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*Research Article*

# New Product Presale Strategies considering Consumers' Loss Aversion in the E-Commerce Supply Chain

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New product presale is a strategic behavior of manufacturers to transfer inventory risks to consumers. The research purpose of this paper is to examine the presale discount, inventory, and service level decisions in an e-commerce supply chain, where the first period is the presale period and the second is the selling period for the new product. First, consumers were divided into two types—those who are risk averse and those who are not. Then, considering different presale discounts applied for new products, three presale strategy models were discussed: no-presale strategy, presale strategy with a moderate discount, and complete presale strategy, and the optimal decisions of e-commerce supply chain members were obtained under different valuations of the new product by consumers. Finally, the effects of the correlation coefficient between the numbers of the two types of consumers, the loss aversion degree of consumers, and the marginal profit in the sales period on the optimal discounted price and the maximum expected profit were analyzed. The conclusions of this article show that the presale strategy is not always optimal but depends on the parameters of the market and the type of consumers. For example, when the correlation coefficient between the two types of consumers is high, it is more profitable for the suppliers if they choose the presale strategy with a moderate discount, while e-commerce platforms tend to adopt the no-presale strategy. The optimal discounted price in the complete presale case is not necessarily lower than that in the moderately discounted presale case. If the marginal profit is high in the normal sales period or consumers are less averse to losses, suppliers are more likely to adopt the complete presale strategy. The research conclusions provide some theoretical reference for companies in the development of new product presale strategies in the e-commerce supply chain.

## 1. Introduction

With the rapid development of Internet information technology, commodity trading is being integrated more with e-commerce. More and more consumers choose to shop via online platforms such as Tmall, Pinduoduo, and JD, and thus, the "e-commerce supply chain" based on Internet information technology has emerged [1]. The e-commerce supply chain is a combination of supply chain management and e-commerce and a new development model of supply chain [2]. Having the advantages of both e-commerce and the supply chain, the e-commerce supply chain model is now widely applied in online shopping malls such as Tmall, JD, and Suning [3]. Meanwhile, some mobile phone manufacturers (such as Apple and Xiaomi, etc.) have adopted the online "hunger marketing" model, which has attracted a large number of consumers to order new products in advance, and major e-commerce platforms have also applied the presale model. For example, in Tmall's "Double Eleven" Shopping Festival in 2019, more than 200,000 brands participated in the presales, and millions of new products were launched during this activity. In the first stage of presales (October 20-31), 64 brands achieved a turnover of over 100 million yuan. In this context, this paper attempts to discuss the decision-making problem in the e-commerce supply chain, that is, what strategies the supplier should choose for the sales and presales of new products on e-commerce platforms.

So far, there have been some research results on the operation and management of the e-commerce supply chain based on e-commerce platform sales. Early research mainly focused on the structure [4], characteristics [5], and advantages [6] of the e-commerce supply chain. In recent years, many scholars have developed an interest in the operation of the e-commerce supply chain. Centobelli et al. [7] analyzed the effects of the e-commerce supply chain operation on the actual business operation of enterprises from the perspective of e-procurement. Li et al. [8] analyzed the effects of the replenishment strategy on the performance of the e-commerce supply chain, and the research shows that when the retail market is highly fair and the retailers have significant marketing advantages, the replenishment strategy may bring an adverse effect to the supplier. Xiao and Shi [9] studied the pricing strategy and channel prioritization strategy for the e-commerce supply chain and the traditional supply chain under the situation of a supply shortage caused by random income. Zhao et al. [10] discussed how consumers' channel loyalty, product complementarity, and market structure affect the pricing decisions in online and offline supply chains. Wang et al. [1] studied the multiagent e-commerce supply chain decision model by taking product substitution and complementarity into account. For the E-closed-loop supply chain composed of a single manufacturer and a single network platform, Wang et al. [11] studied the optimal decision-making problem of the supply chain system led by the network platform. Xu and Bai [12] studied the best management strategy in the capital-constrained e-commerce supply chain under the premise that service quality has an effect on market demand. In addition, some scholars have done in-depth research on e-commerce supply chain coordination, members' behavioral preferences, and green e-commerce supply chain [13–16]. However, in the above research on the operation and management of the e-commerce supply chain, presale, as a strategic behavior of manufacturers, is rarely considered.

Presale refers to a marketing behavior in which the manufacturer begins to accept consumer orders before the official release of its new products or normal sales [17]. The orders received during the presale may have something to do with the demand in the sales period, so presale can help the manufacturer more accurately predict the demand in the sales period and adjust the number of orders accordingly to reduce the risk of overstock and supply shortage [18]. Manufacturers often use price discounts to encourage consumers to preorder products. For example, Amazon once offered a 49% price discount to consumers who preordered the book *Harry Potter and the Deathly Hallows* [19]. At the same time, however, the presale will also reduce the manufacturer's marginal profit due to price discounts, so the manufacturer is faced with a trade-off between the benefits and losses related to the orders. Of course, presale is still profitable in many industries [20]. Nasiry and Popescu [21] studied the effects of consumers' regrets on the presale strategy. Ma et al. [22] discussed the presale strategy for risk-averse consumers. Li et al. [23] studied the presale strategies for newsboy retailers and the problem of false failure returns when the product demand and consumers' product valuation were both uncertain. Zeng et al. [24] used a game model to analyze entrepreneurs' behavioral motives to exaggerate product quality in presale crowdfunding and the preventive measures against such behaviors. In addition, some scholars have studied the presale strategies in competition [25], crowdfunding presale and crowd-sourcing decision-making problems [26], and the option model for presale [27]. However, in the above research on the retailer's presale strategies, the decision-making problem of e-commerce supply chain members in product presales via third-party e-commerce platforms is rarely taken into account.

When a consumer preorders a new product at a discounted price, it means he has given up the opportunity to try the product before buying it. Once he finds that the value of the product is not as expected, the consumer may suffer a loss, that is, a negative surplus [19]. Therefore, manufacturers may need to consider consumers' loss aversion behaviors when adopting the presale strategy [28]. According to whether consumers are loss averse or not, Ma et al. [29] investigated how the manufacturer set an appropriate discount price and how many products should the manufacturer make available for physical shops and online stores, respectively. Liu et al. [30] studied the pricing strategy in a dual-channel supply chain in the presence of consumers' loss aversion. Zhang and Li [31] explored the implications of consumer loss aversion on firm profit, consumer surplus, and social welfare when firms endogenously make quality disclosure decisions. Zhao and Stecke [19] studied the decision-making problem of newsboy retailers regarding presales when there are both loss-averse and rational consumers. On this basis, Wang et al. [17] discussed the issue of product returns by consumers after the presale period, and the results showed that when the return price is below a certain threshold, the return strategy will enable retailers to obtain greater profits. On the basis of literature [17, 19], this paper extended the presale strategies to the e-commerce supply chain, and with the service level of the e-commerce platform as a decision variable in the presale model, it further analyzed the effects of the service strategies of the e-commerce platform on the decisions of e-commerce supply chain members regarding presales.

In summary, on the one hand, the existing research on presale strategies mainly focuses on the situation of a single newsboy retailer, while there is little research considering the presale strategies for new products in a supply chain system; on the other hand, the existing results cover a wide range of aspects regarding the e-commerce supply chain, including operation models, pricing, decision-making models, and supply chain coordination, but the situation is rarely considered where an online platform is used as the carrier for release of new product presale information, and little has been discussed on the effects of the platform's service level on the presale strategies. Therefore, this paper studied the optimal decision in the e-commerce supply chain under the dual factors—new product presale and consumers' loss aversion. The main contributions of the paper are as follows: (1) the service level of the e-commerce platform was used as the endogenous decision variable in the e-commerce supply chain, and the optimal service decision of the e-commerce platform was analyzed under different presale models; (2) based on the optimal service decision of the e-commerce platform, the optimal presale pricing decision and inventory decision of the supplier were obtained under three different presale strategies, assuming that there are both loss-averse consumers and rational ones; (3) the effects of market parameters and consumer types on the presale strategies of the e-commerce supply chain members were analyzed through simulation, which can provide some theoretical basis for companies in formulating their presale strategies for new products on e-commerce platforms.

The remainder of this paper is organized as follows. In Section 2, we describe the basic model and hypotheses. In Section 3, we formulate and analyze three presale strategy models: no-presale strategy, presale strategy with a moderate discount, and complete presale strategy. In Section 4, we carry out numerical analysis that demonstrates the results derived in Section 3 and also provide managerial insights. In Section 5, we conclude the study and offer directions for future research.

## 2. Model Description and Hypotheses

Suppose that there is a two-stage e-commerce supply chain consisting of a single monopoly supplier and a single e-commerce platform. In this supply chain, the supplier not only manufactures new products but also releases presales/sales information on the new products through the third-party e-commerce platform, which is like a medium for the presales/sales of new products. Accordingly, the supplier needs to pay a commission at a certain percentage of the sales revenue to the e-commerce platform as compensation. The structure of the model is shown in Figure 1.

According to whether consumers are loss averse, consumers were divided into two types in this paper—the loss-averse consumers, which are denoted as $L$-type consumers, and the rational consumers or consumers who are not loss averse, denoted as $R$-type consumers. The supplier adopts both presales and normal sales of new products on the third-party e-commerce platform. Suppose that each consumer buys at most one new product, which is not a daily necessity, and that its unit production cost is $c$, and that the unit sales price is $p$ (which is an exogenous variable). In order to attract consumers to make orders in the presale activity on the platform, the supplier will offer consumers a certain discount on the presales price of the new product, so in the presales stage, the unit presales price of the product is $xp$, where $x\,(0 < x < 1)$ represents the discount coefficient applied on the presales price of the new product. In the normal sales stage, the supplier first delivers the presold new products to the consumers and at the same time sells the new products at the normal price $p$. After the end of the sales period, the remaining products are disposed of at the unit salvage price $s$. The loss of supply shortage is not considered. Apparently, $p > c > s$. For notational convenience, we summarize the key notations of the paper in Table 1.

A consumer's valuation of a new product is the highest price that the consumer is willing to pay for it. In the presales stage, the consumer's valuation $V$ of the new product is uncertain, and this uncertainty may be caused by a variety of factors. However, in the normal sales stage, the consumer can collect all the information about the new product through various channels, and thus in this stage, his valuation $v$ of the new product is certain.

The supplier needs to make two decisions. One is about the presale discount; in other words, it needs to determine the value of $x$ at the beginning of the presales period. The other is about the quantity of new products. Suppose that the random variables $N_1$ and $N_2$ represent the number of consumers who preorder the product in the presales stage and buy the product in the normal sales stage, and that at the end of the presales period, the value of $N_1$ is determined to be $n_1$. Based on this information, the supplier can update the quantity of orders in the normal sales stage to $Q + n_1$, where $n_1$ units of new products are used to complete the presales immediately, and the remaining $Q$ units of new products are used to satisfy the demands in the normal sales stage.

In the presale model of the e-commerce supply chain, the e-commerce platform provides the supplier with sales and technical services and charges the supplier two types of fees: (1) fixed fees, such as technical service fees and deposits; such fixed fees can only cover the basic services; that is, the online platform is allocated to the supplier so that the presales/sales information can be released, and consumers can reach a deal with the supplier; (2) commission. When the supplier sells new products on the platform, the platform provides sales services, and when a consumer completes a new product transaction with the supplier on the platform, the platform charges the supplier commission at a certain percentage of the sales revenue, which is mostly between 2% and 10% on e-commerce platforms. Since fixed fees have no impact on the decisions of the platform and the supplier, they are ignored in this paper, and only the impact of the variable fee, that is, the commission, on the decisions of the e-commerce supply chain is considered. Assuming that the amount of the commission charged by the e-commerce platform per unit of the new product is $\tau$, then the total commission charged by the e-commerce platform is $\tau(Q + n_1)$. Suppose that the level of sales services provided by the e-commerce platform is $e$ (which is the decision variable), and similar to the hypotheses made in literature [1, 14], let the cost function be $C(e) = \gamma e^2/2$, where $\gamma\,(\gamma > 0)$ is the service cost parameter, which specifically refers to all the costs needed per unit to improve the level of services (including advertising and marketing services, customer services, payment services, agency operations, and after-sales services, etc.).

In order to facilitate model analysis, the following hypotheses were made.

*Hypothesis 1.* a hypothesis on consumers' valuation of a new product. With reference to the hypothesis made in literature [32], it is assumed that in the presales stage, the consumers' valuation $V$ of the new product obeys a uniform distribution within [0, 1].

*Hypothesis 2.* a hypothesis on the quantitative relationship between the two types of consumers. Let $N_L$ and $N_R$ denote the number of $L$-type and $R$-type consumers in the market,

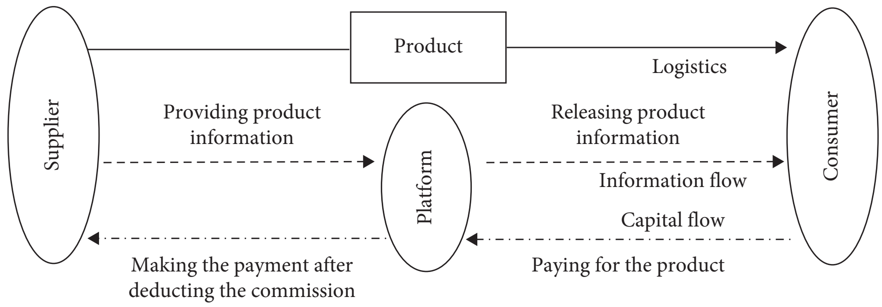


Figure 1: E-commerce supply chain model structure.

Table 1: Summary of notations.

| | |
|---|---|
| *Variables* | |
| $x$ | Percentage of the market price to be charged to presale |
| $Q$ | The quantity of products that the supplier should prepare for demands that will come in the selling season |
| $e$ | The sales service level of the e-commerce platform |
| $N_1$ | Number of consumers who place preorders in the advance selling period, a random variable with a mean $\mu_1$ and standard deviation $\sigma_1$ |
| $N_2$ | Number of consumers who buy in the selling season, a random variable with a mean $\mu_2$ and standard deviation $\sigma_2$ |
| $N_i$ | Number of potential type $i$ consumers, a random variable with a normal distribution $N(\mu_i, \sigma_i)$, $i \in \{R, L\}$ |
| *Parameters* | |
| $p$ | Market price per unit of product sold in the selling season |
| $c$ | Production cost per unit of product |
| $s$ | Salvage price per unit of product |
| $\alpha$ | The elasticity coefficient of the platform's service level |
| $\beta$ | Loss averse index to indicate how averse a consumer is to the possibility of realizing negative surplus |
| $\rho$ | The correlation coefficient between the random variables $N_L$ and $N_R$ |
| $\gamma$ | The service cost parameter |
| $\tau$ | The rate of commission for e-commerce platform per unit of the new product |
| $V$ | The consumers' valuation of the new product |
| $U$ | The consumers' expected utility of the new product |

respectively, and let the joint distribution of random variables $N_L$ and $N_R$ obey a bivariate normal distribution with the mean values being $\mu_L$ and $\mu_R$, the standard deviations being $\sigma_L$ and $\sigma_R$, and the correlation coefficient being $\rho\,(0 < \rho < 1)$.

*Hypothesis 3.* a hypothesis on the consumer surplus. In the presales stage, if a consumer pays a discounted price $xp$ for the new product, then the consumer surplus is $V - xp + \alpha e$, where $\alpha\,(\alpha > 0)$ represents the elasticity coefficient of the platform's service level to the consumer surplus. Since consumers are more sensitive to the prices of new products, it is assumed that $xp - \alpha e > 0$. Since $V$ is a random variable, the consumer surplus from a preorder transaction is also random. Therefore, the consumer may eventually suffer a loss (negative surplus) at the end of the transaction. In the normal sales stage, the consumer's valuation $v$ of the new product is definite. If $v < p - \alpha e$, no consumer will buy the product; otherwise, the consumer will buy it and gain a nonnegative surplus $v - p + \alpha e$. In summary, without preorders, the consumer surplus is $\max\{V - p + \alpha e, 0\}$.

*Hypothesis 4.* a hypothesis on consumers' loss aversion. The loss aversion of a consumer is characterized by the piecewise linear utility function widely used in the literature [17–19]; that is, $U(v) = \begin{cases} v & v \geq 0 \\ v - \beta & v < 0 \end{cases}$, which means that when the surplus that an $L$-type consumer obtains from the purchase of a new product is positive, its utility will not change and that when the surplus obtained is negative, the utility will be lower, reflecting the characteristics of loss aversion.

## 3. Model Analysis

*3.1. Consumers' Buying Behaviors.* Through the above classification of consumers, the utility function for consumers buying the new product at different sales stages can be obtained. Suppose that the subscripts $L$ and $R$ represent these two different types of consumers and that the superscripts $A$ and $B$ represent the purchase made in the presales stage and the normal sales stage, respectively. The expected utilities of the new product for the two types of consumers who purchase the new product at different stages can be expressed as

$$U_L^A = E(V - xp + \alpha e) - \beta F(xp - \alpha e), \quad (1)$$

$$U_R^A = E(V - xp + \alpha e), \quad (2)$$

$$U_L^B = E(\max\{V - p + \alpha e, 0\}), \quad (3)$$

$$U_R^B = E(\max\{V - p + \alpha e, 0\}), \tag{4}$$

where $\beta(\beta > 0)$ represents how averse an $L$-type consumer is to losses, and the greater $\beta$ is, the more averse the consumer is to losses; $F(xp - \alpha e)$ represents the probability of a loss (negative surplus) from a preorder.

After observing consumers' decision-making process, the supplier can influence consumers to make decisions in its favor by adjusting the discounted price $xp$ in the presales stage. In order to characterize the buying behaviors of consumers under different conditions, the two thresholds for the presales price discount coefficient were first calculated.

$$U_L^A - U_L^B = \frac{1}{2} - xp + \alpha e - \beta(xp - \alpha e) - \int_{p-\alpha e}^{1} (v - p + \alpha e)\mathrm{d}v, \tag{5}$$

$$U_R^A - U_R^B = \frac{1}{2} - xp + \alpha e - \int_{p-\alpha e}^{1} (v - p + \alpha e)\mathrm{d}v. \tag{6}$$

From the above equations, it can be seen that $U_L^A - U_L^B < U_R^A - U_R^B$, and $U_L^A - U_L^B$ and $U_R^A - U_R^B$ are monotonically decreasing with respect to $xp$, so there exist two thresholds $x_L$ and $x_R$ that satisfy $U_L^A - U_L^B = 0$ and $U_R^A - U_R^B = 0$. Through the solving of $U_L^A - U_L^B = 0$ and $U_R^A - U_R^B = 0$, respectively, the following equations were obtained:

$$x_L = \frac{1}{(1+\beta)p}\left[p + \beta\alpha e - \frac{(p-\alpha e)^2}{2}\right], x_R = 1 - \frac{(p-\alpha e)^2}{2p}. \tag{7}$$

Based on the above, it is not difficult to draw the following propositions.

**Proposition 1.** *The supplier can adjust the discount coefficient in the presales stage in the following three ways to influence consumers to preorder the new product:*

(1) *When the discount coefficient in the presales stage is relatively high, that is, $x > x_R$, there is $U_L^A - U_L^B < U_R^A - U_R^B < 0$, so no consumers will buy the product in the presales stage*

(2) *When the discount coefficient in the presales stage is moderate, that is, $x_L < x \leq x_R$, there is $U_L^A - U_L^B < 0 < U_R^A - U_R^B$, so only R-type consumers will buy the product in the presales stage*

(3) *When the discount coefficient in the presales stage is low, that is, $x \leq x_L$, there is $0 < U_L^A - U_L^B < U_R^A - U_R^B$, so both types of consumers will buy the product at the presales stage*

**Proposition 2.** *shows that consumers' buying behaviors depend on the supplier's presales price discount decision and the level of service provided by the platform. According to the three different presale methods provided in Proposition 1, the part below will discuss the optimal decisions of the supplier and the e-commerce platforms. For this reason, the game sequence between the two needs to be set. In the e-commerce supply chain, the supplier is usually weaker than the e-commerce platform, and the latter often plays the dominant role, such as JD and Tmall. Therefore, it is assumed that the e-commerce platform is the leader in the Stackelberg game, which means that the platform offers its services first, and then, the supplier determines the price discount coefficient and the quantity of new products in the presales stage. According to the backward induction method, the optimal decisions of the e-commerce supply chain members can be obtained.*

*3.2. No-Presale Scenario.* If the supplier sets a high presales price for the new product, and no consumer buys it in the presales stage, the demand for the new product in the presales stage will drop to $N_1 = 0$. The premise for the two types of consumers buying in the normal sales stage is $v \geq p - \alpha e$, so the demand for the new product in the normal sales stage is

$$N_2 = \overline{F}(p - \alpha e)(N_L + N_R) = (1 - p + \alpha e)(N_L + N_R). \tag{8}$$

The joint distribution of $N_L$ and $N_R$ is a two-dimensional normal distribution. From the additivity of the normal distribution, it can be concluded that $N_2 \in N(\mu_2, \sigma_2^2)$, where $\mu_2 = (1 - p + \alpha e)(\mu_L + \mu_R)$ and $\sigma_2^2 = (1-p + \alpha e)^2(\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R)$. Let $\pi_s^1$ denote the supplier's expected profit function at this time, and then

$$\pi_s^1 = pE(\min\{Q, N_2\}) + sE(\max\{Q - N_2, 0\}) - cQ - \tau Q. \tag{9}$$

The first term on the right side of the above equation represents the revenue during the normal sales stage, the second the residual value income, the third the production cost, and the last the commission paid to the third-party platform. In order to maximize its profit, the supplier is faced with a newsboy problem model where the demand obeys normal distribution. According to the theory provided in the literature [33] and others, given the platform service level $e$, the supplier's optimal quantity of new products and maximum expected profit are as follows:

$$Q = \mu_2 + k\sigma_2 = (1 - p + \alpha e)(\mu_L + \mu_R) + k(1 - p + \alpha e)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R}, \tag{10}$$

$$\begin{aligned}\pi_s^1 &= (p - c - \tau)\mu_2 - (p - s)\varphi(k)\sigma_2 = (p - c - \tau)(1 - p + \alpha e)\mu_R + (p - c - \tau)(1 - p + \alpha e)\mu_L \\ &\quad - (p - s)\varphi(k)(1 - p + \alpha e)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R},\end{aligned} \tag{11}$$

where $k = \phi^{-1}(p - c - \tau/p - s)$, and $\phi(\cdot)$ and $\varphi(\cdot)$ represent the distribution function and density function of the standard normal distribution, respectively.

Below is how the optimal service level of the e-commerce platform is calculated. With $\pi_O^1$ denoted as the expected profit function of the platform, there is

$$\pi_O^1 = \tau Q - \frac{\gamma e^2}{2} = \tau(1 - p + \alpha e)(\mu_L + \mu_R) + \tau k(1 - p + \alpha e)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R} - \frac{\gamma e^2}{2}. \quad (12)$$

The above formula is a quadratic function of $e$, with an inverted-U shape, so there exists a unique optimal value

$$e^{1*} = \frac{\alpha\tau}{\gamma}\left(\mu_L + \mu_R + k\sqrt{\sigma_L^2 + 2\rho\sigma_L\sigma_R + \sigma_R^2}\right), \quad (13)$$

which maximizes the value of $\pi_O^1$.

Substitute the value of $e^{1*}$ into formulas (10)–(12) successively, and we obtain Proposition 2.

**Proposition 3.** *In the no-presale scenario, the optimal service level $e^{1*}$ and the maximum expected profit $\pi_O^{1*}$ of the e-commerce platform and the optimal quantity of new products $Q^{1*}$ and the maximum expected profit $\pi_s^{1*}$ of the supplier are as follows:*

$$\begin{aligned}
e^{1*} &= \frac{\alpha\tau}{\gamma}\left(\mu_L + \mu_R + k\sqrt{\sigma_L^2 + 2\rho\sigma_L\sigma_R + \sigma_R^2}\right),\\
\pi_O^{1*} &= \tau\left(1 - p + \alpha e^{1*}\right)(\mu_L + \mu_R) + \tau k\left(1 - p + \alpha e^{1*}\right)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R} -,\\
Q^{1*} &= \left(1 - p + \alpha e^{1*}\right)(\mu_L + \mu_R) + k\left(1 - p + \alpha e^{1*}\right)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R},\\
\pi_s^{1*} &= (p - c - \tau)\left(1 - p + \alpha e^{1*}\right)\mu_L + (p - c - \tau)\left(1 - p + \alpha e^{1*}\right)\mu_R - (p - s)\varphi(k)\left(1 - p + \alpha e^{1*}\right)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R}.
\end{aligned} \quad (14)$$

Through analysis of the optimal profits of e-commerce supply chain members in the no-presale scenario, the following conclusions can be drawn.

**Corollary 1.** *In the no-presale scenario, the expected profit of the e-commerce platform $\pi_O^{1*}$ increases with the increase of $\rho$, while the expected profit of the supplier $\pi_S^{1*}$ decreases with the increase of $\rho$.*

**Corollary 2.** *shows that the more correlated the numbers of the two types of consumers $N_L$ and $N_R$ are, the more favorable it is for the e-commerce platform, but the less favorable it is for the supplier because the greater $\rho$ is, the more uncertain the market demand will be, and the greater the optimal quantity of new products will be for the supplier, which will lead to a higher inventory risk and a lower expected profit, while the e-commerce platform, on the other hand, does not need to take any inventory risk, and its revenue is positively correlated with the quantity of new products sold on the platform, so its expected profit will increase as $\rho$ increases.*

*3.3. Moderate Discounted Presale Scenario.* When the presales price set by the supplier is moderate, all $R$-type consumers will buy the new products in the presales stage, while all $L$-type ones will only buy them during the normal sales stage. Therefore, the new product demand in the presales stage and the normal sales stage is, respectively, $N_1 = N_R$ and $N_2 = \overline{F}(p - \alpha e)N_L$. Note that the joint distribution of $(N_L, N_R)$ is a bivariate normal distribution, with a correlation coefficient of $\rho$, and thus, the joint distribution of $(N_1, N_2)$ is also a bivariate normal distribution, and $(N_1, N_2) \in N(\mu_R, \overline{F}(p - \alpha e)\mu_L, \sigma_R^2, [\overline{F}(p - \alpha e)\sigma_L]^2, \rho)$.

At the end of the presales stage, the value of $N_1$ is known to be $n_1$, and the supplier will predict the market demand $N_2$ in the normal sales stage based on the sales in the presales stage. According to the conclusion of literature [34], the conditional distribution $(N_2|N_1 = n_1)$ in the normal sales stage still obeys the normal distribution, and its mean and standard deviation are, respectively,

$$\mu_2' = \mu_2 + corr(N_1, N_2)(n_1 - \mu_1)\frac{\sigma_2}{\sigma_1} = \overline{F}(p - \alpha e)\mu_L + \rho(n_1 - \mu_R)\frac{\overline{F}(p - \alpha e)\sigma_L}{\sigma_R}, \quad (15)$$

$$\sigma_2' = \sigma_2\sqrt{1 - \mathrm{corr}^2(N_1, N_2)} = \overline{F}(p - \alpha e)\sigma_L\sqrt{1 - \rho^2}. \quad (16)$$

Let $\pi_s^2$ denote the supplier's expected profit function at this time, and then

$$\pi_s^2 = E_{N_1}\left[(xp - c - \tau)N_1\right] + E_{N_2|N_1=n_1}\left[p\min\{Q, N_2\} + s\max\{Q - N_2, 0\} - cQ - \tau Q\right]. \quad (17)$$

The first term on the right side of the above equation represents the expected profit of the supplier in the presales stage, and the second represents its profit in the normal sales stage. In order to maximize its profit, the supplier is faced with a newsboy problem model where the demand obeys a normal distribution in the normal sales stage. According to the conclusion of literature [33], given the platform service level $e$, based on $E(n_1) = \mu_R$, it can be concluded that the optimal quantity of new products and the maximum expected profit of the supplier during the normal sales stage are as follows:

$$Q = \mu_2' + k\sigma_2' = (1 - p + \alpha e)\mu_L + \rho(n_1 - \mu_R)\frac{(1 - p + \alpha e)\sigma_L}{\sigma_R} + k(1 - p + \alpha e)\sigma_L\sqrt{1 - \rho^2}, \quad (18)$$

$$\begin{aligned}\pi_s^2 &= E_{N_1}\left[(xp - c - \tau)N_1 + (p - c - \tau)\mu_2' - (p - s)\varphi(k)\sigma_2'\right] \\ &= (xp - c - \tau)\mu_R + (p - c - \tau)(1 - p + \alpha e)\mu_L - (p - s)\varphi(k)(1 - p + \alpha e)\sigma_L\sqrt{1 - \rho^2}.\end{aligned} \quad (19)$$

Given the service level $e$ of the e-commerce platform, through comparison of formulas (11) and (19), the following conclusions can be found: (1) when there is a presales activity, the supplier's inventory risk $(p - s)\varphi(k)(1 - p + \alpha e)\sigma_L\sqrt{1 - \rho^2}$ is significantly lower than that in the no-presale scenario, i.e., $(p - s)\varphi(k)(1 - p + \alpha e)\sqrt{\sigma_L^2 + \sigma_R^2 + 2\rho\sigma_L\sigma_R}$; (2) the presale strategy increases the demand of $R$-type consumers by $(p - \alpha e)\mu_R = \mu_R - (1 - p + \alpha e)\mu_R$; (3) the marginal profit of $R$-type consumers decreases due to the discount offered during the presales stage. Therefore, when deciding whether to adopt the presale strategy, the supplier needs to weigh its inventory risk and the relationship between the consumer demand and its profit margin.

The discounted presales price is the core of the presale strategy. According to Proposition 1, in order to attract $R$-type consumers to preorder the products, the presales price needs to be set at $xp \le p - (p - \alpha e)^2/2$; because the supplier's objective is to maximize its expected profit and to achieve this objective, it needs to set the discounted price as high as possible to extract all consumers' surplus, that is,

$$x = 1 - \frac{(p - \alpha e)^2}{2p}. \quad (20)$$

Substitute equation (20) into equation (19), and we obtain the supplier's expected profit as follows:

$$\pi_s^2 = \left(c\alpha e - cp + \frac{p^2 - \alpha e^2}{2}\right) + (p - c - \tau)(1 - p + \alpha e)\mu_R + (p - c - \tau)(1 - p + \alpha e)\mu_L - (p - s)\varphi(k)(1 - p + \alpha e)\sigma_L\sqrt{1 - \rho^2}. \quad (21)$$

From equation (21), it can be seen that the supplier's expected profit function consists of four parts. The two terms in the middle are the same as the maximum expected profit formula (11) in the no-presale strategy. The first term presents the income (which may be negative) brought by the increase in demand after the deduction of the loss caused by the price discount when the supplier adopts the presale strategy, and the last term measures the loss brought by the inventory risk caused by the uncertainty in the demand of the $L$-type consumers.

Below is how the optimal decision of the e-commerce platform is obtained. Let $\pi_O^2$ represent the expected profit function for the platform, and there is

$$\begin{aligned}\pi_O^2 &= E\left[\tau(N_1 + Q)\right] - \frac{\gamma e^2}{2} = \tau\mu_R + \tau(1 - p + \alpha e)\mu_L \\ &\quad + \tau k(1 - p + \alpha e)\sigma_L\sqrt{1 - \rho^2} - \frac{\gamma e^2}{2}.\end{aligned} \quad (22)$$

The above formula is a quadratic function of $e$, with an inverted-U shape, so there exists a unique optimal value

$$e^{2*} = \frac{\alpha\tau\mu_L + k\alpha\tau\sigma_L\sqrt{1 - \rho^2}}{\gamma}, \quad (23)$$

which maximizes the value of $\pi_O^2$.

Substituting the value of $e^{2*}$ into formulas (18) and (20)–(22) successively, and we obtain the following proposition.

**Proposition 4.** *In the moderately discounted presale scenario, the optimal service level $e^{2*}$ and the maximum expected profit $\pi_O^{2*}$ of the e-commerce platform, and the optimal discount rate $x^{2*}$, the optimal quantity of new products $Q^{2*}$ in the normal sales stage, and the maximum expected profit $\pi_s^{2*}$ for the supplier in the two stages are, respectively,*

$$
\begin{aligned}
e^{2*} &= \frac{\alpha\tau\mu_L + k\alpha\tau\sigma_L\sqrt{1-\rho^2}}{\gamma},\\
\pi_O^{2*} &= \tau\mu_R + \tau\left(1-p+\alpha e^{2*}\right)\mu_L + \tau k\left(1-p+\alpha e^{2*}\right)\sigma_L\sqrt{1-\rho^2} - \frac{\gamma\left(e^{2*}\right)^2}{2},\\
x^{2*} &= 1 - \frac{\left(p-\alpha e^{2*}\right)^2}{2p},\\
Q^{2*} &= \left(1-p+\alpha e^{2*}\right)\mu_L + \rho\left(n_1-\mu_R\right)\frac{\left(1-p+\alpha e^{2*}\right)\sigma_L}{\sigma_R} + k\left(1-p+\alpha e^{2*}\right)\sigma_L\sqrt{1-\rho^2},\\
\pi_s^{2*} &= \left(c\alpha e^{2*} - cp + \frac{p^2-\alpha\left(e^{2*}\right)^2}{2}\right) + (p-c-\tau)\left(1-p+\alpha e^{2*}\right)\mu_R + (p-c-\tau)\left(1-p+\alpha e^{2*}\right)\mu_L\\
&\quad - (p-s)\varphi(k)\left(1-p+\alpha e^{2*}\right)\sigma_L\sqrt{1-\rho^2}.
\end{aligned}
\tag{24}
$$

Through the analysis of the optimal profits of the e-commerce supply chain members under the moderately discounted presale scenario, the following conclusions can be drawn.

**Corollary 3.** *In the moderately discounted presale scenario, the following conclusions hold:*

*(1) The expected profit of the e-commerce platform $\pi_O^{2*}$ decreases with the increase of $\rho$, while the expected profit of the supplier $\pi_S^{2*}$ increases with the increase of $\rho$*

*(2) The supplier's optimal discount rate $x^{2*}$ increases as the e-commerce platform's optimal service level $e^{2*}$ increases*

*(3) The supplier's optimal discount rate $x^{2*}$ increases as the elasticity coefficient of the platform's service level $\alpha$ increases*

The first conclusion in Corollary 2 is exactly the opposite of Corollary 1. This is because the larger the correlation coefficient $\rho$ between $N_L$ and $N_R$ is, the more accurate the supplier's prediction of the demand in the normal sales stage will be based on the information of the presales, and accordingly, the lower inventory risk the supplier will have in the normal sales stage. When the two are completely correlated (that is, $\rho = \pm 1$), the supplier will have no inventory risk. Therefore, when $\rho$ is high, the optimal quantity of new products for the supplier will decrease due to the reduced inventory risk, which will lead to a decrease in the expected profit of the e-commerce platform, while the supplier's expected profit will increase due to the higher benefit from reduced inventory risk. The second conclusion indicates that with the improvement of the e-commerce platform service level, the marginal profit per unit of the new products in the presales stage will increase, which will further encourage the supplier to use the presale strategy on the e-commerce platform. Similarly, the third conclusion shows that with the increase of the elasticity coefficient of the platform's service level, the optimal discount rate of the supplier's presale will also increase correspondingly, which will attract more suppliers to adopt the presale strategy on the e-commerce platform.

*3.4. Complete Presale Scenario.* If the supplier sets a low presales price, all consumers will buy the new products in the presales stage, so the number of consumers buying new products in the normal sales stage will be reduced to $N_2 = 0$, while that in the presales stage will be $N_1 = N_R + N_L$. At the end of the presales stage, the quantity of new products prepared by the supplier is exactly equal to the quantity preordered by consumers in the presales stage, that is, $n_1 = \mu_R + \mu_L$. Therefore, the expected profit function for the supplier is

$$\pi_s^3 = (xp-c-\tau)\mu_R + (xp-c-\tau)\mu_L. \tag{25}$$

According to Proposition 1, in order for both types of consumers to buy the new products in the presales stage, the discounted price of the new products in the presales stage must satisfy $xp \leq 1/(1+\beta)[p+\beta\alpha e - (p-\alpha e)^2/2]$. The supplier's objective is to maximize its expected profit, so obviously, it will set the discounted price as high as possible to extract the surplus of all consumers, that is,

$$x = \frac{1}{(1+\beta)p}\left[p + \beta\alpha e - \frac{(p-\alpha e)^2}{2}\right]. \tag{26}$$

Substitute equation (26) into equation (25), and we obtain the supplier's expected profit:

$$\pi_s^3 = \left\{ \frac{1}{(1+\beta)} \left[ p + \beta\alpha e - \frac{(p-\alpha e)^2}{2} \right] - c - \tau \right\} (\mu_R + \mu_L). \tag{27}$$

The final step is to obtain the optimal decision of the e-commerce platform. Let $\pi_O^3$ represent the expected profit function of the platform, and there is

$$\pi_O^3 = \tau(\mu_R + \mu_L) - \frac{\gamma e^2}{2}. \tag{28}$$

The above formula is a quadratic function of $e$, and the coefficient of the first-order term is 0, so the optimal service level of the e-commerce platform $e^{3*} = 0$. From this, Proposition 4 can be derived.

**Proposition 5.** *In the complete presales scenario, the optimal service level $e^{3*} = 0$, the maximum expected profit $\pi_O^{3*}$ of the e-commerce platform, and the optimal discount rate $x^{3*}$ and the maximum expected profit $\pi_s^{3*}$ of the supplier are calculated by the following three formulas:*

$$\pi_O^{3*} = \tau(\mu_R + \mu_L), x^{3*} = \frac{1}{1+\beta} - \frac{P}{2(1+\beta)}, \pi_s^{3*} = \left[ \frac{1}{1+\beta} \left( p - \frac{p^2}{2} \right) - c - \tau \right] (\mu_R + \mu_L). \tag{29}$$

Through the analysis of the optimal decisions of e-commerce supply chain members in the complete presale scenario, the following conclusions can be drawn.

**Corollary 4.** *In the complete presale scenario, the following conclusions hold:*

*(1) The maximum expected profits of e-commerce supply chain members $\pi_O^{3*}$ and $\pi_S^{3*}$ are independent of $\rho$*

*(2) The maximum expected profits of e-commerce supply chain members $\pi_O^{3*}$ and $\pi_S^{3*}$ are independent of the service level e of the e-commerce platform*

*(3) The optimal discount rate $x^{3*}$ and the maximum expected profit $\pi_S^{3*}$ for the supplier both decrease as the loss aversion degree $\beta$ of the L-type consumers increases*

The first conclusion in Corollary 3 is clearly established because both types of consumers have preordered the new products in the presales stage, which means that the supplier can set its production output directly based on the known market demand without any inventory risk, so the maximum expected profits of the e-commerce supply chain members are certainly independent of $\rho$. The second conclusion is established because the discounted price offered by the supplier in the presales stage is low enough to attract all consumers to buy its new products in the presales stage. At this point, it will make no difference if the platform improves its service level. The third conclusion is in line with our intuition. When the $L$-type consumers show their loss aversion in the presales stage, the supplier will have to reduce the presales price of the new products in order to make them place orders, thereby reducing the supplier's marginal profit per unit of product and leading to a decline in its maximum expected profit.

**Corollary 5.** *The relationship between the optimal discount rate $x^{3*}$ for the supplier in the complete presale scenario and the one $x^{2*}$ in the moderately discounted presale scenario satisfies the following: when $\beta \le p^2 - (p - \alpha e^{2*})^2/2p - p^2$, $x^{3*} \ge x^{2*}$, and when $\beta > p^2 - (p - \alpha e^{2*})^2/2p - p^2$, $x^{3*} < x^{2*}$.*

The conclusion in Corollary 4 shows that the optimal discounted price $x^{3*}p$ in the complete presale scenario may not be lower than the one $x^{2*}p$ in the moderately discounted presale scenario, which is obviously different from the conclusion drawn in literature [19]. In the latter, it is concluded that the optimal discounted price in the complete presale scenario is always lower than the one in moderately discounted presale scenario, as the price of the new products needs to be even lower to attract the $L$-type consumers than the $R$-type ones in the presales stage, but this conclusion is drawn without regard to the service level of the platform. The research in this paper shows that when $e^{3*} = 0$, and the consumers are less loss averse, the situation that $x^{3*}p \ge x^{2*}p$ may occur. The reason is that when the service level of the e-commerce platform $e > 0$, the $R$-type consumers' valuation of the new product will increase from $V$ to $V + \alpha e$, which means that the market demand for the new products will expand. To attract these additional $R$-type consumers to preorder the products, the supplier may have to offer a lower price than $x^{3*}p$. In addition, Corollary 4 would enrich and optimize the theoretical basis of the e-commerce supply chain that has implications for practitioners in some ways. The value of the optimal discount price under different presale modes is related to the level of loss aversion of consumers. When the level of loss aversion of consumers is high, the supplier should set the optimal discount price for the complete presale scenario to be lower than the optimal discount price for a moderately discounted presale scenario. When the level of loss aversion of consumers is low, the supplier should set the optimal discount price for the complete presale scenario higher than the optimal discount price for a moderately discounted presale scenario.

## 4. Numerical Analysis

The above model discusses the optimal decision of each member in the e-commerce supply chain when different presale strategies are chosen. The following section will further explore how the coefficient of correlation between the numbers of $L$-type and $R$-type consumers, the loss aversion degree of $L$-type consumers, and the marginal profit per unit of the new product affect the presale strategies of the e-commerce supply chain members, through numerical analysis. Let $P = 0.55$, $c = 0.2$, $s = 0.1$, $\beta = 0.04$, $\rho = 0.4$, $\mu_L = \mu_R = 25$, $\sigma_L = \sigma_R = 5$, $\alpha = 0.1$, $\gamma = 1$, $\tau = 0.05$, $k = \phi^{-1}(p - c - \tau/p - s)$, and $\phi(\cdot)$ and $\varphi(\cdot)$ denote the distribution function and density function of the standard normal distribution, respectively.

Figures 2 and 3 show the effects of the changes in the correlation coefficient $\rho$ on the maximum expected profits of e-commerce supply chain members, verifying the first conclusion in Corollary 1, Corollary 2, and Corollary 3. From Figure 2, it can be seen that when the correlation coefficient $\rho$ between the two types of consumers increases, the supplier will gain more income from the presale strategy with a moderate discount. This is because a higher $\rho$ value means the supplier updates and forecasts the new product demand in the normal sales stage more accurately, which can reduce the supplier's inventory risk and increase its expected profit. Therefore, when the correlation coefficient $\rho$ is high, the supplier should choose the presale strategy with a moderate discount. The higher the inventory risk of new products is, the more beneficial it will be to the e-commerce platform, so from Figure 3, it can be seen that the larger the correlation coefficient $\rho$ is, the greater inventory risk the supplier will have under the no-presale strategy, and the more beneficial it will be to the e-commerce platform, and in this case, the e-commerce platform will prefer the no-presale strategy.

Figure 4 shows the effects of the changes in the loss aversion coefficient $\beta$ of consumers on the supplier's maximum expected profit. It can be seen that the loss aversion coefficient $\beta$ of consumers has no effect on the supplier under the no-presale strategy and the presale strategy with a moderate discount, because, under these two strategies, $L$-type consumers did not buy new products in the presales stage, and natural loss aversion is out of the question. Under the complete presale strategy, however, the supplier's maximum expected profit is negatively correlated with the consumers' loss aversion. In addition, Figure 4 also shows that when the value of $\beta$ is small, the complete presale strategy can bring greater expected profit to the supplier than the other two, as in this case, it is easier for the supplier to encourage both $L$-type and $R$-type consumers to preorder new products. Therefore, when the consumers are less loss averse, the supplier should better choose the complete presale strategy.

Figure 5 shows the relationship between the consumers' loss aversion coefficient $\beta$ and the supplier's optimal discount rate for presales, which is consistent with the conclusion in Corollary 4. From Figure 5, it can be seen that, in the moderately discounted presale scenario, the optimal discount rate is independent of the consumers' loss aversion coefficient $\beta$, while, in the complete presale scenario, the optimal discount rate decreases monotonically as the consumers' loss aversion coefficient $\beta$ increases, and when the value of $\beta$ is small, the optimal discount rate in the complete presale scenario may be greater than that in the moderately discounted presale scenario. This also means that when the

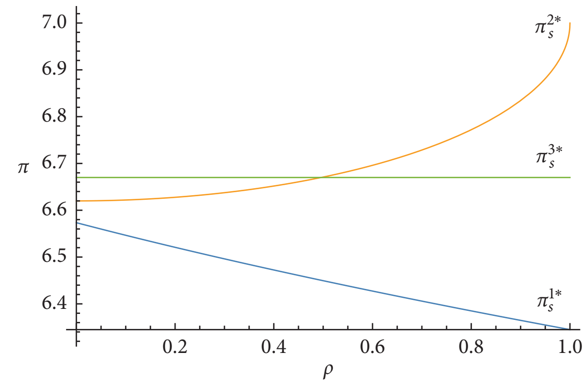


Figure 2: Effects of $\rho$ on the maximum expected profit of the supplier.

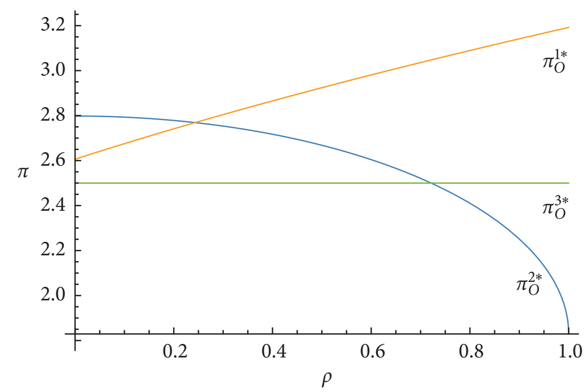


Figure 3: Effects of $\rho$ on the maximum expected profit of the e-commerce platform.

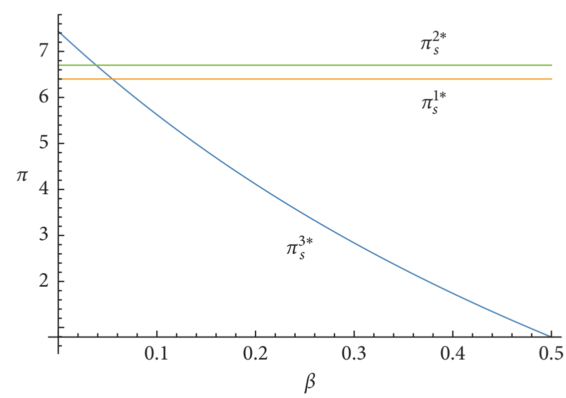


Figure 4: Effects of $\beta$ on the maximum expected profit of the supplier.

e-commerce platforms provide services in the presales of new products, the supplier may not need to set a minimum discounted price to have $L$-type consumers who are less loss averse to preorder new products.

Finally, let us take a look at the effects of the marginal profit per unit of new product $(p - c - \tau)$ in the normal sales stage on the supplier's presale strategy. With other parameters unchanged, let the value of $p$ increase from 0.5 to 0.8. Figure 6 shows the effects of the marginal profit per unit of new product $(p - c - \tau)$ on the supplier's

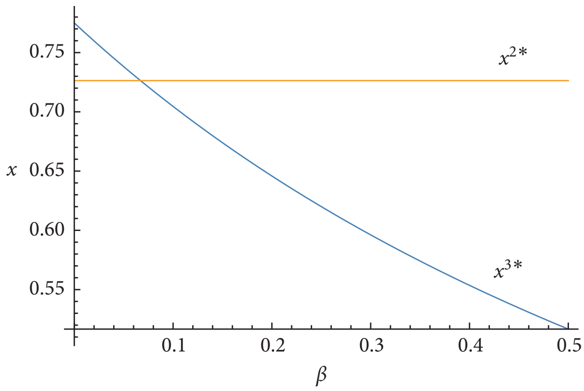


FIGURE 5: Effects of $\beta$ on the optimal discount rate for presales.

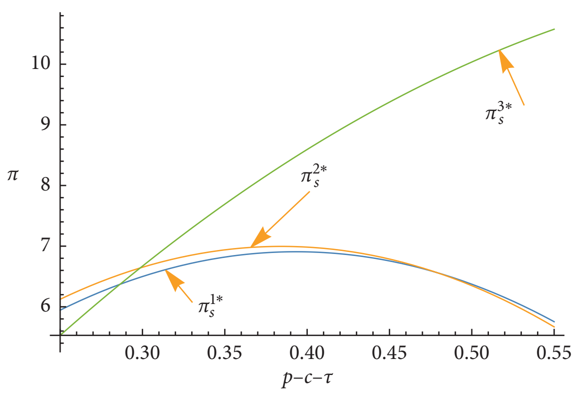


FIGURE 6: Effects of the marginal profit $(p - c - \tau)$ on the supplier's presale strategy.

maximum expected profit. It can be seen that, as the marginal profit per unit of new product increases, the maximum expected profit of the supplier in the complete presale scenario is significantly higher than that in the other two scenarios. This means that when the marginal profit per unit of new product is high in the normal sales stage, the supplier is more likely to offer a larger price discount and adopt the complete presale strategy.

## 5. Conclusions

This paper studied the optimal decisions of the e-commerce supply chain members on new product presales under random demands assuming that there are both loss averse and rational consumers and discussed how some features of consumer demands in the sales periods (consumers' loss aversion and correlation between the numbers of $R$-type and $L$-type consumers) and the marginal profit per unit of the new product affect the presale strategies of the e-commerce supply chain members. The results of the research are as follows:

(1) Under the three different strategy models—no-presale, presale with moderate discount, and complete presale strategies— considering the different values of new products expected by consumers, the optimal price discount for presales, the optimal product quantity, the optimal service level, and the maximum expected profit for e-commerce supply chain members were obtained. The relevant conclusions can provide some theoretical basis for e-commerce supply chain members when they are making presale decisions on new products.

(2) When there is a strong correlation between the numbers of the two types of consumers, the supplier will tend to choose the presale strategy with a moderate discount, while the e-commerce platform may prefer the no-presale strategy. The supplier may collect the demand information on the new products during the presales stage and use it to predict the demand in the normal sales stage, and then, it will obtain the optimal product quantity. The larger the correlation coefficient $\rho$, the more accurate the demand prediction, so through presales with a moderate discount, part of the supplier's inventory risk can be transferred to consumers, thereby increasing the supplier's profit, but the commission of the e-commerce platform will decrease.

(3) In the complete presale scenario, the supplier's maximum expected profit $\pi_S^{3*}$ and optimal discount rate $x^{3*}$ both decrease as the loss aversion degree $\beta$ of the $L$-type consumers increases. The demand from $L$-type consumers becomes uncertain due to their aversion to loss. In order to reduce loss aversion and encourage them to preorder new products, the supplier usually has to reduce the price of new products in the presales stage to increase the utility obtained by $L$-type consumers, thereby reducing the supplier's marginal profit per unit of product, and leading to a reduction in its maximum expected profit.

(4) When the marginal profit is high in the normal sales stage, the supplier is more inclined to encourage consumers to preorder products by offering a larger discount; in other words, the supplier is more likely to choose the complete presale strategy to transfer the inventory risk completely to consumers. In addition, the research also obtained a different conclusion from those in previous studies: when consumers are less loss averse, the optimal discounted price for the supplier in the complete presale scenario may be higher than that in the moderately discounted presale scenario.

The results also provide significant managerial insights for relevant firms that are involved in the e-commerce supply chain. For the supplier, the selection of appropriate presale strategies for new products should take full account of the service level of the e-commerce platform, the correlation between the two types of consumers, and the degree of loss aversion of $L$-type consumers and maximize expected profits by setting the optimal presale discount price. For the e-commerce platform, it should choose the appropriate service level according to the presale strategy provided by the supplier and the market situation and realize the win-win profit of the supply chain system through mutual cooperation.

The research conclusions of this paper provide some normative guidance for suppliers in selecting the presale strategies for new products to be sold on e-commerce platforms, but this research did not consider consumers' return behaviors after the end of the sales period. On the one hand, the return of goods will increase suppliers' costs as the returned goods need to be repackaged and shipped; on the other hand, it may increase suppliers' inventories, forcing new products to be sold at their residual values and thus reducing suppliers' profit margins. Therefore, allowing consumers to return goods will have quite different effects on the presale strategies adopted in the e-commerce supply chain, which will be the focus of future research.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

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

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