^{\text{rw}}$, there is $d_{\text{bops}}^{\text{mw}} + d_b^{\text{mw}} \geq d_{\text{bops}}^{\text{rw}} + d_b^{\text{rw}}$. From the perspective of supply chain, although the sales price under the MW contract is not higher than the RW contract, the profit brought by the increase in the demand in the BOPS and offline channel that is attracted by this compensates for the profit loss from the lower price. Especially, when consumers' low-carbon preference and BOPS preference are high, the increase in the demand in the BOPS and offline channels brings more additional profits so that the total profit of the BOPS supply chain under the MW contract is higher than the RW contract.

Further comparison of equation (15) and equation (21) shows that when consumers' low-carbon preference and BOPS preference are so high that they meet $A_{\text{mw}} \leq 0$, we get $w^{\text{mw}} > w^{\text{rw}}$. It indicates when the retailer rather than the manufacturer decides the wholesale price, the manufacturer benefits less from the demand of the offline channel. Therefore, the manufacturer will have the motivation to increase the sales price to get compensation from the demand of the online and BOPS channels. As a result, the number of consumers shopping in store and the retailer's additional profit will be reduced, which will bring losses to the whole BOPS supply chain. This is also the key reason why the total profit of the BOPS supply chain under the MW contract is better than the RW contract. \square

7. Further Discussion on the Better Contract (MW Contract)

7.1. Pareto Efficiency. Given that the MW contract is better, we continue to compare the profit of the BOPS supply chain with the DLSC under the MW contract to analyze its Pareto efficiency. Because the anti-cross-price elasticity has a complex effect on the total profit of the BOPS supply chain and the DLSC, the value of n is divided into two discrete cases with low anti-cross-price elasticity ($n=0.1$) and high anti-cross-price elasticity ($n=1$) to simplify the analysis without loss of generality.

Substituting $n=0.1$ and equation (9) into $\pi^{\text{dou}} = \pi_e^{\text{dou}} + \pi_b^{\text{dou}}$, we get

$$\pi^{\text{dou}}(n=0.1) = \frac{79}{16}a^2 + \frac{155}{312}ma + \frac{6007}{24336}m^2. \quad (24)$$

Substituting $n = 0.1$ into equation (22) and comparing the outcome with equation (24), we can get Proposition 4.

Lemma 4. *Under the condition of $n = 0.1$, the total profit of the BOPS supply chain under the MW contract is lower than the total profit of the DLSC.*

Substituting $n = 1$ and equation (9) into $\pi^{\text{dou}} = \pi_e^{\text{dou}} + \pi_b^{\text{dou}}$, we get

$$\pi^{\text{dou}}(n = 1) = \frac{7}{16}a^2 + \frac{11}{24}ma + \frac{31}{144}m^2. \quad (25)$$

Substituting $n = 1$ into equation (22) and comparing the outcome with equation (25), we can get Proposition 5.

Lemma 5. *Under the condition of $n = 1$, when $\frac{31}{288} \leq \lambda \leq 1/2$ and $m > (-(36/7)\lambda + (15/14) + (3/14)\sqrt{576\lambda^2 - 240\lambda + 67})a$, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. Otherwise, the total profit of the BOPS supply chain under the MW contract is lower than the total profit of the DLSC.*

The following proposition can be drawn from Lemmas 4 and 5.

Proposition 5. *When the anti-cross-price elasticity, consumers' low-carbon preference, and BOPS preference are high enough, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. At this time, the MW contract has Pareto efficiency on the profit of the original DLSC.*

Proposition 5 indicates the conditions for the MW contract realizing Pareto improvement. When the values of n , m , and λ are all high, the profit of the manufacturer and the retailer can be both improved under a certain fixed compensation. Then, the two sides can successfully sign and realize the MW contract. Obviously, the values of m and λ represent the additional profit of the overall supply chain after the demand in the online channel is transferred to offline when the BOPS channel is implemented. When they are higher, this additional profit is higher, and it is easier for both sides to reach the MW contract. However, when the values of n , m , and λ are all low enough, the BOPS channel increases the conflict between channels, which results in lower total profit of the BOPS supply chain compared with the original DLSC.

This proposition is inconsistent with the conclusion of the literature [26] in which offering the BOPS channel is always an effective initiative to boost supply chain performance. The reason is that literature [26] assumes that the BOPS channel provides consumers with maximum flexibility and thus creates new demand while our paper does not. This assumption may hold in the long term, but our paper focuses on the short term. In addition, literature [26] assumes that the online and offline prices are inconsistent. This assumption contrary to much literature would relieve competition between different channels, which lead to a higher profit of the dual-channel supply chain.

From Proposition 5, it can be seen that whether the manufacturer and the retailer can sign the MW contract is

determined by three forces: cross-price elasticity, consumers' low-carbon preference, and BOPS preference. As consumers' buying habits gradually solidify, their low-carbon preference increases, and they gradually adapt to and prefer BOPS shopping. The MW contract with fixed compensation proposed in this study will have great practical significance.

7.2. Sensible Discussion. Through sensitivity discussion on equations (14) and (15), we can get the propositions as follows:

Proposition 6. *Under the MW contract, when $A_{mw} \equiv mn - (2 - 4\lambda)a \leq 0$, that is, consumers' low-carbon preference and BOPS preference are low, the demand in the BOPS channel tends to 0.*

Proposition 7. *Under the MW contract, when $A_{mw} \equiv mn - (2 - 4\lambda)a > 0$, we can get the following: (i) the demand in the BOPS channel is significantly greater than zero; (ii) the sales price p^{mw} is decreasing in m ; (iii) the wholesale price w^{mw} is increasing in m ; and (iv) the sales price p^{mw} is decreasing in n .*

Propositions 6 and 7 indicate that consumers' low-carbon preference and BOPS preference have a significant influence on the demand in the BOPS channel. When they are low, the retailer lowering price can only attract little potential demand in the BOPS channel, and his profit is not as good as the dual-channel profit at a higher price. But when they are high, the retailer has incentives to lower price to attract more potential demand in the BOPS and offline channels to achieve higher returns. The higher potential market demand contributes less to implement BOPS based on the DLSC.

Proposition 7 also shows sensible discussion on the sales price and the wholesale price, which indicates the relation between consumers' low-carbon preference and the retailer's/manufacturer's profit resources. The reason why (ii) and (iii) holds is that, with the increase in consumers' low-carbon preference and corresponding additional offline profit m , the retailers are more willing to set lower price to attract potential consumers in the BOPS channel to shop in his brick-and-mortar store which ensures his huge additional profit, and the manufacturer can set a higher wholesale price to profit from them. The reason why (iv) holds is that, with the decrease in anti-cross-price elasticity n , the price competition between different channels is more fiercer, and consumers' price elasticity increases, which results in higher sales price.

We can see (iv) is consistent with the conclusion of the literature [26]. In fact, (ii)-(iii) and the conclusion of the literature [26] are interlinked and can be verified by each other. They all reflect a fact that, with the higher utility consumers get from the offline and BOPS channels, the more the additional purchases they make, the lower the offline price, and the higher the online price. The wholesale price in this paper can be understood as the online price in literature [26] because they are all key factors of the manufacturer's profit. This fact indicates the retailer's/manufacturer's profit resources.

Proposition 8. Under the MW contract, when $A_{mw} \equiv mn - (2 - 4\lambda)a > 0$, the total profit of the BOPS supply chain π^{mw} (i) is increasing in m and (ii) is increasing in λ .

Proposition 8 is consistent with literature [26]. It shows sensible discussion on the total profit of the BOPS supply chain, which indicates the resource of it. The total profit of BOPS supply chain comes from the consumers with BOPS preference, who would rather transfer from the online channel to BOPS channel to pick up their purchasing, bringing additional profit to the retailer. It is easy to understand π^{mw} is increasing in consumers' low-carbon preference and BOPS preference.

7.3. How the Anti-Cross-Price Elasticity Works. Analyzing the influence of the anti-cross-price elasticity on the MW contract, we can further discover the inner mechanism of the MW contract realizing Pareto efficiency based on the DLSC. We simply calculate and obtain the following proposition.

Proposition 9. $\partial p_e^{dou}/\partial n < 0, \partial p_d^{dou}/\partial n < 0; \partial d_e^{dou}/\partial n > 0, \partial d_b^{dou}/\partial n < 0; \partial w^{dou}/\partial n < 0; \partial p^{mw}/\partial n < 0, \partial (d_{bops}^{mw} + d_b^{mw})/\partial n > 0$.

This proposition is consistent with the conclusion of the literature [26]. In the DLSC, $\partial p_e^{dou}/\partial n < 0$ and $\partial p_d^{dou}/\partial n < 0$ indicate that when the anti-cross-price elasticity is larger, the customer loyalty is higher, and the ability of the channel to attract consumers from another channel decreases. Therefore, both sides of the DLSC must lower price to make small profits but quick turnover. Because the manufacturer has a first-mover advantage, in the case of $\partial w^{dou}/\partial n < 0$, the manufacturer would increase the demand in the online channel as much as possible but decrease the demand in the offline channel, which can also be seen from $\partial d_e^{dou}/\partial n > 0$ and $\partial d_b^{dou}/\partial n < 0$. Given the additional profit brought by the demand in the offline channel, the decreasing demand in it will reduce the overall profit of the DLSC. The MW contract reduces the first-mover advantage of the manufacturer and promotes cooperation between the manufacturer and the retailer. The demand in the BOPS channel and offline channel increases as the value of n increases. When consumers' low-carbon preference (parameter m) is large, the total profit of the BOPS supply chain under the MW contract will be greater than the DLSC.

8. Numerical Experimentation

In order to demonstrate the validity and conditions of the MW contract more intuitively and to verify the reliability of the propositions, we conduct the analysis of numerical experimentation. We can assume that the potential demand (parameter a) is 100.

8.1. Case 1: Fixed $\lambda = 0.4$ and $n = 0.95$. We use Matlab 2016 to carry out simulation calculations to obtain the total profit of the DLSC, the BOPS supply chain under the MW contract and RW contract (parameter m), and the upper and lower

limits of the value of the fixed compensation T under the MW contract with the change in consumers' low-carbon preference (Figure 6).

Figure 6 shows that the total profit of the BOPS supply chain under the MW contract is not less than RW contract. When parameter m rises to about 80, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. When it rises to about 220, the total profit of the BOPS supply chain under the RW contract is higher than the total profit of the DLSC. These results validate Propositions 6 and 7.

It also shows that there are upper and lower limits for the fixed compensation T under the MW contract. When parameter m is less than 80, the manufacturer and the retailer in the DLSC cannot realize the MW contract. When parameter m is higher than 80, the range of fixed compensation T in the MW contract becomes wider, which is conducive to realizing the contract.

8.2. Case 2: Fixed $m = 200$ and $n = 0.95$. We use Matlab 2016 to carry out simulation calculations to obtain the total profit of the DLSC, the BOPS supply chain under the MW contract and RW contract, and the upper and lower limits of the value of the fixed compensation T under the MW contract with the change in consumers' BOPS preference (parameter λ) (Figure 7).

Figure 7 also shows that the total profit of the BOPS supply chain under the MW contract is not less than RW contract. When parameter λ rises to about 0.15, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. When it rises to about 0.42, the total profit of the BOPS supply chain under the RW contract is higher than the total profit of the DLSC.

In addition, Figure 7 shows that when parameter λ is less than 0.15, the manufacturer and the retailer in the DLSC cannot realize the MW contract. When parameter λ is higher than 0.15, the range of fixed compensation T in the MW contract becomes wider, which is conducive to realizing the contract.

8.3. Case 3: Fixed $m = 200$ and $\lambda = 0.4$. We use Matlab 2016 to carry out simulation calculations to obtain the total profit of the DLSC, the BOPS supply chain under the MW contract and RW contract, and the upper and lower limits of the value of the fixed compensation T under the MW contract with the change in anti-cross-price elasticity (parameter n) (Figure 8).

Figure 8 also shows that the total profit of the BOPS supply chain under the MW contract is not less than RW contract. When parameter n rises to about 0.68, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. When it rises to about 0.96, the total profit of the BOPS supply chain under the RW contract is higher than the total profit of the DLSC.

In addition, Figure 8 shows that when parameter n is less than 0.68, the manufacturer and the retailer in the DLSC cannot realize the MW contract. When parameter n is higher than 0.68, the range of fixed compensation T in the MW

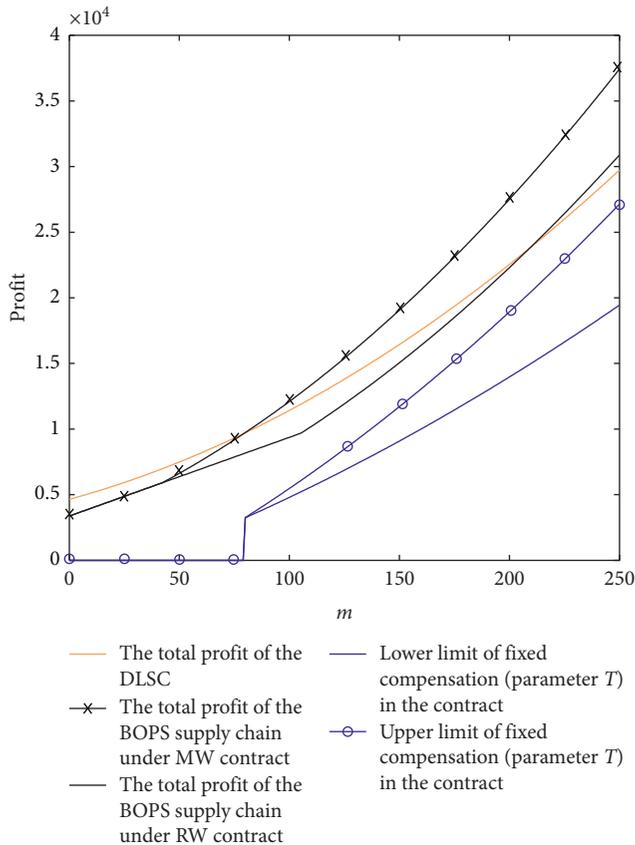


FIGURE 6: The total profit of the DLSC and the BOPS supply chain under the MW and RW contracts and the upper and lower limits of the fixed compensation with the change in consumers' low-carbon preference.

contract becomes wider, which is conducive to realizing the contract.

9. Conclusions

The threat of global warming forces our business world to concentrate on the low-carbon products. Nowadays, buy-online-and-pick-up-in-store (BOPS) is a popular sales strategy to promote product sales and retailers' profit. Implementing BOPS in the dual-channel low-carbon supply chain (DLSC) can not only improve both low-carbon manufacturers' and retailers' profit which can increase their investment and enthusiasm in low-carbon energy conservation but also reduce energy consumption in the DLSC by coordinating online and offline inventory and allowing consumers to pick up or return their purchasing items in store by the way. In this paper, we study how the DLSC consisting of one manufacturer and one retailer can realize BOPS cooperation to implement it with Pareto efficiency considering consumers' low-carbon preference. Two kinds of BOPS contract (MW contract and RW contract) based on pricing structure with fixed compensation are designed to answer the above question. The sales price, wholesale price, and total profit of BOPS supply chain under the two contracts are calculated. By comparing the total profit of the

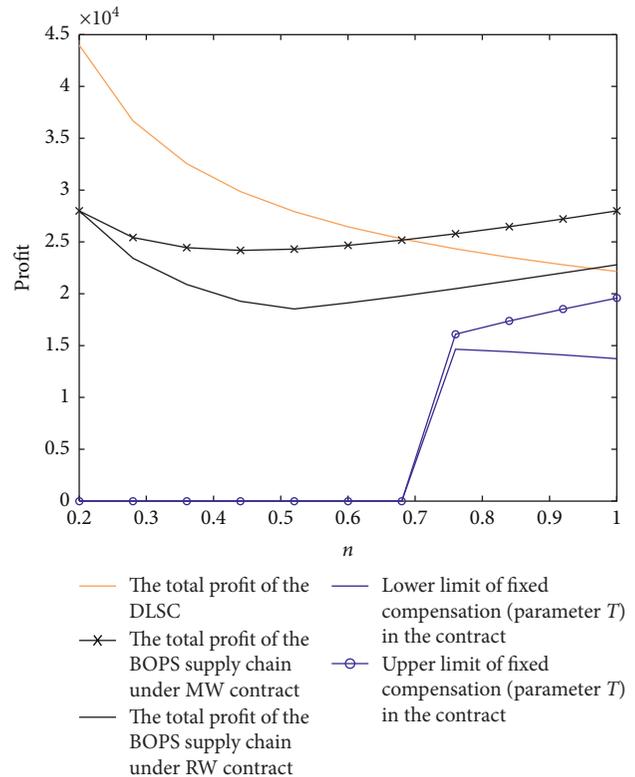


FIGURE 7: The total profit of the DLSC, the BOPS supply chain under the MW and RW contracts, and the upper and lower limits of the fixed compensation with the change in consumers' BOPS preference.

BOPS supply chain under the two contracts, we find that the better contract is MW contract. Furthermore, by comparing the total profit of the BOPS supply chain with the DLSC, we obtain the conditions for the implementation of BOPS cooperation. The findings in this paper can accordingly be summarized as follows:

- (1) In the DLSC, the optimal direct selling price and wholesale price rise, and the optimal offline price declines as consumers' low-carbon preference increases. This reflects the effect of consumer's low-carbon preference on the sales price in different channels in the DLSC. The increase in consumers' low-carbon preference makes their in-store consumption bring more additional profits to the retailer. Thus, the low-carbon manufacturer is willing to increase not only the wholesale price to get more profit from the retailer's additional profits but also the direct selling price to avoid channel cross-selling. The higher the consumer's low-carbon preference, the less competitive the direct online channel, and the less the demand.
- (2) In the BOPS supply chain under the MW and RW contracts, when consumers' low-carbon preference and BOPS preference are high enough, the demand in the BOPS channel is significantly greater than zero, the sales price decreases, and the wholesale price increases as consumers' low-carbon preference

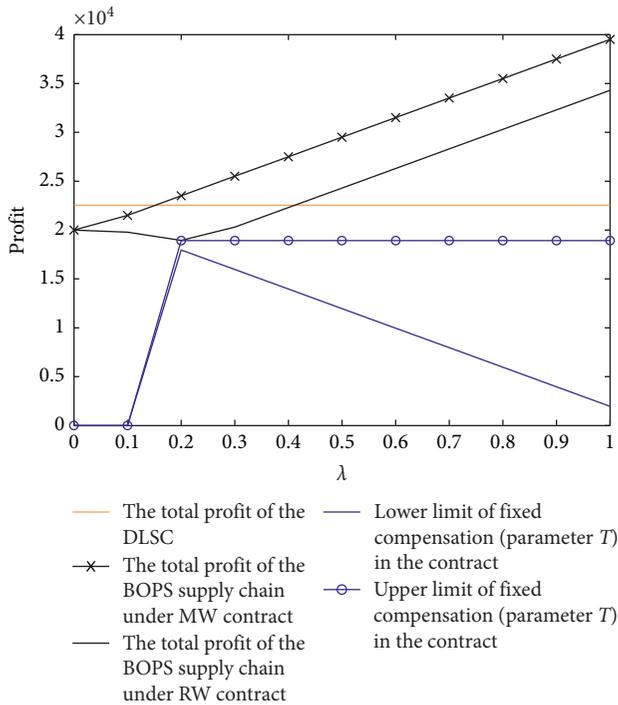


FIGURE 8: The total profit of the DVLSC, the BOPS supply chain under the MW and RW contracts, and the upper and lower limits of the fixed compensation with the change in anti-cross-price elasticity.

increases. This reflects the effect of consumer’s low-carbon preference on the sales price and the wholesale price in the BOPS supply chain.

- (3) The total profit of BOPS supply chain under MW contract is not lower than under RW contract, which indicates MW contract is better than RW contract for the manufacturer and the retailer in the DLSC to realize cooperation with BOPS. This reflects the effect of pricing structure on the total profit of BOPS supply chain. When the retailer rather than the manufacturer decides the wholesale price, the manufacturer benefits less from the demand of the offline channel. Therefore, the manufacturer will have the motivation to increase the sales price to get compensation from the demand of the online and BOPS channels. As a result, the number of consumers shopping in store and the retailer’s additional profit will be reduced, which will bring losses to the whole BOPS supply chain. This is also the key reason why the total profit of the BOPS supply chain under the MW contract is better than the RW contract.
- (4) When consumers’ low-carbon preference and BOPS preference and the anti-cross-price elasticity are high enough, the total profit of the BOPS supply chain under the MW contract is higher than the total profit of the DLSC. At this time, the manufacturer and the retailer in the DLSC can realize cooperation with BOPS under the MW contract because it has Pareto efficiency on the profit of the original DLSC. This

reflects the conditions under which the DLSC can implement BOPS based on the Pareto efficiency principle. The unified sales price necessary to implement BOPS limits the pricing space for the manufacturer and the retailer, which indicates it would reduce the total profit of the supply chain. However, implementing BOPS can transfer the demand from the online channel to the BOPS channel, which can improve the retailer’s additional profit, thus improving the total profit of the supply chain. When consumers’ low-carbon preference and BOPS preference are high enough, it can make up for the loss of the total profit of the supply chain caused by unified pricing. The above analysis tells us that the supply chain should be committed to improve the consumers’ low-carbon preference and BOPS preference and the anti-cross-price elasticity to implement BOPS and obtain more profits. The other revelation is that, with the growing popularity of low carbon and BOPS, it is more and more feasible to realize BOPS cooperation in the DLSC through the MW contract. This can further reduce the energy consumption of the supply chain, encourage the manufacturer to invest in research and development on low-carbon products, and form a benign low-carbon cycle system.

This paper has the following problems that can be further studied. The first is that this paper only considers the situation that the potential consumers who prefer to buy online transfer to shop in the BOPS channel. In reality, there are also a small number of potential consumers who prefer to buy offline transfer to shop in the BOPS channel. Second, the implementation of BOPS may stimulate more potential consumers, increase new demand, and expand the total scale of demand that we did not study. Third, we can further study the contract between one manufacturer and multiple retailers to implement BOPS. These studies will get more interesting conclusions and provide reference for the operation of the BOPS supply chain.

Data Availability

The numerical experiment in this paper is mainly based on the inferred conclusion in this paper. The data used to support the findings of this paper are included within the paper. If readers need related data, they can contact the authors.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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