

ONLINE PROMOTION FORMAT SELECTION FOR A SUPPLY CHAIN WITH ENVIRONMENT RESPONSIBILITY IN AN UNCERTAIN MARKET

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Abstract. Corporate environmental responsibility has received considerable attention. In our study, we consider a supply chain in which a manufacturer invests in green technology to decrease the carbon footprint. The main issue addressed here is how the manufacturer selects the optimal online selling format between agency selling and reselling to ensure profitability with a lower carbon footprint. In an uncertain market with considering different pricing sequences in dual-channel promotion, we explore six scenarios. The results show that the different pricing sequences will not affect the equilibrium green degree and pricing strategies under agency selling, whereas it may result in an improved greenness in reselling format. Furthermore, under the interaction of uncertain demand, pricing sequence and green technology investment, we reveal the agent selling format is not always superior to the reselling format with a double-marginalization effect, which contrary to the general intuition. Specifically, in an optimistic market, the manufacturer is more profitable in reselling format when the promotion price set in online channel prior to traditional channel, and in a pessimistic market, the opposite pricing sequence formulated will bring a considerable benefit to the manufacturer.

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1. INTRODUCTION

In recent years, the increase of carbon dioxide emissions and the enhancement of greenhouse effect have led to serious damage to the ecological environment [47, 69]. According to the latest report released by the International Energy Agency (IEA), global carbon emissions plummeted after the outbreak of COVID-19, and there are strong signs of rebound at present. Follow the recovery of countries after the epidemic, it is estimated that global carbon emissions will rise further this year and next, and reach an all-time high by 2023. To effectively control and reduce carbon emissions, enterprises' green management has attracted more and more attention in practice and theory. In practice, enterprises undertake the responsibility of reducing carbon emissions. Theoretically, the past decades have witnessed a booming green supply chain, which not only pays attention to the economic objectives of enterprises, but also maintains the environmental benefits [39, 42, 45, 74, 78].

Keywords. Green supply chain, Online promotion, Pricing sequence, Environmental responsibility, Uncertain market.

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For the enterprise, there are various ways to realize carbon emission reduction, such as invest in green manufacturing technology, standard the green design or adopting green manufacturing materials [66,79]. For example, the brand of LiNing applies coffee carbon technology to create the most environmentally friendly sportswear. Furthermore, the proportion of materials used by H&M from recycled or other sustainable sources has reached 57%. Although more industries gradually invest in low-carbon manufacturing to improve the green attribute of products, and therefore facilitate the potential market demand, the issue of product surplus is still serious, which makes the enterprise face a great challenges, even bear the pressure of capital loss, especially for seasonal and fashionable products. To alleviate the backlog of a large number of inventories, the enterprise introduces the online promotion channel (*e.g.*, Vipshop and TaoBao) with a discount price based on the traditional offline channel. With the advent of the “Internet+” era, people are more and more inclined to online consumption.

According to the 43rd statistical report on China’s Internet development released by China Internet Network Information Center (CNNIC), the number of online shopping users in China has reached 600 million as of December 2018, an increase of 14.4% over the end of 2017, accounting for 73.3% of the total Internet users. Facing such a huge user scale, more and more enterprises choose to introduce online selling format by entering the e-commerce platform to serve more consumers. There are mainly two online selling formats for the enterprise to promote products, namely reselling format and agency selling format [1, 13, 51, 72]. For the reselling format, such as the JingDong self operated platform, the e-tailer wholesales the product from the manufacturer firstly. Then, he sets the retail price by maximizing the profit and finally sells the product to online consumers. However, this format is always with a double-marginalization effect. In the agency selling format, the e-commerce platform mainly plays the role of market intermediary, and it allows enterprises selling product to online consumers directly by charging a certain proportion of commission fees. In essence, this agency selling format gives enterprises the direct pricing right to better meet market demand [41, 58, 62, 73]. With the application of agency selling and reselling formats, it is essential for enterprises to know the driving motivation behind the selection of promotion format.

The selection of online promotion formats can be affected by pricing sequence between the traditional and the online channels. Generally, enterprises will set the pricing sequence in three ways, namely deciding the retail price in the traditional channel prior to, simultaneously with and after the online channel, respectively. Under each pricing sequence, the equilibrium online selling format selected by the enterprise is differentiated, which can accordingly affect the formulation of green degree and pricing decisions. From the research results of previous scholars, in the reselling format with a double-marginalization effect, the green degree of product is usually low, and the retail prices are often high, which will lead to the reduction of demand eventually. Thus compared with the agency selling format, the settlement costs of enterprises are higher under reselling format. However, when we considering the external interference factors such as the market uncertainty, the pricing sequence and the corporate environmental responsibility, counter intuitive effects may occur. Since there are more enterprises develop dual-channel to promote end of season products online, the research on the pricing sequence in dual channel needs the high attention of scholars.

In addition, the supply chain composed by enterprises is a typical open system, which will be continuously disturbed by the outside factors, and make the characteristics of the system more complex. The uncertainty of demand is the most important one among the many interference factors in the supply chain [10, 34, 40, 46, 50]. Specially, when the demand in market is optimistic, the sales volume of products is enough in season, thus the product surplus will decrease in the end of season. Otherwise, enterprises will promote more end of season products due to the excessive product surplus. From the previous studies, its not clear that how enterprises choose equilibrium online promotion channel in an uncertain market to better fulfill their environmental responsibilities and achieve profitability. In this paper, we explore the effects of uncertain demand and pricing sequence on the equilibrium decision-making of manufacturer in the supply chain with environmental responsibility. Furthermore, we provide a guidance for the manufacturer to select the optimal online promotion format to compliance with environmental responsibility. Based on the above discussion, our work mainly discusses the following problems:

- (1) In an uncertain market, how should a manufacturer with environmental responsibility formulate the optimal pricing sequence between the traditional channel and online channel?
- (2) In an uncertain market with different pricing sequences, how a manufacturer selects the optimal online promotion format between the agency selling and reselling? and what is the differences for the equilibrium green degree and retail price strategies under each selling format?
- (3) Whether the agency selling format always better than the reselling format in promoting the fulfillment of environmental responsibility, demand and profit of supply chain?
- (4) Whether the equilibrium results of manufacturer conform to the optimal profit of e-tailer?

To answer the above problems, this paper explore a two-echelon supply chain composed of a monopoly manufacturer with environmental responsibility and committed to the production of green product. In this supply chain system, the manufacturer sells in two periods due to the seasonality and fashion of the product. In the first period (in season), the manufacturer sells the green product to offline consumers at an upward price only through a traditional channel. In the second period (end of season), the manufacturer introduces online channel on the basis of traditional channel, and sells the green products to online and offline consumers at a downward price. There are two mainly online promotion formats for the manufacturer, namely the agency selling format and reselling format. Moreover, in the second period, the manufacturer can decides different promotion pricing sequences in the dual-channel, such as setting the discount price in traditional channel prior to, simultaneously with and after online channel. Considering the above factors, based on the game theory, we use the Stackelberg game model to establish six different game models to study the decision-making of supply chain in two periods. By comparing the results, we obtain that the pricing sequence between traditional channel and online channel will not have any effect on the equilibrium strategies under agency selling. However, it has a significant impacts on the manufacturer's environmental responsibility fulfillment and profit under the reselling format. Interestingly, by considering the interaction of environmental responsibility, uncertain market and pricing sequence in dual-channel, we find that the product greenness and the optimal profit of manufacturer in agency selling are not always higher than it in reselling format.

This paper contributes to the literature in three respects. Firstly, we consider the demand uncertainty and the pricing sequence in dual-channel to analyze the online promotion formats selection of the supply chain with environmental responsibility. Secondly, we establish theoretical models consistent with the enterprise in reality who promotes the end of season green products by agent selling or reselling in an uncertain market. Finally, we provide some related management insights for the manufacturer to promote the end of season products.

This paper is organized as follows. Section 2 provides a review of related literature. Section 3 describes the model, and presents the benchmark scenario. Sections 4 and 5 analyze the promotion pricing sequence in agency selling and reselling formats. Section 6 compares the equilibrium online promotional formats and describes some sensitivity analyses. Section 7 expands the models by changing the main assumptions in our research. Section 8 summarizes our findings and concludes this study by providing some directions for future research. All proofs are relegated to Appendix A and Appendix B.

2. LITERATURE REVIEW

2.1. Online marketing strategy of enterprise under environmental responsibility

Our research complements the literature flow on how a supply chain selects the optimal online promotion format with environmental responsibility. Previous scholars have made a lot of studies on green operation of supply chain [8, 18, 24, 32, 36, 38, 49, 57, 61, 63, 75], for example, [59] investigated the effect of different selling structures on supply chain's green investment level. Compared with an manufacturer without green investment, [43] declared that green investment can improve the supply chain's profit as well as promote the potential demand. Next, [69] explored the pricing and green investment decisions of supply chain under the online and offline sales simultaneously. For the online sales channel, with the vigorous development of e-commerce, how to select the optimal online sales format for the enterprise in a supply chain has aroused the interest of scholars.

Previous research results show that the elasticity of service demand, commission fee and order fulfillment cost would have an impact on the choice of enterprise online selling format [53,54,56]. Abhishek *et al.* [1] discussed the online selling strategies from the perspective of e-commerce platform. They found that the demand in online channel relative to traditional channel can affect the decisions of enterprise. Hagi and Wright [30] studied whether the e-commerce platform provider should introduce consignment format on the basis of existing retail mode. The results showed that the marketing information has an impact on the enterprise's online selling format selection. Furthermore, [9] analyzed the effect of online-to-store channel on the demand distribution and profit level of multi-channel retailers. They claimed that the introduction of "online-to-store" channel can stimulate the competitiveness of retailers and the customer loyalty. Yan *et al.* [64] considered the spillover effect of e-commerce platforms from online sales to offline sales. Unlike the above studies, few scholars discuss the operation strategies of enterprises under the background of uncertain market. Fan *et al.* [17] explored whether the two-echelon supply chain chooses to introduce online sales channel under uncertain demand. In addition, [65] investigated the strategic introduction of online channel in the form of agency selling under the condition that manufacturers faced uncertain market. Zhen *et al.* [76] proposed a green and sustainable supply chain network model under an immediate demand with CO₂ emissions and total operating costs as targets.

Throughout the above literature, although the existing research on green technology investment and sales mode selection has been very extensive, few relevant scholars consider the impact of uncertain demand and endogenous pricing on the online selling format selection of supply chain, especially considering the environmental responsibility at the same time. However, in reality, under the pressure of environmental protection and the fierce competition of e-commerce environment, due to the increasing diversification of consumer demand and the differentiation of consumer purchase channels, it is difficult for the manufacturer to obtain the demand information, thus the increase of demand uncertainty will lead to the difficulty to make optimal decisions for the enterprises in supply chain. In the face of fierce competition and potential risks brought by uncertain demand, manufacturers tend to be more cautious in decision-making. In such a context, different from [9,17,30,64,65,76], our research is more complex and practical. This study is related to the reality that an enterprise sells her green products in two periods and through dual-channel to promote the surplus products in the end of season. Compared with the existing research, we consider the green investment of supply chain to alleviate the environmental pressure. Moreover, we explore the impacts of uncertain demand and pricing sequence in dual-channel on the manufacturer's choice of online selling format. Interestingly, the interaction between green investment, uncertain demand and endogenous pricing timing will generate higher greenness and demand in the reselling format compared to the agency selling, this result is contrary to the most existing research [11,20,24,29,33].

2.2. Theoretical game in supply chain decision

Next, we discuss the literature related to our research on theoretical game. These literature study the implementation of endogenous strategies among these game participants. In a decentralized supply chain, each interest subject aims to maximize its own profit. At this time, for the supply chain system, it is important to formulate optimal pricing sequence between the game players, because different pricing sequences will bring different benefits to the supply chain. Gal-Or [22] proposed that in a non-cooperative game, for two players with the same order, the first (second) mobile player obtains higher returns than the second (first) mobile player. Because this advantage stems from the order of decision-making among players, many game participants now realize that the order of action should be determined internally by the game subject and end with the decision of the game players [16,19,21,31]. In recent studies, [43] explored the endogenous pricing strategy in a dual-channel supply chain by establishing a delay game model. He found that the manufacturer should make price decisions prior to or simultaneously with the retailer, rather than after the retailer. Furthermore, [14] discussed how enterprises choose the optimal online sales strategy between consignment and reselling modes with endogenous pricing. In their research, the enterprise sells products through two periods, and at the end of the season, the enterprise introduces online sales format on the basis of traditional channel to promote the product. Their results show that the equilibrium decisions under the agency selling format will not be affected by the pricing sequence between the

online and traditional channels. However, there are obvious differences in the optimal retail price and demand strategies under the reselling format.

Although the above literature discusses issues related to endogenous pricing, especially the study by [14], which is also most related to our study. However, compared to the above studies, the difference in our research is that we considering the green investment of manufacturer, and by establishing a game model in which the manufacturer promotes her end-of-season green product through dual-channel in the end of season, this paper explores how the manufacturer chooses the equilibrium online selling format when facing an uncertain market and different pricing sequences. The research results show that endogenous pricing will not affect the optimal greenness and price strategies of supply chain under the agency selling format. But in the reselling format, we obtain that the manufacturer should set the discounted price for traditional channel prior to or after the online selling, rather than set the price simultaneously. Under these two pricing sequences, the product greenness in the reselling format with double-marginalization effect is always higher than it in the agency selling, which can bring more potential demand for the supply chain.

In the end of season, enterprises are accustomed to using price discounts to deal with the surplus product. This phenomenon is particularly obvious in fashion industries with strong seasonality and short storage time. There is also a wealth of literature on enterprises promotion, such as [37] described the retailer's optimal promotion pricing strategy based on the multiplicative demand model and assuming that the promotion effort occurs after the demand is realized. Srinivasan *et al.* [52] used empirical methods to study the impact of promotion strategies on supply chain operation, and pointed out that the profit of retailer are usually reduced due to the price discount. Then, [3] considered the random cashing rate of coupons on the basis of the single cycle newsboy model, and studied the pricing of sellers and the formulation rules of coupon discount. Aydin and Porteus [5] compared and analyzed the supply chain performance in the scenario of manufacturers and retailers providing discount promotions, respectively. The study found that in general, the discount promotions provided by manufacturers will be better than those provided by retailers. Wang *et al.* [55] discussed the joint promotion problem under the mixed demand model of addition and multiplication, and established the sufficient conditions for the existence of the optimal solution. Yang *et al.* [68] compared and analyzed how retailers maximize profits by jointly optimizing order quantity and discount under the two promotion situations of discount promotion and daily low price. Jian *et al.* [35] not only considered the promotion pricing of enterprises, but also incorporated product quality, return guarantee service and risk aversion into the supply chain system according to different business realities, and explored the impact of promotion on enterprise decision-making by establishing a game model. In our research, we establish the relevant game models with considering the endogenous pricing the randomness of demand, and in the end of season, the manufacturer sells her green products at a discount price through traditional and online channels. The focus of this paper, as well as that of most of the related studies, is presented in Table 1.

3. MODEL PRELIMINARIES

Here, we provided the model setup by describing the major online selling formats and the game sequence in Section 3.1. In addition, we establish the benchmark scenario in Section 3.2 without considering the online selling.

3.1. Model setup

Considering a two-echelon supply chain in which a monopolistic manufacturer (denoted as “M”, she) is committed to producing green product and sells it over two periods: period 1 (in season) and period 2 (end of season). In the first period, the manufacturer sells the in season green product to consumers at a premium price through traditional channel. More realistic, we assume the total production is which is large enough, thus in the end of season, the manufacturer usually has a leftover (*i.e.*, surplus product), and the unit loss cost for the manufacturer to process the surplus product is to reduce this loss, in the second period, the manufacturer introduces online selling formats based on the traditional channel to promote the leftover. The Online selling

TABLE 1. Comparison of previous models with the current study.

Authors	Green investment	Agency selling	Reselling	Single-channel	Dual-channel	One-period	Two-period	Uncertain demand	Game theory
Abhishek <i>et al.</i> [1]		✓	✓	✓		✓			
Cao <i>et al.</i> [9]					✓	✓			✓
Chen <i>et al.</i> [14]		✓	✓		✓		✓	✓	✓
Fan <i>et al.</i> [17]				✓		✓			✓
Hagiu and Wright [30]		✓	✓	✓		✓			✓
Jian <i>et al.</i> [35]	✓			✓		✓			✓
Madani and Rasti-Barzoki [43]	✓			✓		✓			✓
Wang <i>et al.</i> [55]				✓		✓		✓	
Wang <i>et al.</i> [59]				✓		✓			
Yan <i>et al.</i> [64]					✓	✓			✓
Yang <i>et al.</i> [68]					✓	✓			✓
Yang <i>et al.</i> [70]				✓		✓			✓
Zhen <i>et al.</i> [76]	✓			✓					
This paper	✓	✓	✓		✓		✓	✓	✓

is achieved by an e-commerce platform dominated by the e-tailer (denoted as “E”, he), and the discount prices set for the end of season product in online and traditional channels are and , respectively.

Online Promotion. There are mainly two selling formats for the manufacturer to cooperate an e-tailer to sell products on the e-commerce platform: reselling (R) and agency selling (A). For the reselling format, the e-commerce platform wholesales products from the manufacturer at price, and then earns profits by selling self operated products on the platform. In this situation, the platform plays the role of a retailer, such as JingDong self operated and Amazon.com. For the agency selling format, it allows the manufacturer to sell products directly on the platform, and obtains profits by charging a fixed proportion to the manufacturer. At this time, the e-commerce platform plays the role of electronic intermediary, such as Taobao and eBay. Compared with the reselling format, the agency selling gives the manufacturer a power to directly control the retail price, but the platform cost involved is also very high. For example, the profit sharing rate in Vipshop and Taobao is nearly 30%, which reflects the long-term decision-making of an enterprise and related to the actual application of industry standard [1, 9, 14, 41, 53, 56, 62, 72]. Moreover, in the model extension, we study the scenario when the proportion of profit sharing is an endogenous variable. Section 7.1 verifies the equilibrium results still remain qualitatively valid. Figure 1 shows the green product sales structure in the supply chain.

Promotion Pricing Sequences in Dual Channel. When both the traditional and online channels promote the end of season product, the manufacturer is faced with the issue of pricing sequence in the online and offline channels, because different pricing sequences will have an effect on the profit of the supply chain. Generally, the manufacturer can set the promotion price in traditional channel prior to, simultaneously with and after the online channel, which is a long term decision in terms of cooperation between the manufacturer and the e-tailer in a supply chain and super-scripts indicate the above three promotion pricing sequences, respectively. A few previous studies also considered the pricing sequences in dual-channel sales, such as [31] and [44].

Market Uncertainty. Based on previous scholars’ research on strategic consumer behavior (see *e.g.*, [2, 14, 15, 60]), we assume the demand function in our research is linear and shows a downward sloping with an uncertain intercept. Specifically, the demand curve is given by

$$A := \begin{cases} a - \tau, & \text{the probability } y \text{ is } \beta, \\ a + \tau, & \text{the probability } y \text{ is } 1 - \beta, \end{cases}$$

where a is the basic market demand, and τ ($0 \leq \tau < 1$, and the expression of threshold ϑ is shown in Appendix A) reflects the degree of demand uncertainty. Due to the complexity of models, we normalized the value of a to one.

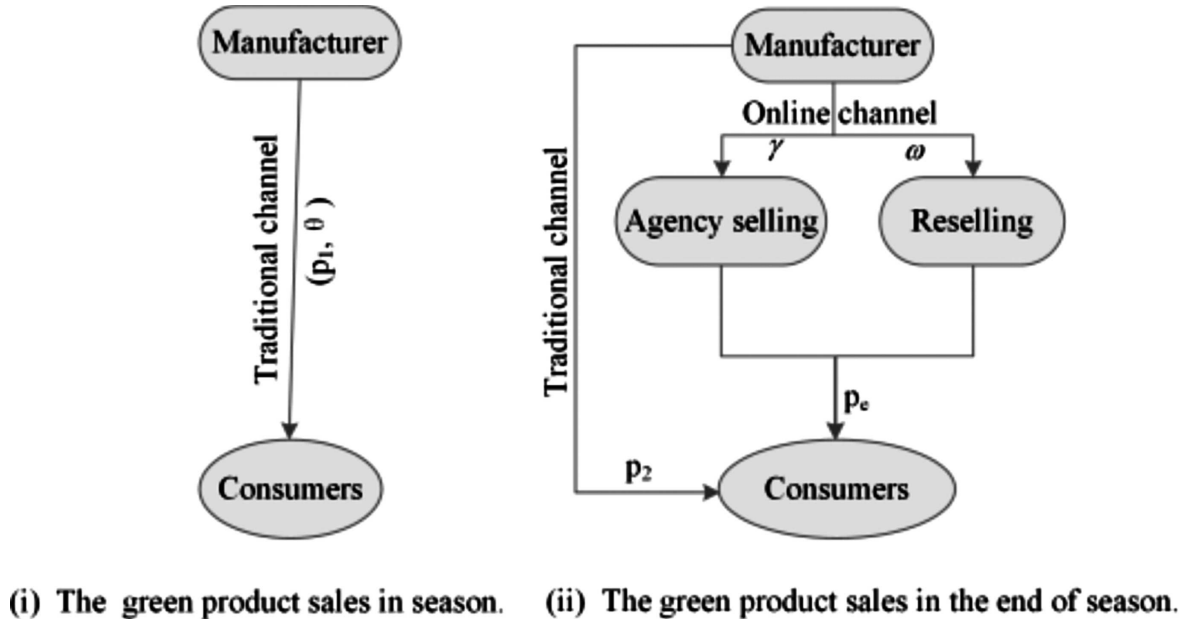


FIGURE 1. Green product sales structure in the supply chain.

The intercept A is random and can take one of two values: a high value $a+\tau$ with probability $1-\beta$ ($0 \leq \beta \leq 1$) and a low value $a-\tau$ ($< a+\tau$) with probability β . The average market demand intercept is $A = \beta(a-\tau) + (1-\beta)(a+\tau)$. Moreover, when $0 \leq \beta \leq 0.5$, it implies the probability that the market tends to possess a high demand, which we call the optimistic market. Otherwise, when $0.5 < \beta \leq 1$, it means the probability that the market tends to possess a low demand, which we call the pessimistic market. In the above two types of markets, customer types v are uniformly distributed on the unit interval $[0, A]$. Although the distribution of customer types is common knowledge, however, the manufacturer does not know the type of any particular customer, thus perfect price discrimination is not feasible. In each period, the total market size allocation to demand depends on the manufacturer's pricing strategies.

Consumer Buying Options. The dynamic pricing of manufacturer provides an opportunity for strategic consumers who can decide whether and when to buy the green product to maximize the utilities. In this paper, we propose that consumers have three options: (i) buying the in season product through traditional channels in the first period; (ii) purchasing the end of season product through traditional channel in the second period; and (iii) buying the end-of-season product through online channel in the second period. The valuation (willingness to pay) of consumers gradually decreased over time, that is to say under the equal conditions, consumers prefer to buy product sooner rather than later. Specifically, the value of the product will decrease by in the second period. Thus, indicates perishability of the product value for consumers and measures the customer impatience. In our research, describes the degree of customer patience and a higher indicates that consumers are more patient to wait for promotion in the second period [14, 25, 72]. In summary, under the corresponding options, the respective utility functions of consumers are

$$U_1 = v - p_1 + \theta, \quad U = \sigma v - p_2 + \theta, \quad U_e = \sigma \alpha v - p_e + \theta, \quad (3.1)$$

where is the green degree of the product, and represents the weight of consumers willing to buy the green product in online channel compared to traditional channel. It is worth noting that $0 < \alpha < 1$ (the expression of threshold is shown in Appendix A). In our main models, we assume that consumers have a low willingness to

pay for online channel, which is usually in line with consumer behavior in reality, because when consumers select to purchase products through online channel, they cannot feel and touch the real product, this will result in a higher mismatch rate with actual product. Such assumptions also exist in a other literature studied on dual-channel sales (see *e.g.*, [4, 5, 36, 48, 64, 67, 77]). Next, in Section 7.2, we expand the assumptions that consumers prefer online shopping to traditional channel. The results show that the change of will not have a qualitative impact on the main insights in this paper. Moreover, in the main models, we only introduced online promotion channel in the second period, which is more conducive to the processing and observation of the model. Similar model settings exist in previous literature, such as [71].

Demand Functions. The consumers appear at time zero, and they will leave the market after buying a unit of product. In the first period, consumers are faced with the choice of buying in season product or waiting for buying end of season product in the second period. Without losing generality, we assume that when the utility obtained by consumers in the first period is higher than the expected utility in the second period, they will choose to buy the in season product. Otherwise, they will buy the promotional product in the second period. The manufacturer's demand in the first period is $D_1 = A - v_1$, where $v_1 = \frac{p_1 - \hat{p}_2}{1 - \delta}$ represents the consumer who is indifferent in buying in season product through traditional channel between the first period and second period. $\hat{p}_2$ is the expected price of consumer for the second period after seeing the pricing in the first period. In addition, the manufacturer's demands through traditional channel and online channel in the second period are $D_2 = v_1 - v_2$ and $D_e = v_2 - v_s$, respectively, where $v_2 = \frac{p_2 - p_e}{\delta(1 - \alpha)}$ represents the consumer who is indifferent in buying end of season product between the traditional channel and the online channel, and $v_s = \frac{p_e - \theta}{\delta\alpha}$ describes the consumer who is indifferent between buying end of season product though online channel and not buying any product.

π_H and π_E represent the profit of the manufacturer and the e-tailer, A, R superscripts indicate the agent selling and reselling formats, and 1, 2 subscripts indicate the first and the second periods, respectively. Therefore, the manufacturer's expect profit functions in the first and the second periods under agent selling format are as defined follows:

$$\pi_{M1}^\lambda = E \left[p_1 D_1 + \pi_{M2}^\lambda - \frac{\theta^2}{2} \right], \quad (3.2)$$

$$\pi_{M2}^i = p_2 D_2 + (1 - \lambda) p_e D_e - c(Q - \hat{D}_1 - D_2 - D_e), \quad (3.3)$$

where $\hat{D}_1$ is the realized demand in the first period. In equation (3.3), $p_2 D_2, (1 - \lambda) p_e D_e$ represent the profit of manufacturer obtained from the traditional channel and the online channel in the second period, respectively. $c(Q - \hat{D}_1 - D_2 - D_e)$ describes the cost of manufacturer to deal with the end of season product. Accordingly, the profit function of e-tailer is expressed as:

$$\pi_E^A = p_e D_e. \quad (3.4)$$

Alternatively, under the reselling format, the profit functions of manufacturer in the first and the second periods are as defined follows:

$$\pi_{M1}^R = E \left[p_1 D_1 + \pi_{M/2}^R - \frac{\theta^2}{2} \right], \quad (3.5)$$

$$\pi_{M/2}^R = p_2 D_2 + w D_e - c(Q - \hat{D}_1 - D_2 - D_e). \quad (3.6)$$

Correspondingly, the profit function of e-tailer is expressed as:

$$\pi_E^R = (p_e - w) D_e. \quad (3.7)$$

		Manufacturer strategies	
		Agent selling	Reselling
Promotional sequence	Prior to the e-tailer	Scenario AP	Scenario RP
	Simultaneously with the e-tailer	Scenario AS	Scenario RS
	After the e-tailer	Scenario AL	Scenario RL

FIGURE 2. Six strategic combinations of the supply chain.

Main Scenarios. According to the above discussion, the end-of-season product can be sold by agency selling format or reselling format in the online channel. So, in this research, we study the problem with six scenarios. The first three consider that the manufacturer sells the end of season product through agency selling in the second period, and consider the pricing sequence that the discount price is set in traditional channel can prior to (AP), simultaneously with (AS) and after (AL) the online channel. The other three scenarios are the promotion price is decided in traditional channel prior to (RP), simultaneously with (RS) and after (RL) the online channel through reselling format. Figure 2 illustrates these scenarios more intuitively.

Sequence of Events. In the first period, the manufacturer selects the online cooperation format between agency selling and reselling firstly, and then decides the pricing sequence of traditional channel relative to online channel. After this, the manufacturer formulates the optimal product greenness and premium price for the in-season product. Finally, consumers decide whether to buy or wait. In the second period, based on different online promotion formats and pricing sequences in dual-channel, there exist six possible scenarios: (i) In scenario AP, the manufacturer sets the discount price for the traditional channel prior to the online channel. (ii) In scenario AS, the manufacturer sets the discount price for the traditional channel simultaneously with the online channel. (iii) In scenario AL, the manufacturer sets the discount price for the traditional channel after the online channel. (iv) In scenario RP, the manufacturer first decides the discount price in the traditional channel, and then determines the wholesale price. Lastly, the e-tailer decides the discount price in the online channel. (v) In scenario RS, the manufacturer first decides the wholesale price, and then sets the discount price in the traditional channel simultaneously with the e-tailer in online channel. (vi) In scenario RL, the manufacturer first sets the wholesale price, and then the e-tailer decides the discount price for online channel. Finally, the manufacturer formulates the discount price for the traditional channel. The sequence of events is summarized in Figure 3. Furthermore, the notations used in this study are shown as follows (Table A.1):

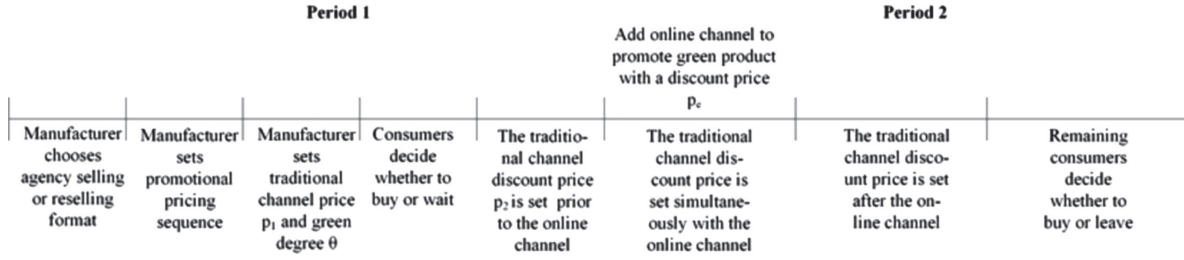


FIGURE 3. Sequence of events.

3.2. Benchmark scenario

In this section, we begin by studying the benchmark scenario (Scenario B) without considering online promotion in the second period. Under this circumstance, the manufacturer sales the end of season product only through traditional channel. The sequence of determination is as follows: (i) In the first period, the manufacturer sets the premium price and the green degree of products in traditional channel, and then the first period demand is realized. (ii) In the second period, the manufacturer formulates the discount price for traditional channel, and then the second period demand is achieved. The backward induction procedure is applied to solve this problem.

In the second period, the manufacturer sets the discount price for end of season products in traditional channel to maximize her profit:

$$\text{Max}_m \pi_{M/2}^s = p_2 D_2 - c(Q - \hat{D}_1 - D_2), \quad (3.8)$$

where $\hat{D}_1 = \hat{A} - \Delta$ and $D_2 = \Delta - \frac{p_2 - \theta}{\delta}$ are the realized demands in the first and second periods, respectively. $\hat{A}$ denotes the realized value of A . Δ represents the customer's marginal value who is indifferent between purchasing green product in the first period and the second period. Then, the manufacturer's optimal discount price in traditional channel can be calculated as follows:

$$p_2^s = \frac{\Delta\delta - c + \theta}{2}. \quad (3.9)$$

In the first period, the strategic consumers predict the second period price $\hat{p}_2^s$ after seeing the pricing of the manufacturer in the first period. When the consumers with valuations higher than Δ , they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. Consumers' marginal value Δ satisfies $\Delta - p_1 + \theta = \delta\Delta - \hat{p}_2^s + \theta$, or equivalently, $\Delta = \frac{p_1 - \hat{p}_2^s}{1 - \delta}$. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^s = p_2^s$. Under this condition, the manufacturer sets the optimal premium price and the product greenness to seek the maximization of two periods profit. The decision of manufacturer in first period is expressed as:

$$\max_{(A \rightarrow 1)} \pi_{M1}^s = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^s(p_2^s) \right], \quad (3.10)$$

where the demand $D_1 = A - \frac{p_1 - p_2^s}{1 - \delta}$.

Based on the above analysis, we can calculate the optimal green degree, the premium and discount prices are as follows:

$$\begin{aligned} \theta^* &= \frac{c + (1 + (1 - 2\beta)\tau)\delta}{2\delta - 1}, \quad p_1^* = \frac{(1 + (1 - 2\beta)\tau)(6\delta^2 - \delta^3 - 8\delta + 2) + c(7\delta - 3\delta^2 - 4)}{(2\delta - 1)(3\delta - 4)} \quad \text{and} \\ p_2^{g*} &= \frac{(1 + (1 - 2\beta)\tau)(\delta^3 - \delta^2 - \delta) + c(7\delta - 3\delta^2 - 4)}{(2\delta - 1)(3\delta - 4)}. \end{aligned} \quad (3.11)$$

TABLE 2. Optimal solutions and second-order conditions for scenarios AP, AS and AL.

Solutions	Scenarios AP, AS,AL
p_{F1}^*	$\frac{\phi_3 - (\delta\alpha\alpha^3((\gamma^2 + 2(1-\gamma))^2\delta^2 + (22\gamma^3 + 50\gamma - 4\gamma^4 - 48\gamma^2 - 22)\delta + (\gamma-2)^2(3\gamma^2 - 8\gamma + 6)) + \phi_1)\phi_2}{2(\delta\alpha^2(\gamma-2)^2 + 4\alpha\delta(\gamma-1) + 2(1-\alpha)(\gamma-1)^2)((1-\alpha)(1-\gamma)(4-3\delta) - (1-\delta)\alpha\gamma^2)}$
θ^*	$\frac{(\gamma-1)(\alpha\delta(2\tau\beta - \tau - 1)(\gamma-2)(1-\alpha) + 2c) + c\alpha(\gamma^2 - 2\gamma + 2)}{\delta\alpha^2(\gamma-2)^2 + 4\alpha\delta(\gamma-1) + 2(1-\alpha)(\gamma-1)^2}$
p_{F2}^*	$\frac{(\alpha-1)((1-\delta)(2-\gamma)(\theta^{AT*}(\gamma-1) + c) - 2p_{F1}^{AA*}\delta(1-\gamma))}{(\delta-1)\alpha\gamma^2 + 2(\delta-2)(\alpha-1)(1-\gamma)}$
p_E^*	$\frac{(1-\alpha)((2-\gamma)\alpha\Phi_{F1}^{AT*} + (\theta^{AT*}(\gamma-1) + c)(\delta(\alpha+1) - 2))}{(\delta-1)\alpha\gamma^2 + 2(\delta-2)(\alpha-1)(1-\gamma)}$
Condition 1	$4 - 4\gamma - \alpha(\gamma - 2)^2 > 0$
Condition 2	$2((4 - 3\delta)(1 - \gamma)(1 - \alpha) + \alpha(\delta - 1)\gamma^2)(2(1 - \gamma)^2(1 - \alpha) - 4\alpha\delta(1 - \gamma) + \delta(\gamma - 2)^2\alpha^2) < 0$

Note: $\phi_1 = (4(\gamma^2 + 2(1-\gamma))\delta^3 + (2\gamma^3 - 24\gamma^2 + 52\gamma - 42)\delta^2 + (16\gamma^2 - 48\gamma + 40)\delta + 2(1-\gamma)(\gamma-2)^2)\alpha^2(\gamma-1) + (4\delta^3 + 2(\gamma-9)\delta^2 + (8+8\gamma-2\gamma^2)\delta + 2\gamma^2 + 16(1-\gamma))(1-\gamma)^2\alpha - 2(1-\gamma)^3(\delta-2)^2$, $\phi_2 = 1 + \tau - 2\beta\tau$, and $\phi_3 = 2(\gamma-2)((\delta-1)\alpha\gamma^2 + (4-3\delta)(1-\gamma)(1-\alpha))c(\alpha-1)(\alpha\delta + \gamma - 1)$.

From the above equilibrium results, it is worth noting that if the market is optimistic (*i.e.*, $0 \leq \beta \leq \frac{1}{2}$), the product greenness, the premium and the discount prices will increase when the market uncertainty rises, however, it will show a downward trend in a pessimistic market (*i.e.*, $\frac{1}{2} < \beta \leq 1$). The reason behind this is that high demand uncertainty enables the manufacturer to improve green degree of the product to attract more consumers, accordingly, the manufacturer will set a higher price to benefit from the margin increment. In contrast, the pessimistic market with a high demand uncertainty means the manufacturer is inevitably induced to reduce the price to maintain the basic demand.

4. PROMOTION PRICING SEQUENCE IN AGENCY SELLING FORMAT

This section obtains the equilibrium strategies for the supply chain under three different scenarios, namely Scenarios AP, AS and AL. According to the backward induction procedure, first, we get the optimal discount prices in the second period, which the first period premium price and green degree as constants. Second, we analyze the equilibrium strategies in the first period, and calculate the optimal premium price and the product greenness based on the total of two periods profit. Third, back substitution is applied to obtain the optimal discount prices. Lastly, we get the equilibrium decisions of the supply chain under three different pricing sequence in dual-channel with agent selling format. The solutions as shown in Table 2.

4.1. Scenario AP

In the scenario of AP, the manufacturer determines the discount price in traditional channel prior to the online channel with agency selling. In the second period, the manufacturer sets the discount prices and based on the following optimization problem:

$$\begin{cases} \max_{p_2} \pi_{M/2}^{AP} = p_2 D_2 + (1-\gamma)p_\theta D_\theta - c(Q - \hat{D}_1 - D_2 - D_\theta) \\ \text{s.t.} \\ p_\theta^{iP} = \operatorname{argmax}_{\theta\theta} p_2 D_2 + (1-\gamma)p_\theta D_\theta - c(Q - \hat{D}_1 - D_2 - D_\theta), \end{cases} \quad (4.1)$$

where the constraint means that the manufacturer will select the online channel discount price to maximize the second period profit. The demands $\hat{D}_1, D_2$ and D_θ are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1-\alpha)}$ and

$D_\theta = \frac{p_2 - p_e}{\delta(1-\alpha)} - \frac{p_\theta - \theta}{\delta\alpha}$, respectively. Thus the discount prices can be calculated as follows:

$$\begin{aligned} p_2^{\alpha\beta} &= \frac{(1-\alpha)(2\Delta\delta(\gamma-1) + \theta\gamma(3-\gamma) + c(2-\gamma) - 2\theta)}{(\gamma-2)^2 + 4\gamma - 4} \quad \text{and} \\ p_e^{\alpha P} &= \frac{(1-\alpha)(\Delta\alpha\delta(\gamma-2) + 2\theta(\gamma-1) + 2c)}{(\gamma-2)^2 + 4\gamma - 4}. \end{aligned} \quad (4.2)$$

Accordingly, the objective function of e-tailer is formulated as:

$$\pi_E^{\text{AP}} = p_e D_\theta. \quad (4.3)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{ip}$ and $\hat{p}_e^{\alpha P}$. Similar to Scenario B, when consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{ip}}{1-\delta}$, they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{\alpha P} = p_2^{4P}$ and $\hat{p}_e^{\text{AP}} = p_e^{\text{AP}}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods, and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(p, \theta)} \pi_{M1}^{\text{AP}} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{\text{AP}}(p_2^{\text{AP}}, p_e^{\text{AP}}) \right], \quad (4.4)$$

where the demand $D_1 = A - \frac{p_1 - p_2^{\text{AP}}}{1-\delta}$.

4.2. Scenario AS

Under the AS scenario, the manufacturer determines her discount price in traditional channel simultaneously with the online channel. Under this circumstance, in the second period, the manufacturer sets the discount prices p_e and p_2 based on the following optimization problem:

$$\max_{(p_2, \theta)} \pi_{M2}^{\text{AS}} = p_2 D_2 + (1-\gamma)p_e D_e - c(Q - \hat{D}_1 - D_2 - D_e), \quad (4.5)$$

where the demands $\hat{D}_1$, D_2 and D_e are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1-\alpha)}$ and $D_e = \frac{p_2 - p_e}{\delta(1-\alpha)} - \frac{p_e - \theta}{\delta\alpha}$, respectively. Thus the discount prices can be calculated as follows:

$$\begin{aligned} p_2^{\text{AS}} &= \frac{(1-\alpha)(2\Delta\delta(\gamma-1) + \theta\gamma(3-\gamma) + c(2-\gamma) - 2\theta)}{(\gamma-2)^2 + 4\gamma - 4} \quad \text{and} \\ p_e^{\text{AS}} &= \frac{(1-\alpha)(\Delta\alpha\delta(\gamma-2) + 2\theta(\gamma-1) + 2c)}{(\gamma-2)^2 + 4\gamma - 4}. \end{aligned} \quad (4.6)$$

Accordingly, the objective function of e-tailer is formulated as:

$$\pi_E^{\text{AS}} = p_e D_e. \quad (4.7)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{*s}$ and $\hat{p}_e^{ss}$. Similar to Scenario AP, when consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{*s}}{1-\delta}$, they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{4s} = p_2^{4s}$ and $\hat{p}_e^{us} = p_e^{as}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods, and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(\beta, \theta)} \pi_{M1}^{ks} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{ks}(p_2^{ks}, p_e^{ks}) \right], \quad (4.8)$$

where the demand $D_1 = A - \frac{p_1 - p_2^{4s}}{1-\delta}$.

4.3. Scenario AL

Under the AL scenario, the manufacturer determines her discount price in traditional channel after the online channel. Under this circumstance, in the second period, the manufacturer sets the discount prices p_c and p_2 based on the following optimization problem:

$$\begin{cases} \max_{P_e} \pi_{M/2}^{at} = p_2 D_2 + (1 - \gamma) p_c D_c - c(Q - \hat{D}_1 - D_2 - D_e) \\ \text{s.t.} \\ p_2^{at} = \arg \max_{R_e} p_2 D_2 + (1 - \gamma) p_c D_e - c(Q - \hat{D}_1 - D_2 - D_e), \end{cases} \quad (4.9)$$

where the constraint means that the manufacturer will select the traditional channel discount price to maximize the second period profit. The demands $\hat{D}_1, D_2$ and D_e are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1 - \alpha)}$ and $D_e = \frac{p_2 - p_e}{\delta(1 - \alpha)} - \frac{p_e - \theta}{\delta\alpha}$, respectively. Thus the discount prices can be calculated as follows:

$$\begin{aligned} p_2^{AL} &= \frac{(1 - \alpha)(2\Delta\delta(\gamma - 1) + \theta\gamma(3 - \gamma) + c(2 - \gamma) - 2\theta)}{(\gamma - 2)^2 + 4\gamma - 4} \quad \text{and} \\ p_e^{AL} &= \frac{(1 - \alpha)(\Delta\alpha\delta(\gamma - 2) + 2\theta(\gamma - 1) + 2c)}{(\gamma - 2)^2 + 4\gamma - 4}. \end{aligned} \quad (4.10)$$

Accordingly, the objective function of e-tailer is formulated as:

$$\pi_E^{AL} = p_e D_e. \quad (4.11)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{AL}$ and $\hat{p}_e^{AL}$. Similar to the former scenarios, when consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{AL}}{1 - \delta}$, they will buy the in-season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{AL} = p_2^{AL}$ and $\hat{p}_e^{AL} = p_e^{AL}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods, and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(p, \theta)} \pi_{M1}^{AL} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{AL}(p_e^{AL}, p_2^{AL}) \right], \quad (4.12)$$

where the demand $D_{F1} = A - \frac{p_{F1} - p_{F2}^{AL}}{1 - \delta}$.

In summary, following the backward induction procedure, this section obtains the solutions of the above three scenarios and the second order conditions as shown in Table 2. From the solutions, we can see that the manufacturer will implement the same green degree, premium and discount prices strategies among Scenarios AP, AS and AL. By substituting these equilibrium solutions to each period profit functions of the manufacturer, we can conclude the impact of different pricing sequences on the profit of manufacturer, as shown in Proposition 1.

Proposition 1. *The manufacturer's promotion pricing sequences between traditional channel and online channel with agency selling format in the second period have no effect on her profit.*

From Proposition 1, we can find that the different pricing sequences in dual-channel will not have any impact on the performance of supply chain under agency selling. The reason for the above phenomenon may be lies in that when the supply chain adopts the agency selling format, the manufacturer can promote the end of season product to consumers through the e-commerce platform, and then formulates the retail price directly. In this situation, both the discount prices in traditional channel and online channel are decided by the manufacturer, thus the pricing sequences will not have a substantive effect on the manufacturer's decisions, even for the profit. From the above analyze, we can obtain that the supply chain system does not have to distinguish the channel pricing sequences over cautiousness.

5. PROMOTION PRICING SEQUENCE IN RESELLING FORMAT

This section obtains the equilibrium green degree and price strategies for the manufacturer and the e-tailer under three different promotion pricing sequences, namely Scenarios RP, RS and RL. According to the backward induction procedure, first, we get the optimal wholesale and discount prices in the second period, which the premium price and green degree in the first period as constants. Second, we analyze the equilibrium strategies in the first period, calculating the optimal premium price and the green degree based on the total of two periods profit. Third, back substitution is applied to obtain the optimal wholesale and discount prices. Lastly, we get the equilibrium decisions of the manufacturer and the e-tailer under the overall promotion sequences with reselling format. The solutions as shown in Table 3.

5.1. Scenario RP

Under the RP scenario, the manufacturer with reselling format determines the discount price prior to the e-tailer in the second period. Under this circumstance, the manufacturer and the e-tailer make their decisions based on the following optimization problem:

$$\begin{cases} \max_{p_2} \pi_{M2}^{RP} = p_2 D_2 + w D_e - c(Q - \hat{D}_1 - D_2 - D_e) \\ \max_w \pi_{M2}^{RP} = p_2 D_2 + w D_e - c(Q - \hat{D}_1 - D_2 - D_e) \\ \text{s.t.} \\ p_e^{RP} = \arg \max_{p_e} (p_e - w) D_e, \end{cases} \quad (5.1)$$

where the first and second constraints mean that the manufacturer will select a wholesale price, and the e-tailer will set a discount price in the online channel to maximize the second period profit, respectively. The demands $\hat{D}_1, D_2$ and D_e are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1-\alpha)}$ and $D_e = \frac{p_2 - p_e}{\delta(1-\alpha)} - \frac{p_e - \theta}{\delta\alpha}$, respectively. Thus the discount and wholesale price decisions of manufacturer, and the discount price strategy of e-tailer can be calculated as follows:

$$p_2^{RP} = \frac{\Delta\delta - c + \theta}{2}, \quad w^{RP} = \frac{\alpha\Delta\delta - c + \theta}{2}, \quad \text{and} \quad p_e^{RP} = \frac{(2\Delta\delta - c - \theta)\alpha - c + 3\theta}{4}. \quad (5.2)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{RP}$ and $\hat{p}_e^{RP}$. Consumers' marginal value Δ satisfies $\Delta - p_1 + \theta = \delta\Delta - \hat{p}_2^{RP} + \theta$, or equivalently, $\Delta = \frac{p_1 - \hat{p}_2^{RP}}{1-\delta}$. When consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{RP}}{1-\delta}$, they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{RP} = p_2^{RP}$ and $\hat{p}_e^{RP} = p_e^{RP}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(\rho_1, \theta)} \pi_{M1}^{RP} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{RP}(p_2^{RP}, w^{RP}, p_e^{RP}) \right], \quad (5.3)$$

where the demand $D_1 = A - \frac{p_1 - p_2^{RP}}{1-\delta}$.

5.2. Scenario RS

Under the RS scenario, the manufacturer with reselling format determines the discount price simultaneously with the e-tailer in the second period. Under this circumstance, the manufacturer and the e-tailer make their

decisions based on the following optimization problem:

$$\begin{cases} \max_{\sigma} \pi_{M2}^{RS} = p_2 D_2 + w D_c - c(Q - \hat{D}_1 - D_2 - D_c) \\ \quad \text{s.t.} \\ p_2^{RS} = \arg \max_{p_2} p_2 D_2 + w D_c - c(Q - \hat{D}_1 - D_2 - D_c) \\ p_c^{RS} = \arg \max_{p_c} (p_c - w) D_c, \end{cases} \quad (5.4)$$

where the first and second constraints mean that the manufacturer will select a discount price for the traditional channel, and the e-tailer will set a discount price for the online channel to maximize their own profit, respectively. The demands $\hat{D}_1, D_2$ and D_c are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1-\alpha)}$ and $D_e = \frac{p_2 - p_e}{\delta(1-\alpha)} - \frac{p_e - \theta}{\delta\alpha}$, respectively. Thus the discount and wholesale price decisions of manufacturer, and the discount price strategy of e-tailer can be calculated as follows:

$$\begin{aligned} p_2^{RS} &= \frac{\alpha(\Delta\delta - 3c - \theta) + 8\Delta\delta - 6c + 10\theta}{2(\alpha + 8)}, \\ w^{RS} &= \frac{8(\theta - c) + 2\alpha(4\Delta\delta - c) + \alpha^2(\Delta\delta + c + \theta)}{2(\alpha + 8)}, \\ \text{and } p_{\theta}^{RS} &= \frac{4(3\theta - c) + 2\alpha(4\Delta\delta - 2c - \theta) + \alpha^2(\Delta\delta - c - \theta)}{2(\alpha + 8)}. \end{aligned} \quad (5.5)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{RS}$ and $\hat{p}_c^{RS}$. Consumers' marginal value Δ satisfies $\Delta - p_1 + \theta = \delta\Delta - \hat{p}_2^{RS} + \theta$, or equivalently, $\Delta = \frac{p_1 - \hat{p}_2^{RS}}{1-\delta}$. When consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{RS}}{1-\delta}$, they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{RS} = p_2^{RS}$ and $\hat{p}_e^{RS} = p_e^{RS}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(\rho, \theta)} \pi_{M1}^{RS} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{RS}(w^{RS}, p_2^{RS}, p_e^{RS}) \right], \quad (5.6)$$

where the demand $D_{F1} = A - \frac{p_{F1} - p_{F2}^{25}}{1-\delta}$.

5.3. Scenario RL

Under the RL scenario, the manufacturer with reselling format determines the discount price after the e-tailer in the second period. Under this circumstance, the manufacturer and the e-tailer make their decisions based on the following optimization problem:

$$\begin{cases} \max_w \pi_{M/2}^{RL} = p_2 D_2 + w D_e - c(Q - \hat{D}_1 - D_2 - D_e) \\ \quad \text{s.t.} \\ \max_{p_e} \pi_E^{RL} = (p_e - w) D_e \\ \quad \text{s.t.} \\ p_2^{RL} = \arg \max_{p_2} p_2 D_2 + w D_e - c(Q - \hat{D}_1 - D_2 - D_e), \end{cases} \quad (5.7)$$

where the first and second constraints mean that the e-tailer will select a discount price for the online channel, and the manufacturer will set a discount price for the traditional channel to maximize their own profit, respectively. The demands $\hat{D}_1, D_2$ and D_e are denoted as $\hat{D}_1 = \hat{A} - \Delta$, $D_2 = \Delta - \frac{p_2 - p_e}{\delta(1-\alpha)}$ and $D_e = \frac{p_2 - p_e}{\delta(1-\alpha)} - \frac{p_e - \theta}{\delta\alpha}$,

respectively. Thus the discount and wholesale prices of manufacturer, and the discount price of e-tailer can be calculated as follows:

$$\begin{aligned} p_2^{\alpha e} &= \frac{\alpha^2(2\theta + \Delta\delta) + \alpha(2c - 8\theta - 5\Delta\delta) + 2(5\theta - 3c + 4\Delta\delta)}{2(\alpha^2 - 5\alpha + 8)}, \\ w^{\theta 2} &= \frac{\Delta\alpha^3\delta + \alpha^2(2\theta - 5\Delta\delta) + 2\alpha(4\Delta\delta + 2c - 3\theta) + 8(\theta - c)}{2(\alpha^2 - 5\alpha + 8)}, \\ \text{and } p_\varepsilon^{\beta e} &= \frac{\Delta\alpha^3\delta + \alpha^2(2\theta - 5\Delta\delta) + 2\alpha(4\Delta\delta - 5\theta) + 4(3\theta - c)}{2(\alpha^2 - 5\alpha + 8)}. \end{aligned} \quad (5.8)$$

In the first period, the strategic consumers' expectation discount prices in the second period are described as $\hat{p}_2^{\text{RL}}$ and $\hat{p}_e^{\text{RL}}$. Consumers' marginal value Δ satisfies $\Delta - p_1 + \theta = \delta\Delta - \hat{p}_2^{\text{RL}} + \theta$, or equivalently, $\Delta = \frac{p_1 - \hat{p}_2^{\text{RL}}}{1 - \delta}$. When consumers with valuations higher than $\Delta = \frac{p_1 - \hat{p}_2^{\text{RL}}}{1 - \delta}$, they will buy the in season green product in first period, otherwise, they will buy the end of season product in second period. In our research, since consumers are rational, their price expectation for the second period is equal to the resulting price in equilibrium, thus $\hat{p}_2^{\text{RL}} = p_2^{\text{RL}}$ and $\hat{p}_e^{\text{RL}} = p_e^{\text{RL}}$. Under this condition, the manufacturer sets the optimal premium price and the green degree to seek the maximization profit over two periods, and the optimization problem of manufacturer in first period is expressed as:

$$\max_{(p, \theta)} \pi_{M1}^{\text{RL}} = E \left[p_1 D_1 - \frac{\theta^2}{2} + \pi_{M2}^{\text{RL}}(w^{\text{RL}}, p_e^{\text{RL}}, p_2^{\text{RL}}) \right], \quad (5.9)$$

where the demand $D_1 = A - \frac{p_1 - p_2^{\text{RL}}}{1 - \delta}$.

Following the backward induction procedure, we can get all the solutions of the manufacturer and the e-tailer in Scenarios RL, RS and RP as shown in Table 3. Contrary to Table 2, the results in Table 3 show that under various scenarios, there are significant differences in the manufacturer's optimal green degree and pricing decisions. By comparing the optimal greenness and prices, we conclude the effects of promotion pricing sequences on those greenness and price strategies, as presented in Propositions 2 and 3, respectively.

Optimal solutions and second-order conditions for Scenarios RP, RS and RL.

Proposition 2. *Comparing the manufacturer's optimal green degree decisions among Scenarios RP, RS and RL, we can obtain $\theta^{\text{RL}*} \leq \theta^{\text{RS}*} \leq \theta^{\text{RP}*}$.*

Proposition 2 shows the impacts of promotional pricing sequences on manufacturer's optimal green degree strategies. From Proposition 2, we can see that in the first period, the manufacturer will formulate the lowest green degree in Scenario RL, followed by Scenarios RS and RP. In essence, the reason for this result is that the manufacturer can obtain different leadership from different promotion pricing sequences. From Scenario RL to Scenario RS, and finally to Scenario RP, with this leadership grows, the manufacturer is more likely to build a high green performance product to realize the environmental friendliness and stimulate the demand. Thus as the demand rises, the surplus product will decrease in the second period, and the manufacturer can reap a profit from the increased demand.

Proposition 3. *Comparing the manufacturer's optimal price decisions among Scenarios RP, RS and RL, we can obtain:*

- (i) *In the first period, the premium prices of manufacturer $p_{F1}^{\text{RL}*} \leq p_{F1}^{\text{RS}*} \leq p_{F1}^{\text{RP}*}$.*
- (ii) *In the second period, the discount prices of manufacturer $p_{F2}^{\text{RL}*} \leq p_{F2}^{\text{RS}*} \leq p_{F2}^{\text{RP}*}$.*

Proposition 3 shows the impacts of promotional pricing sequences on manufacturer's optimal price strategies during the two periods selling. To clearly describe this result, we first analyze the second period in Proposition 3(ii), and then study the first period in Proposition 3(i). Specifically, as shown in Proposition 3(ii), in the

TABLE 3. Optimal solutions and second-order conditions for Scenarios RP, RS and RL.

Solutions	Scenario RP	Scenario RS	Scenario RL
p_{F1}^*	$\frac{4(\alpha+1)(1+\tau-2\beta\tau-2c)+\phi_4}{2((4\delta-1)\alpha-1)(3\delta-4)}$	$\frac{\alpha^3\delta^2(4-\delta)+64(1-\delta)+2\alpha^3(1-2\delta)+2\alpha^2\delta^2(31-8\delta)(1+\tau-2\beta\tau)+\phi_{11}}{(6\delta^2-7\delta+4)\alpha^3+(96\delta^2-172\delta+48)\alpha^2+(384\delta^2-616\delta+144)\alpha-96\delta+128}$	$\frac{(1+\tau-2\beta\tau)(\alpha^5(8\delta(1-\delta)-\delta^3)+\alpha^4(76\delta(1-\delta)+10\delta^3)-\alpha^3(41\delta^3-282\delta^2+296\delta)+\phi_3)}{\alpha^5(6\delta^2-7\delta)+\alpha^4(74\delta-60\delta^2)+\alpha^3(246\delta^2-315\delta)+\alpha^2(616\delta+16-480\delta^2)+\phi_6}$
θ^*	$\frac{((2+2(1-2\beta\tau)\delta)\alpha+c(1+\alpha))}{(4\delta-1)\alpha-1}$	$\frac{\alpha\delta(1+\tau-2\beta\tau)(20\alpha\delta+224\delta-\alpha^2\delta-36\alpha-288)-\phi_{10}}{(6\delta^2-7\delta+4)\alpha^3+(96\delta^2-172\delta+48)\alpha^2+(384\delta^2-616\delta+144)\alpha-96\delta+128}$	$\frac{\alpha\delta(1+\tau-2\beta\tau)(\alpha^4(5\delta-6)+\alpha^3(56-46\delta)+\alpha^2(173\delta-214)+\alpha(388-308\delta))+\phi_{12}}{\alpha^5(6\delta^2-7\delta)+\alpha^4(74\delta-60\delta^2)+\alpha^3(246\delta^2-315\delta)+\alpha^2(616\delta+16-480\delta^2)+\phi_6}$
w^*	$\frac{(\theta^{RR^*}-c)(2-\delta-\alpha\delta)+2p_{F1}^{R^*}\alpha\delta}{2(2-\delta)}$	$\frac{\left(\left(\left(c+p_{F1}^{RS^*}\right)\delta+c+\theta^{RS^*}\right)\alpha^2+\left(\left(4c+8p_{F1}^{RF^*}\right)-5\theta^{RS^*}\right)\delta-2c\right)\alpha+4(\delta-2)(c-\theta^{RS^*})}{(2-\delta)(\alpha+8)}$	$\frac{\delta\alpha^3\left(\frac{RS^*}{p_{F1}}-\theta^{RS^*}\right)-\left(\left(c+5p_{F1}^{RS^*}-3\theta^{RS^*}\right)\delta-2\theta^{RS^*}\right)\alpha^2}{-\left(\left(2\theta^{RS^*}-c-8p_{F1}^{RS^*}\right)\delta-4c+6\theta^{RS^*}\right)\alpha+\phi_8}$
p_{F2}^*	$\frac{(\theta^{RR^*}-c)(1-\delta)+p_{F1}^{RR^*}\delta}{2-\delta}$	$\frac{\left(\left(3c+p_{F1}^{RS^*}+\theta^{RS^*}\right)\alpha+6c+8p_{F1}^{RS^*}\right)\delta}{-\left(3c+\theta^{RS^*}\right)\alpha-6c+10\theta^{RS^*}(1-\delta)}$	$\frac{\alpha^2\left(2\theta^{RS^*}-\left(2\theta^{RS^*}-\frac{RS^*}{p_{F1}}\right)\delta\right)-\left(\left(2c+5p_{F1}^{RS^*}-8\theta^{RS^*}\right)\delta+8\theta^{RF^*}-2c\right)\alpha-\left(10\theta^{RS^*}-6c-8p_{F1}^{RS^*}\right)\delta+\phi_9}{(2-\delta)(\alpha^2-5\alpha+8)}$
p_E^*	$\frac{\theta^{RP}(6-2\alpha-\delta(3+\alpha))+4p_{F1}^{RP}\alpha\delta+\phi_5}{4(2-\delta)}$	$\frac{\left(\left(2c+p_{F1}^{RS^*}+\theta^{RS^*}\right)\delta-c-\theta^{RS^*}\right)\alpha^2}{+\left(\left(5c+8p_{F1}^{RS^*}-4\theta^{RS^*}\right)\delta-4c-2\theta^{RS^*}\right)\alpha+\phi_7}$	$\frac{\delta\alpha^3\left(\frac{RS^*}{p_{F1}}-\theta^{RS^*}\right)-\left(\left(c+5p_{F1}^{RS^*}-3\theta^{RS^*}\right)\delta-2\theta^{RS^*}\right)\alpha^2}{-\left(10\theta^{RS^*}-\left(3c+8p_{F1}^{RS^*}\right)\delta\right)\alpha+\phi_7}$
Condition	$4\delta\alpha-\alpha-1>0$	$\frac{\alpha^3(7\delta-6\delta^2-4)+\alpha^2(172\delta-48-96\delta^2)+\alpha(616\delta-384\delta^2-144)+96\delta-128>0}{(2-\delta)(\alpha+8)}$	$\frac{\alpha^5(7\delta-6\delta^2)+\alpha^4(60\delta^2-74\delta)+\alpha^3(315\delta-246\delta^2)+\alpha^2(480\delta^2-616\delta-16)+\alpha(4485-384\delta^2+80)+96\delta-128>0}{(2-\delta)(\alpha^2-5\alpha+8)}$

where $\phi_4 = (\alpha\delta^2(23-4\delta)-\delta(4-\delta+28\alpha))(1+\tau-2\beta\tau)-2\alpha\delta(6\alpha\delta-11\alpha-3)$, $\phi_5 = c((3\alpha+1)\delta-2(\alpha+1))$,
 $\phi_6 = \alpha(384\delta^2-448\delta-80)-96\delta+128$, $\phi_7 = 2(\delta-2)(c-3\theta^{RS^*})$, $\phi_8 = 4(\delta-2)(c-\theta^{RS^*})$, $\phi_9 = 10\theta^{RS^*}-6c$,
 $\phi_{10} = c(\alpha^3\delta+4\alpha^3-44\alpha^2\delta+48\alpha^2-104\alpha\delta+144\alpha-96\delta+128)$, $\phi_{11} = (224\delta-288)\alpha\delta(1+\tau-2\beta\tau)$
 $-c(\alpha^5\delta-6\alpha^4\delta+13\alpha^3\delta-24\alpha^2\delta+16\alpha^2+64\alpha\delta-80\alpha-96\delta+128)$, $\phi_{12} = (4\alpha^2(6-23\delta)+4\alpha\delta^2(101-16\delta)+8\alpha(9-61\delta)-16\delta^2)(1+\tau-2\beta\tau)+c(7\alpha^3\delta(\delta-1)+76\delta^2\alpha^2+4\alpha^3-136\alpha^2\delta+160\alpha\delta^2+48\alpha^2-328\alpha\delta+144\alpha-96\delta+128)$,
 $\phi_{13} = (1+\tau-2\beta\tau)(\alpha^2(80\delta^3-512\delta^2+540\delta+8)+(376(\delta-1)-64\delta^3-40)\alpha+16(\delta-2)^2)+$
 $((\delta^2-\delta)\alpha^5+(18\delta-14\delta^2)\alpha^4+(73\delta^2-101\delta)\alpha^3+(228\delta-172\delta^2+16)\alpha^2+(160\delta(\delta-1)-80)\alpha-96\delta+128)c$.

end of season, the manufacturer sets the lowest promotion price in Scenario RL, followed by Scenario RS and Scenario RP. As explained in Proposition 2, from Scenario RL to Scenario RS, and finally to Scenario RP, the greenness of product decided by the manufacturer gradually rise, which means the green R&D investment also improve, accordingly, the price of green product will increase. Next, for the first period in Proposition 3(i), we conclude the same result as the second period in Proposition 3(ii) but has a different significance. Formally, in the first period, the rational consumers will wait for the price reduction of green product, thus the competition between the two periods will explicate such pricing strategies. This is also to say that the increased promotion prices of end of season green product from Scenario RL to Scenario RS and Scenario RP will, accordingly, lead the same rising order of the sales prices for the in season green product.

The optimal green degree and prices decisions of the manufacturer in Scenarios RP, RS and RL are substituted into the corresponding profit functions, we can get the optimal profit under the three scenarios. To examine the impacts of promotion pricing sequences on manufacturer's profit, we compare the profit among Scenarios RP, RS and RL, and obtain the following proposition.

Proposition 4. *Comparing the manufacturer's optimal profit among Scenarios RP, RS, and RL yields:*

$$\begin{aligned} &\text{if } 0 \leq \beta \leq \frac{1}{2}, \text{ then } \pi_{M_1}^{\text{RP}*} \leq \pi_{M_1}^{\text{RS}*} \leq \pi_{M_1}^{\text{RL}*} \\ &\text{if } \frac{1}{2} \leq \beta \leq 0, \text{ then } \pi_{M_1}^{\text{RL}*} \leq \pi_{M_1}^{\text{RS}*} \leq \pi_{M_1}^{\text{RP}*} \end{aligned}$$

Proposition 4 describes the effects of promotion pricing sequences on the optimal profit of manufacturer with the reselling format. From Proposition 4(i), we find that in an optimistic market ($0 \leq \beta \leq 0.5$), the manufacturer prefers to decide a promotion price after introducing the e-tailer (Scenario RL). Actually, the reason for this phenomenon is that the optimistic market makes manufacturer faces the possibility of high market demand. In a market where consumers are actively consuming, the manufacturer is motivated to reduce green R&D investment cost, and fully benefit from high sales. In this case, the manufacturer will try to transfer leadership through Scenario RL, because this structure can enables her to develop the lowest level of green R&D investment, so as to obtain sufficient value of sales from the minimum cost and high sales volume. However, in a pessimistic market ($0.5 \leq \beta \leq 0$), as described in Proposition 4(ii), Scenario RL is not necessarily preferred by the manufacturer, while Scenario RP, *i.e.*, the manufacturer decides the discount price for traditional channel prior to introducing the online promotional channel under the power driven leadership, is more profitable for the manufacturer due to a pessimistic market environment makes she faces a high possibility of demand loss. Under this circumstance, the manufacturer will try to improve the green attribute of product to alleviate the current environmental pressure, and attract environmentally friendly consumers in the market, so as to stimulate the demand and obtain more benefits. Therefore, in a pessimistic market, Scenario RP with high green degree is more attractive to the manufacturer. There exist different promotion pricing sequences in reality, which also proves our above insights. In addition, by comparing the equilibrium solutions of the manufacturer with a single promotion channel and dual-channel (see Appendix A for details), we find that the manufacturer can always benefit from the increasing demand (*i.e.* $\pi_{M_1}^{B*} > \pi_{M_1}^{\text{RP}*}$) by introducing online promotion channel as a supplement to traditional channel.

6. ANALYSIS OF THE EQUILIBRIUM ONLINE PROMOTIONAL FORMATS

The above section analyzes the optimal decisions of manufacturer under the agency selling and reselling formats respectively. The result proves that the pricing sequence in dual-channel can only affect the equilibrium solutions of manufacturer under the reselling format. Specially, in an optimistic market, when the manufacturer applies the reselling format to promote the green product, she prefers to set the discount price for online channel prior to traditional channel, otherwise, in a pessimistic market, she tends to decide the discount price for online channel after traditional channel. However, under the influence of uncertain demand and different pricing sequences, the problem of which online selling format between agency selling and reselling the manufacturer will choose has not been studied. Thus we address the problem in this section. To begin with, we discuss the

promotional effects on retail price and demand of manufacturer with the agency and reselling formats. On top of that, we explore the optimal selling format selection of manufacturer by comparing the equilibrium profit.

6.1. Promotional effects of agency selling and reselling formats with different pricing sequences

This section compares the retail prices and demands of supply chain under different online selling formats and pricing sequences to gain more management insights. Proposition 6.1 obtains the optimal decisions for the manufacturer. In addition, the total demand over the two selling periods are denoted as D^{AT^*} , D^{RP^*} and D^{RL^*} respectively, which $T \in \{P, S, L\}$

Proposition 5. *Comparing the manufacturer's optimal retail price and demand under different online promotion formats and pricing sequences to obtain the following:*

- (i) If $0 \leq \beta \leq \frac{1}{2}$, then $\theta^{AT^*} \leq \theta^{RL^*}$, $p_1^{AT^*} \leq p_1^{RL^*}$, $p_2^{AT^*} \leq p_2^{RL^*}$, and $D^{AT^*} \leq D^{RL^*}$.
- (ii) If $\frac{1}{2} < \beta \leq 1$, then $\theta^{AT^*} < \theta^{RP^*}$, $p_1^{AT^*} < p_1^{RP^*}$, $p_2^{AT^*} < p_2^{RP^*}$, and $D^{RP^*} < D^{AT^*}$.

Proposition illustrates how the selling formats affect the manufacturer's optimal price decisions and demands. The results show that in an optimistic market () shown in proposition 4(i), when the manufacturer introduces a online promotion channel, it will produce higher green degree, retail price and demands in the reselling format than agency selling. This result is actually contrary to the universal cognition, that is, the reselling format usually leads to low greenness and demands due to the double-marginalization effect [6, 7, 23, 26–28]. However, this finding is reasonable, because in an optimistic market, the possibility of high market demand increases, which indicate that high sales are more attractive to the manufacturer. Therefore, she is more likely to improve the green degree to attract potential green consumers in the market, so as to fully benefit from the high sales. Simultaneously, with the increase of manufacturer green R&D investment cost, the price of green product also rises. In a pessimistic market ($0 \leq \beta \leq 0.5$) shown in Proposition 4(ii), the introduction of online promotion channel will lead to high consumer demand under the Scenario AI than Scenario RP. This conclusion is consistent with the intuitive inference under the double-marginalization effect in the reselling format. In this case, it is inadvisable for the manufacturer to keep increasing green R&D investment due to the weakening of market demand.

6.2. Optimal selling format

Now, we explore the preference of the manufacturer under agency selling and reselling formats, and an optimal selection of the manufacturer are concluded in Proposition 6. Furthermore, Figure 4 presents this equilibrium result intuitively. Seeing Appendix A for details τ_1 , τ_2 , τ_3 , τ_4 .

Proposition 6. *By Comparing the manufacturer's optimal retail prices and demands with different online promotion formats and pricing sequences to obtain the following:*

- (i) When $0 \leq \beta \leq \frac{1}{2}$, if $\max\{\tau_1, 0\} \leq \tau \leq \min\{\tau_2, \tilde{\tau}\}$, then $\pi_{M1}^{AI^*} \geq \pi_{M1}^{RL^*}$; otherwise, $\pi_{M1}^{RL^*} > \pi_{M1}^{AI^*}$.
- (ii) When $\frac{1}{2} < \beta \leq 1$, if $\max\{\tau_3, 0\} \leq \tau \leq \min\{\tau_4, \tilde{\tau}\}$, then $\pi_{M1}^{AI^*} \geq \pi_{M1}^{RP^*}$; otherwise, $\pi_{M1}^{RP^*} > \pi_{M1}^{AI^*}$.

Proposition 6 shows the manufacturer's choice of online promotion formats under specific circumstances. Meanwhile, the selling format preference of manufacturer is affected by both the uncertain demand and the promotion pricing sequence. From the proposition, we can find that the agency selling format is not always better than the reselling format with a double-marginalization effect, and this result has also been confirmed by existing studies [1, 14]. In the optimistic market ($0 \leq \beta \leq 0.5$) shown in Proposition 6(i), when the market demand uncertainty is neither small nor large, the manufacturer can set a promotion price for online channel prior to traditional channel under the reselling format to lower the retail price, and benefit from the high total market demand. However, when the market demand uncertainty is large or small, the manufacturer should

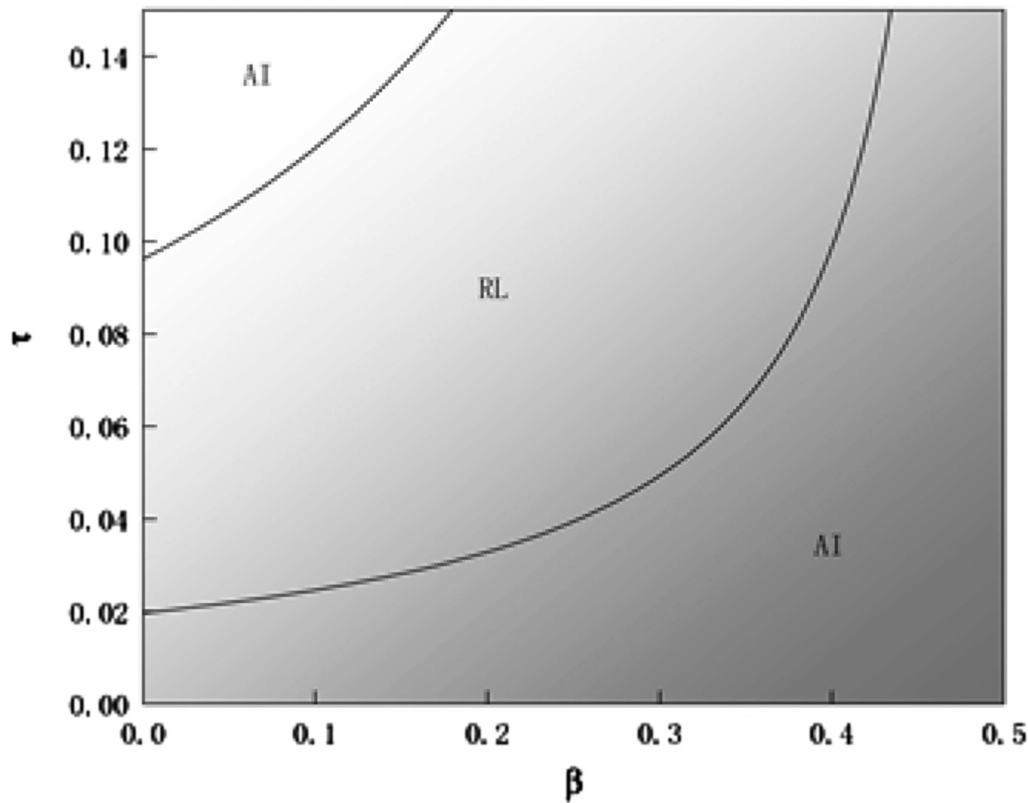


FIGURE 4. Preferred strategies of the manufacturer.

adopts agency selling format to benefit from the direct pricing power without double-marginalization effect. Figure 4 intuitively describes the result in Proposition 6. In the picture, areas “AI” and “RL” represent the preferred strategies of the manufacturer in Scenarios AI and RL, respectively. From Figure 4, we can know that as the possibility of low demand market increases, the manufacturer prefers to remember the direct pricing power in the format of agency selling. In addition, as shown in Proposition 6(ii), in the pessimistic market, the optimal channel select of manufacturer is similar to result shown in Proposition 6(i), and the only difference lies in that under a pessimistic market, the manufacturer should determine her online promotion price after the traditional channel to benefit from high profit. Based on the above analysis, the optimal online selling format of the manufacturer is obtained. Next, we will explore the equilibrium profit and discuss the preference selling format of e-tailer.

According to the numerical simulation, Figure 5 shows the e-tailer’s equilibrium profit based on the manufacturer’s selling format preference. In the picture, “AI” and “RL” areas show the preferred strategies of e-tailer under Scenarios RL and AI, respectively. Combined with Figure 4, the solid line area pointed by the arrow and the area surrounded by the dotted line in Figure 5 show a win-win state, that is, in this condition, both the manufacturer and the e-tailer can achieve profit equilibrium. In addition, from the picture, we can obtain that the low demand state with high probability extremely reduces the possibility of a win-win situation. However, this win-win situation is more likely to occur under high market uncertainty and low demand probability, or when the market uncertainty and high demand probability are low.

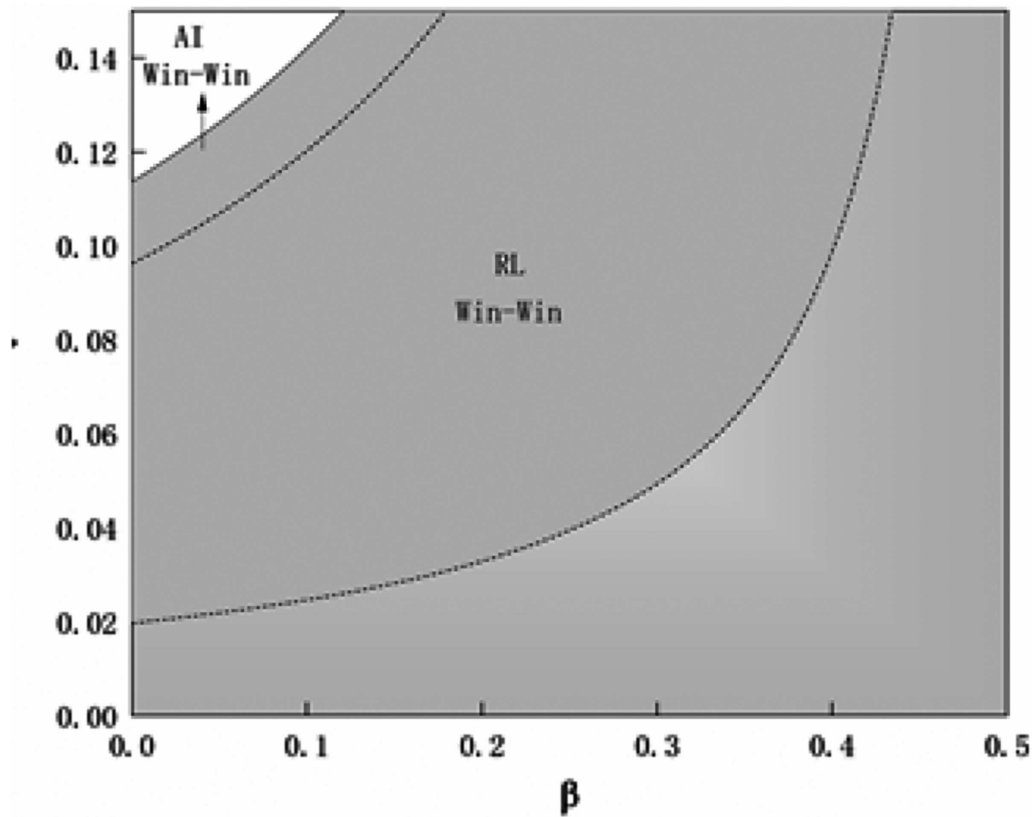


FIGURE 5. Preferred strategies of the e-tailer.

7. MODEL EXTENSIONS

The purpose of this section is to relax the assumptions in our main model to obtain further insights. The detailed solving processes are shown in Appendix B.

7.1. Endogenous revenue sharing rate

In the core model of the paper, we assume the proportion of revenue sharing is fixed, and not affected by other factors. On the contrary, in this section, we consider the proportion of revenue sharing is variable, and determined by the e-tailer. So next, we will study the change trend of the optimal sharing proportion between the manufacturer and the e-tailer. Due to complexity of the model, we present the detailed solution processes in Appendix B. Figure 6 intuitively shows the optimal revenue sharing proportion strategies of the e-tailer with the change of demand uncertainty and low demand probability. From the picture, we can find that with the demand uncertainty rises, the proportion of revenue sharing showed a downward trend. However, in an optimistic market, with the improve of low demand probability, the proportion of platform revenue sharing set by e-tailer shows an upward trend. The reason for the above phenomenon may be that the lower demand of consumers in season can cause the promotion product increases in the second period, therefore, to seek more profit, the e-tailer will exact a high platform fee for the manufacturer. In addition, combined with the manufacturer's equilibrium promotion selling format, we set the same parameters (and) and the numerical range as Figures 4 in 6 (as the part surrounded by the dotted line) to explore the trend of the optimal revenue sharing proportion. From the picture, we can concluded that although different and corresponding to different optimal profit sharing ratios,

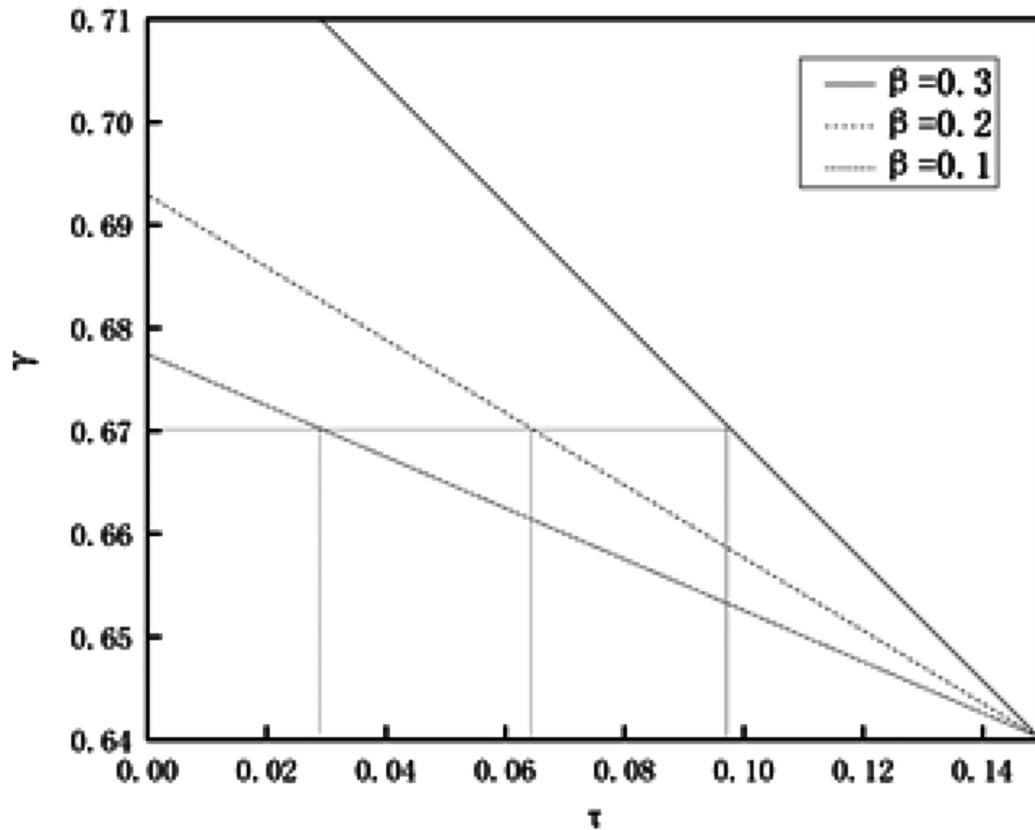


FIGURE 6. Changes of the optimal revenue sharing rate.

the manufacturer still have a optimal strategy. In essence, introducing variables will not necessarily affect the optimal promotion selling format strategy of the manufacturer as described in the main model.

7.2. Discount future payoff

In the setting of the above models, we assumed that the manufacturer, the e-tailer and the strategic consumers will not discount their future profit. However, the profit usually owns a certain time value, and has a corresponding discount rate. Therefore, in the next, we will analyze the effects of discount rate $A(0 < A < 1)$ on the manufacturer's strategic preference with the supply chain players and the strategic consumers discount their second period profit.

When the discount rate is introduced, the solution process of the model is consistent with that of the core model in this paper, and the detailed processes are shown in Appendix B. According to the numerical simulation, we can know that there is no significantly changed for the equilibrium promotion format of the manufacturer and the e-tailer. More importantly, we simulated the parameter on the manufacturer's strategic preference, and found that with the discount rate rises, the manufacturer is more inclined to implement agency selling format to promote the green product, which reflect that when the manufacturer reduces the profit discount in the second period, the direct pricing strategy is more helpful to promote the entire efficiency of supply chain system.

8. CONCLUSIONS

8.1. Contributions of the paper

In a low carbon context, we presented a game model to study the online promotion strategy and the environmental responsibility fulfillment of a supply chain. Moreover, different from the first period, in the second period, the manufacturer promotes her end-of-season products through the dual-channel by introducing an e-tailer. However, the pricing sequence in dual-channel and the different online selling formats may affect the optimal decision-making of manufacturer. Thus we build game models for seven scenarios to analyze the equilibrium strategies of the supply chain. Compared with the existing literature, the contributions of our study mainly lies in two aspects. First, we consider the pricing sequence in traditional channel relative to online channel to analyze the selection of online selling format for manufacturer between the agency selling and the reselling. As far as we know, the previous scholars rarely consider pricing sequence in this topic although the agency selling and the reselling formats have been widely studied. Second, corporate green investment is proposed in a two-period selling supply chain, whereas most of recent literature only focus on the online selling format selection, they do not consider the environmental responsibility of supply chain, and ignore the possibility that the improvement of product greenness can also bring considerable benefit to the supply chain system and the environment.

8.2. Theoretical and managerial implications

The results show that in the agency selling format, the pricing sequence between traditional channel and online channel will not affect the equilibrium green degree, and pricing strategies of manufacturer. However, it will have a significant impacts for the reselling format. In an optimistic market, when the manufacturer decides the promotional price in online channel prior to traditional channel under the reselling format, the product greenness is the lowest, thus the promotional price decreases. However, relative to the agency selling format, the product greenness in reselling format is always higher, which contrary to the general intuition, namely the reselling format with double-marginalization effect will inevitably lead to a lower green degree than agency selling. As the greenness increases, the retail price also rises. Interestingly, in an optimistic market, a high greenness in reselling format will generate more demand than agency selling although the retail price is high, but in a pessimistic market, compared with the agency selling, it will generate a lower demand. In the end, we conclude that the performance of green supply chain system under agency selling format is not always better than reselling format. As described in the main sections, we assume the market is uncertain, and therefore the manufacturer's profit can be affected by the uncertainty and the probability of low demand. Specifically, in an optimistic market, when the uncertainty of demand is neither large nor small, the manufacturer is more profitable in reselling format when the online price is formulated prior to the traditional channel. However, in a pessimistic market, the opposite promotional pricing sequence set will bring a considerable benefit to the manufacturer.

8.3. Limitations of the research and future research directions

There are several limitations to our model that can be the subject of future research. First, this paper assumes enterprises sell the in season product by traditional channel and sell the end of season product in dual-channel, thus how enterprises select the optimal online selling format when they sells products through dual-channel in both periods is worth studying. Second, this paper assumes that the green investment of enterprises occurs in the first period and remains unchanged in the second period. Generally, for some industries such as mobile phone, the manufacturer usually upgrades the product functions in the second period to keep sales. Third, we assume the supply chain contains a manufacturer in our research, future research can study the effort of retailer and explore the impact of adding the retailer on the carbon reducing initiatives and the performance of green supply chain.

Data availability. All the data in this manuscript are from the references, and all the data are available.

Conflict of interest. I declare that I do not have any conflict of interest in the process of submission and have been approved by the author for publication.

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