Pricing Game Models of Hybrid Channel Supply Chain: A Strategic Consumer Behavior Perspective

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Abstract: The current sales model combining online and offline channels meets the diverse requirements of consumers. However, consumers’ inter-channel switching behavior and strategic behavior also pose significant challenges to pricing decisions in the hybrid channel. Using game theory and consumer utility theory, a retailer-driven pricing model is developed to study the optimal pricing problem for each channel in a mixed-channel supply chain considering the characteristics of channel competition and the waiting behavior of strategic consumers. Study results show there is a negative correlation between the proportion of strategic consumers and the optimal pricing and profit of each channel, and as the proportion of strategic consumers rises, the optimal pricing and profit of manufacturers and retailers all trend downward. Incorporating strategic consumers into the pricing model will assist the supply chain in elucidating the behavior of consumer heterogeneity during various decision-making periods and in making reasonable pricing decisions. Effective guiding strategies, such as pre-discount and purchase restrictions, can reduce the profit loss caused by strategic consumer behavior. The optimal combination of pre-announcement discount and strategic consumer ratio can generate the greatest profit for retailers and the supply chain.

Keywords: hybrid channel supply chain; strategic consumer; Stackelberg; restricted; pre-discount

1. Introduction

Today, the rapid growth of online sales channels encourages manufacturers and retailers to actively investigate their own online channels. Traditional offline sales channels also hold a portion of the market, so a combination of online and offline sales is becoming the norm. A mixed-channel supply chain is a new supply-chain model developed with the development of e-commerce and the Internet and has become the mainstream of the market. Compared with the traditional supply chain, the mixed-channel supply chain enables both manufacturers and retailers to reach consumers at the end of the supply chain. In addition, consumers have more convenient access to information, and cross-period price reference behavior of consumers is becoming more and more common, making the pricing problem of the mixed-channel supply chain more difficult.

Under the current environment, various discount shopping festivals (such as 618 and Double 11) are frequently held and a large number of Internet price-comparison tools around consumers all pass on the information of more affordable purchases during the discount period to consumers, which has greatly promoted consumers’ attention to prices and indirectly increased the proportion of strategic consumers in the market. Strategic consumers, as consumers with intertemporal utility, will choose to wait for a discount before purchasing to maximize their utility to grab the profits of supply-chain enterprises [1]. Strategic consumers’ attention to price makes them have very low purchase intention during the positive price period and prefer to wait for the discount period. The behavior of strategic consumers has seriously damaged the interests of supply-chain enterprises.
Therefore, how to reduce the negative influence of strategic consumers’ strategic behavior, and formulating reasonable pricing strategies has become a research hotspot in supply-chain management.

The current state of research on hybrid online and offline sales pricing revolves around developing effective pricing strategies that consider both online and offline channels. Some recent studies have focused on optimizing pricing decisions in the mixed sales mode by incorporating consumer behavior and preferences, supply-chain dynamics, and market competition. For instance, researchers have explored the impact of strategic consumers’ behavior on pricing decisions in the mixed sales mode [2]. Other studies have investigated the role of promotions and discounts in hybrid sales pricing, examining how different types of discounts, such as bundle discounts and volume discounts, affect pricing decisions in the mixed sales mode [3]. Moreover, some studies have also examined the impact of channel integration on hybrid online and offline sales pricing. For instance, researchers have explored the role of online-offline channel integration in the price of hybrid sales channels, finding that channel integration can improve pricing decisions in the mixed sales mode by reducing the information asymmetry between online and offline channels [4]. Another study has examined the impact of consumer preferences on pricing decisions in the hybrid sales mode, finding that consumer preferences for channel diversity and product variety can significantly affect pricing decisions in the mixed sales mode [5].

As the research on hybrid online and offline sales prices is still developing, there are some shortcomings in the current studies. (1) Most of the literature on mixed channels only focuses on retailers or manufacturers, and the research on mixed-channel supply chains containing upstream and downstream structures of supply chains is relatively scarce. (2) Aiming at the current frequent promotion of commodities, the impact of strategic consumer behavior on pricing problems of manufacturers and retailers in different periods is studied.

This paper addresses the challenges posed by strategic consumer behavior and inter-channel switching in mixed sales channels, which is a crucial issue for retailers and manufacturers. The study also examines the effects of purchase restrictions, pre-release discounts, and combination strategies on the optimal price and profit of each supply-chain channel. Moreover, the study provides effective guiding strategies, such as pre-discount and purchase restrictions that can reduce the profit loss caused by strategic consumer behavior. The optimal combination of pre-announcement discount and strategic consumer ratio can generate the greatest profit for retailers and the supply chain. Overall, the article presents a comprehensive approach to address the challenges of pricing decisions in the hybrid online and offline sales mode and provides useful insights for retailers and manufacturers to make informed pricing decisions.

The remainder of this paper is organized as follows: In Section 2, the literature review is made for this research, and Section 3 describes the two-stage multi-channel sales model and related parameter settings. In Section 4, we studied the influence of strategic consumer behavior on supply-chain pricing based on the Stackelberg game dominated by retailers. Finally, Section 5 makes a summary and puts forward the future research direction.

2. Literature Review

The mixed-channel model that includes both manufacturers and retailers is now widely acknowledged. The development of the network has surpassed the limitations of price and location, therefore gratifying consumers’ demand for channel diversity, while simultaneously complicating the relationship between manufacturers and retailers [6]. According to research, moderate channel conflict improves retailers’ and manufacturers’ competitiveness, whereas excessive channel conflict causes consumers to lose interest in shopping [7]. In recent years, it has been challenging to manage the supply chain by focusing solely on the manufacturers’ and retailers’ strategies due to incomplete information, market volatility, and divergent consumer preferences. In the mixed-channel supply chain, consumers’ channel preference and product pricing strategy will impact their ultimate
decision [8]. For instance, Cai et al. [9] studied the impact of service quality on dual-channel optimal price; Liao et al. [10] discussed the impact of consumers’ green preference on supply-chain pricing decisions; Chen et al. [11] studied the impact of consumer comments on supplier pricing; and Zhang et al. [12] studied the impact of consumer scarcity sensitivity on pricing. In addition, the network acceptability [13], patience [14], and preferences [15,16] of consumers as well as other factors influence the multi-channel price. For example, several studies have investigated the impact of various factors, such as consumer fairness concerns [17,18], risk preference [19], loss aversion [20], and sensitivity to product quality differences [21–24]. Additionally, researchers have studied the influence of consumer loyalty, patience, and preferences on pricing in dual-channel supply chains [22,23]. The results show that considering consumer behavior can have a significant impact on the supply chain and overall profitability. Overall, the literature suggests that consumer behavior should be a crucial consideration for channel managers when making pricing decisions.

Due to the Internet’s influence, consumers are more informed than ever before. Although some enterprises are reluctant to disclose preferential information on the Internet, consumers can still use the Internet to track and predict the preferential information and product prices of enterprises and make decisions to maximize their own benefits accordingly [25]. In this case, the influence of consumers’ strategic behavior is particularly prominent [26]. Although this behavior is beneficial to consumers, it seriously damages the interests of supply-chain members, poses new challenges to the preferential policies of the platform, and urges many scholars to start studying issues related to strategic behavior. Fan et al. [27] studied the influence of the learning behavior of strategic consumers on the dynamic pricing and inventory mechanism of retailers. Zhou et al. [28] studied the dynamic pricing of perishable goods in the presence of strategic consumers, and the results showed that the profit when considering the behavior of strategic consumers was higher than that when ignoring strategic consumers. Zhao et al. [29] studied the influence of the proportion of strategic consumers on the optimal price of retailers in two periods of environment, and the results showed that there was a certain threshold for the proportion of strategic consumers; When it is lower than this threshold, it is the best pricing strategy to transfer all strategic consumers to the last quarter; Above this threshold, the price reduction in the early stage of the sales season is optimal for both short-sighted and strategic consumers. At present, pre-sale is particularly popular in the e-commerce industry. To curb the waiting behavior of strategic consumers, sellers must lower consumer expectations during the promotion period [30], and purchase restriction and pre-sale [31,32] are the most commonly used means. Chen et al. [33] can restrain strategic behavior by booking or reducing prices so that retailers can obtain sales information in advance. Pre-sale strategy can help sellers collect strategic consumer information in advance to adjust future arrangements and reduce the future impact of strategic behavior. Li et al. [34] established a two-cycle model to study the influence of strategic consumers on the discount pricing strategy of the platform, and to study the inhibitory effect of the purchase-restriction policy on consumers’ strategic behavior; Making reasonable pricing decisions in response to the waiting behavior of strategic consumer has become a hot issue in academia and enterprises. Li et al. [35] studied the influence of a pre-announced price strategy on supply-chain pricing.

The present study focuses on the impact of strategic consumer behavior on a retailer-led mixed-channel supply chain. It aims to investigate the following research questions: (1) How does the channel transfer behavior of strategic consumers affect the competition and profit of mixed channels? (2) How does the strategic behavior of consumers affect their two-stage purchase decision in the mixed-channel supply chain? (3) What are the optimal price and profit strategies for the supply chain when considering the impact of strategic consumer behavior, and how can strategic behavior be restrained to achieve the best result?

Compared to existing studies, the present study focuses specifically on the retailer-led mixed-channel supply chain and considers the impact of strategic consumer behavior on the supply chain’s pricing and profit strategies. Although many previous studies have investigated the impact of consumer behavior on pricing decisions in multi-channel supply
chains, few have focused on the impact of strategic consumer behavior in a retailer-led mixed-channel supply chain. Furthermore, the present study seeks to investigate the optimal price and profit strategies for the supply chain while considering the impact of strategic consumer behavior, which is a topic that has received relatively little attention in the literature.

Under the environment of e-commerce, the influence of consumer strategic behavior is more and more obvious. Relevant scholars have researched how to inhibit strategic consumption behavior and achieved fruitful results. However, most of these studies ignore the impact of the upstream and downstream structure of the supply chain. The main contributions of this paper are as follows: (1) The influence of strategic consumers on channel pricing is studied in the mixed-channel sales model; (2) The periodic utility model based on strategic consumer behavior is established, and the influence of strategic consumer proportion, pre-discount, and purchase-restriction strategy on the optimal price of each channel is discussed. (3) The effectiveness of the portfolio pricing strategy has been confirmed in the current environment, which provides some theoretical guidance and a decision-making basis for managers to solve the current pricing problems.

3. Model Description

3.1. Models and Assumptions

It is presumed that the supply chain consists of manufacturers M and dual-channel retailers, with retailers as the Stackelberg game leaders and manufacturers as followers; the market contains both strategic and tactical consumers. Durable commodities are sold concurrently by manufacturers and retailers on the market. As depicted in Figure 1, the sales cycle consists of a normal sales period and a discount sales period, both of which are cyclical and sold through three channels.

The basic assumptions of the model are as follows:

1. The mixed-channel supply chain consists of dual-channel manufacturers and dual-channel retailers. To make the model more general, manufacturers and retailers sell homogeneous products.

2. There are dominant enterprises in the supply chain, and the traditional sales model is that manufacturers control the sales of products and control the sales channels and prices of products. However, some large retailers gradually occupy the dominant position in the supply chain due to their unique advantage of being close to end consumers. Considering this fact, this article uses a retailer-led model for modeling and analysis.

3. There is a certain risk in the competition of mixed channels, and the target customers of both sides overlap to create competition; If one side of the supply chain is too competitive, it will destroy the market balance, and excessive competition will make the retail channel members lose their vitality and even withdraw from the supply
chain in retaliation. To maintain the universality of the model, it is assumed that the profit of each channel is positive; otherwise, the products will not be sold through this channel. In addition, the goods are sold separately, so there are no bundled sales, and consumers will not make repeated purchases. Both manufacturers and retailers are risk-neutral, and they have no obvious preference for risks.

(4) Considering that the difference in cost and market position between retailers in a competitive market may be much smaller than that between suppliers and retailers, and for the convenience of calculation, it is assumed that all retailers’ parameters are symmetrical; Although this limitation does not meet the actual situation, it is still possible to obtain representative conclusions with certain reference value through analysis.

3.2. Symbol Description

A description of various symbols used in the model is shown in Table 1:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Symbol Description and Its Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>Potential market demand</td>
</tr>
<tr>
<td>$\alpha, \beta$</td>
<td>Manufacturer online preference, retail online channel preference, $\alpha, \beta \in [0, 1]$, $\alpha + \beta &lt; 1$</td>
</tr>
<tr>
<td>$k_i$</td>
<td>The proportion of strategic consumers corresponding to the channel, the subscripts 1, 2, and 3 represent direct sales, online, and offline channels, respectively</td>
</tr>
<tr>
<td>$b, r$</td>
<td>$b$ represents the price sensitivity coefficient, $r$ represents the cross-price elasticity between channels Subscripts $m, 1,$ and 2, respectively, indicate the manufacturer’s direct sales channels, online retail, and offline retail</td>
</tr>
<tr>
<td>subscript $i$</td>
<td></td>
</tr>
<tr>
<td>superscript $j$</td>
<td>$j = T_1$ indicates the normal sales period, $j = T_2$ indicates the discount period</td>
</tr>
<tr>
<td>$c, c_i$</td>
<td>$c$ is the manufacturer’s production cost; $c_i$ represents the sales cost of different channels, generally default $c &lt; c_i$</td>
</tr>
<tr>
<td>$w_1$</td>
<td>$w_1$ is the wholesale price in the online retail channel, and $w_2$ is the wholesale price in the offline retail channel</td>
</tr>
<tr>
<td>$p_m$</td>
<td>$p_m$ is the manufacturer’s direct selling price in online channels, $p_1$ is the retail channel online selling prices, and $p_2$ is the retail channel offline selling price</td>
</tr>
<tr>
<td>$v$</td>
<td>utility of commodity</td>
</tr>
<tr>
<td>$h$</td>
<td>The range of $h \in (0, 1)$, which is the probability of consumers obtaining goods when the purchase restriction is implemented</td>
</tr>
<tr>
<td>$U$</td>
<td>Consumer utility</td>
</tr>
<tr>
<td>$D$</td>
<td>$D_{m}, D_1$ and $D_2$ are direct sales channel demand, retailer online demand, and offline demand</td>
</tr>
<tr>
<td>$\Pi$</td>
<td>$\Pi_m$ is the manufacturer’s profit, $\Pi_r$ is the retailer’s profit, and $\Pi_T$ is the overall supply-chain profit</td>
</tr>
</tbody>
</table>

3.3. Establishment of the Basic Decision Model

The subscripts $m, 1,$ and 2, respectively, represent the direct sales channel of the manufacturer, the online channel, and the offline channel of the retailer. $c_1$ represents the channel cost of online retailers, and $c_2$ represents the channel cost of offline retailers. $p_i$ and $D_i (i = m, 1, 2)$ represent the price and demand of corresponding channels, respectively; This article refers to Heydari et al. [30] Zhang et al. [31] and Khouja et al. [32] to construct the linear demand function of each channel, in which $b_1$ and $b_2$ represent the price sensitivity coefficients of manufacturers’ direct sales and retailers’ online and offline, $r_1, r_2$ and $r_3$ are the cross-price elasticity between the two channels, and $b > r$.

$$D_m = \alpha \cdot A - bp_m + r_1(p_1 - p_m) + r_2(p_2 - p_m)$$

(1)
\[ D_1 = \beta \cdot A - b_1 p_1 + r_1 (p_m - p_1) + r_3 (p_2 - p_1) \] (2)

\[ D_2 = (1 - \alpha - \beta) \cdot A - b_2 p_2 + r_2 (p_m - p_2) + r_3 (p_1 - p_2) \] (3)

The profit functions of manufacturers and retailers are expressed as follows:

\[ \prod_m = (p_m - c) D_m + (w_1 - c) D_1 + (w_2 - c) D_2 \] (4)

\[ \prod_r = (p_1 - w_1 - c_1) D_1 + (p_2 - w_2 - c_2) D_2 \] (5)

\[ \prod_T = \prod_m + \prod_r \] (6)

To facilitate simulation analysis, this paper standardizes the parameters of retailers across all channels. This hypothesis differs from the actual situation, but considering that the cost and market differences between most retailers are likely to be far less significant than those between suppliers and their retailers, the analysis of symmetric retailers still has some usefulness.

4. Model Establishment and Solution

4.1. Strategic Consumer Utility Model

On the market, there are two categories of consumers: strategic consumers and tactical consumers. Consumers with a lack of foresight make purchase decisions based on current sales prices, disregarding the negative influence of future price changes on current purchases. To maximize their intertemporal utility, strategic consumers consider not only the current price but also the future price and strategically choose the timing of their purchases. Strategic consumers’ delaying behavior has a negative impact on supply-chain profits and makes pricing in the supply chain more difficult.

Based on the retailer-led Stackelberg game, this section analyses the impact of strategic consumer behavior on supply-chain pricing. In the strategic consumer model, consumer utility serves as the decision-making criterion, while parameters irrelevant to strategic consumers, such as wholesale price, are assigned fixed values. Assume that the proportion of strategic consumers in the three channels is \( k_1, k_2, \) and \( k_3, \) respectively, with \( k_1, k_2, k_3 \in [0, 1]; \) \( s \) represents the discount coefficient, satisfying the conditions \( s \in [0, 1] \) and \( p_i > p_i p_s. \)

To facilitate the study, it is assumed that there is no shortage of goods during the normal period. During the discount period, merchants employ restrictive strategies to curb the waiting behavior of strategic consumers, and the probability of successful purchase of goods by consumers during the discount period is \( h. \) Taking into account the heterogeneity and dynamics of consumers’ valuation, it is represented by the probability density function \( f(x) = xe^{-x}, \) assuming \( v \) is between \([0, v^*]\) and follows a uniform distribution, \( v^* \) represents the maximum valuation, and consumers will not purchase goods whose price exceeds the maximum valuation.

Figure 2 depicts the decision-making process of consumers. Strategic consumers evaluate the utility of the two periods and make purchases when the utility is greatest. Short-sighted consumers purchase when their utility is not negative during the \( T_1 \) period; otherwise, they wait until \( T_2; \) if this sales cycle does not meet their utility requirements, they enter the subsequent sales cycle and resume the above steps.
Table 2. Consumer utility decision table.

<table>
<thead>
<tr>
<th>Type</th>
<th>Purchase Stage</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-sighted consumer</td>
<td>$T_1$</td>
<td>$p^{v_1} \leq v &lt; v^*$</td>
</tr>
<tr>
<td></td>
<td>$T_2$</td>
<td>$p^{v_2} \leq v &lt; p^{v_1}$</td>
</tr>
<tr>
<td>Strategic consumer</td>
<td>$T_1$</td>
<td>$\frac{p^{v_1} - hp^{v_2}}{1-h} \leq v \leq v^*$</td>
</tr>
<tr>
<td></td>
<td>$T_2$</td>
<td>$p^{v_2} \leq v &lt; \frac{p^{v_1} - hp^{v_2}}{1-h}$</td>
</tr>
</tbody>
</table>

Note: When the price is lower than the cost, the merchant is in a state of loss, so the utility $v < c$ consumers are not in the target group.

In the manufacturer’s direct sales channel, the proportion of strategic consumers is $k_1$, and the proportion of short-sighted consumers is $1 - k_1$. At this time, the market demand function is:

$$Q_{m}^{T_1 + T_2} = (1 - k_1) \left( D_m \int_{p^{v_1}}^{v^*} f dv + D_m' \int_{p^{v_2}}^{p^{v_1}} f dv \right) + k_1 \left( D_m \int_{p^{v_1} - hp^{v_2}}^{p^{v_1}} f dv + D_m' \int_{p^{v_2}}^{p^{v_1} - hp^{v_2}} f dv \right)$$  \hspace{1cm} (7)

In the online retail channel, the proportion of strategic consumers is $k_2$, the proportion of short-sighted consumers is $1 - k_2$, and the total demand of consumers in two stages is expressed as $Q_1$:

$$Q_1^{T_1 + T_2} = (1 - k_2) \left( D_1 \int_{p^{v_1}}^{v^*} f dv + D_1' \int_{p^{v_2}}^{p^{v_1}} f dv \right) + k_2 \left( D_1 \int_{p^{v_1} - hp^{v_2}}^{p^{v_1}} f dv + D_1' \int_{p^{v_2}}^{p^{v_1} - hp^{v_2}} f dv \right)$$  \hspace{1cm} (8)

In the offline retail channel, the proportion of strategic consumers is $k_3$, the proportion of short-sighted consumers is $1 - k_3$, and the total demand of consumers in two stages is expressed as $Q_2$:
\[ Q_{T_1+T_2}^2 = (1 - k_3) \left( D_2 \int_{\rho_1}^{\nu^*} f dv + D_2 \int_{\rho_2}^{\nu_1} f dv \right) + k_3 \left( D_2 \int_{\nu_1}^{\nu^*} \int_{w_1}^{T_1} f dv + D_2 \int_{\nu_1}^{\nu_2} \int_{w_1}^{T_2} f dv \right) \]  

In the actual sales process, if the cost of a certain channel is higher than the selling price, the merchant will close the operation of the channel and realize the sales of products through other channels, so the selling price of \( T_1 \) and \( T_2 \) is higher than the cost.

4.2. Retailer-Led Supply-Chain Model

The Stackelberg model is constructed with retailers as the leader and manufacturers as the followers, and both parties seek to maximize their respective interests. The model is solved by backward induction, assuming that retailers determine the wholesale prices \( w_1 \) and \( w_2 \) for both online and offline channels, manufacturers make optimal decisions based on the contract, and then retailers determine optimal online and offline pricing based on the manufacturers’ decisions. The procedure is as detailed as follows.

4.2.1. Game Analysis of \( T_1 \) Stage

In the \( T_1 \) stage, consumers are short-sighted consumers whose utility belongs to the interval \( p_1^{T_1} \leq v \leq \nu^* \), and strategic consumers whose utility belongs to the interval \( \frac{p_1^{T_1} - h v w}{1 - h} \leq v \leq \nu^* \), which are, respectively, expressed by \( Q_{T_1}^i (i = m, 1, 2) \).

First, the manufacturer’s profit in the \( T_1 \) stage is determined as direct sales profit plus wholesale profit, and the function of profit is expressed as follows:

\[ \prod_m = (p_m - c) Q_{T_1}^1 + (w_1 - c) Q_{T_1}^{T_1} + (w_2 - c) Q_{T_2}^{T_1} \]  

By finding the first derivative of Formula (10) about \( p_m \) and making it equal to zero, the optimal price of manufacturers can be obtained as follows:

\[ p_{T_1}^m = \frac{Ae \left( k_1 + k_1 \left( \frac{hp/v}{n(h-1)} - 1 \right) - 1 \right) + Ae \left( \frac{k_3 - 1}{v} + \frac{k_3}{v(h-1)} \right)}{2Ae \left( \frac{k_1 - 1}{v} + \frac{k_1}{v(h-1)} \right)} \]  

Online and offline retailers make decisions at the same time, and the total profit of retailers in stage \( T_1 \) is expressed as Formula (12):

\[ \prod = (p_1 - w_1 - c_1) Q_{T_1}^1 + (p_2 - w_2 - c_2) Q_{T_2}^{T_1} \]  

The Hessian matrix of Formula (12) is shown as \( H_1 \):

\[ H_1 = \begin{bmatrix} \frac{\partial^2 \prod}{\partial p_1^2} & \frac{\partial^2 \prod}{\partial p_1 \partial p_2} \\ \frac{\partial^2 \prod}{\partial p_2 \partial p_1} & \frac{\partial^2 \prod}{\partial p_2^2} \end{bmatrix} = \begin{bmatrix} 2Ae \left( \frac{k_3 - 1}{v} + \frac{k_3}{v(h-1)} \right) & 0 \\ 0 & -2A(e - 1) \left( \frac{k_3 - 1}{v} + \frac{k_3}{v(h-1)} \right) \end{bmatrix} \]  

It is obvious that the first-section sequential principal subformula is less than 0 and the second-order sequential principal subformula is greater than 0 in the Hessian matrix \( H_1 \). Therefore, Formula (12) is a concave function about \( p_1, p_2 \) and the total profit of retailers has a maximum value. By calculating the first derivative of Formula (12) to \( p_1 \) and \( p_2 \) and making it zero, the optimal price of two channels can be obtained:

\[
\begin{align*}
p_{T_1}^1 & = \frac{c_1 + \nu + w_1 - c_2 h - h w - h w}{2(h k_2 - h + 1)} + c_3 h k_2 + h k_3 w_2 + h k_3 w_3 \\
p_{T_1}^2 & = \frac{c_3 + w_2 - c_2 h - h w + c_2 h k_3 + h k_3 + h k_3 w_2}{2(h k_3 - h + 1)}
\end{align*}
\]
4.2.2. Game Analysis of $T_2$ Stage

In the $T_2$ stage, consumers are short-sighted consumers whose utility belongs to the interval $p^{T_2} \leq v < p^{T_1}$, and strategic consumers whose utility belongs to the interval $p^{T_2} < v < \frac{c_3 h - h v - 3 c_1 h - h v + 3 c_1 h k_2 + 3 k_2 w_1}{5 k_2 - 4 k_2 + 4}$, which are, respectively, expressed by $Q_i^{T_2}$ ($i = 1, 2$).

The manufacturer’s profit in the $T_2$ stage is also the direct selling profit plus wholesale profit, and the function of profit is expressed as Formula (14):

$$
\Pi_m = (p_m - c)Q_m^{T_2} + (w_1 - c)Q_1^{T_2} + (w_2 - c)Q_2^{T_2}
$$

(14)

By finding the first derivative of Formula (14) about $p_m$ and making it equal to zero, the optimal price of manufacturers can be obtained as follows:

$$
p_m^{T_2} = \frac{A e\left(\frac{p_m(k_1 - 1)}{v} + \frac{k_3 p_m}{v(h - 1)}\right) + A c e\left(\frac{k_1 - 1}{v} + \frac{k_1 (\frac{h}{v} - 1)}{v}\right)}{2 A e\left(\frac{k_1 - 1}{v} + \frac{k_1 (\frac{h}{v} - 1)}{v}\right) + A c e\left(\frac{k_1 - 1}{v} + \frac{k_1 (\frac{h}{v} - 1)}{v}\right)}
$$

(15)

Online and offline retailers make decisions at the same time, and the total profit of retailers in stage $T_2$ is expressed as Formula (16):

$$
\Pi_i = (p_i - w_i - c_1)Q_i^{T_2} + (p_i - w_i - c_2)Q_i^{T_2}
$$

(16)

The Hessian matrix of Formula (16) is shown as $H_2$:

$$
H_2 = \begin{bmatrix}
2 A d \left(k_2 - 1 + k_2 \left(\frac{h}{v} - 1\right)\right)/v & 0 \\
0 & 2 A (1 - d - c) \left(k_3 - 1 + k_3 \left(\frac{h}{v} - 1\right)\right)/v
\end{bmatrix}
$$

It is obvious that the Hessian matrix $H_2$ is negative, so Formula (16) is a concave function about $p_1$ and $p_2$, and the total profit of retailers has a maximum value. By calculating the first derivative of Formula (16) to $p_1$ and $p_2$ and making it zero, the optimal price of two channels can be obtained:

$$
\begin{align*}
\left\{\begin{array}{l}
p_1^{T_2} = \frac{3 c_1 h - h v - 3 w_1 + 3 c_1 h k_2 + 3 k_2 w_1}{5 k_2 - 4 k_2 + 4} \\
p_2^{T_2} = \frac{3 c_2 h - h v - 3 w_2 + 3 c_2 h k_3 + 3 k_3 w_2}{5 k_3 - 4 k_3 + 4}
\end{array}\right.
\end{align*}
$$

(17)

5. Numerical Analysis and Result Discussion

This paper uses data simulation to examine the relationship between the proportion of strategic consumers, discount coefficients, purchase-restriction coefficients, supply-chain pricing, and profits, and the impact of strategic consumer behavior on the optimal price and optimal profit of mixed channels in a market composed of strategic and short-sighted consumers.

According to the previous analysis, the cost and wholesale price are not independent variables of the model, assuming that consumer valuation follows a uniform distribution at $[0, v^*]$ and assigning $b = 2$, $b_1 = 1.5$, $b_2 = 1.5$, $r_1 = 1$, $r_2 = 1$, $r_3 = 1$, $c = 1$, $c_1 = 1.5$, $c_2 = 2$, $w_1 = w_2 = 2$, $v^* = 30$. The range 0 to 1 is the range of $k_i (i = 1, 2, 3)$. In the presence of strategic consumers, price and profit are related to consumer ratio, commodity discount, and commodity availability. Therefore, the following numerical simulation focuses primarily on analyzing the impact of relevant parameters on the optimal price and profit of mixed channels.

5.1. The Impact of Strategic Consumer Ratio on Channel Price and Profit

To analyze the impact of changes in the strategic consumer ratio ($k$) on optimal price and profits for each channel, we have set the purchase-restriction coefficient ($h$) to 0.9 while keeping other parameters unchanged. Figures 3 and 4 depict the relationship between the
proportion of consumers following each channel strategy and the optimal price for the $T_1$ and $T_2$ periods.

![Influence of strategic consumer ratio k on optimal price in the $T_1$ period](image1)

**Figure 3.** Influence of strategic consumer ratio $k$ on optimal price in the $T_1$ period ((a–c) show the relationship between the proportion of consumers following each channel strategy and the optimal price).

![Influence of strategic consumer ratio k on optimal price in the $T_2$ period](image2)

**Figure 4.** Influence of strategic consumer ratio $k$ on optimal price in the $T_2$ period ((a–c) show the specified parameter values between the optimal price of both manufacturers and retailers and the strategic consumer ratio).

Figures 3 and 4 illustrate that, given the specified parameter values, there is a clear negative correlation between the optimal price of both manufacturers and retailers and the strategic consumer ratio ($k$). As the proportion of strategic consumers increases, the optimal price of all three channels shows a downward trend. In the case of retailers, the optimal price of their dual channels is significantly lower than that of manufacturers’ direct sales channels, particularly in the $T_2$ stage where they aim to attract consumers through price advantage. For manufacturers, developing direct sales channels can help increase their market share and profits, while also training loyal customers and building a positive corporate image.

Figures 5 and 6 display the relationship between the ratio of strategic consumers and optimal profits during the normal and discount periods, respectively. The results reveal that as the proportion of strategic consumers increases in all three channels, the profits of both manufacturers and retailers decrease. At the highest point of supply-chain profits, the ratio of strategic consumers tends to zero, indicating a negative correlation between the proportion of strategic consumers and the overall profits of both channels and the supply chain. In the $T_1$ stage, short-sighted consumers dominate, and consumers who choose the waiting strategy have a detrimental effect on supply-chain profits. Therefore, reducing the influence of strategic consumers’ waiting behavior is crucial in increasing profits during the $T_1$ stage.
Strategic consumers have the option to either buy products at regular prices or delay their purchases and wait for discounted prices. Although purchasing at regular prices allows consumers to enjoy products right away, waiting for non-perishable products may lead to strategic consumers obtaining higher consumer surplus at lower prices. However, this waiting behavior also comes with the risk of uncertainty. In the $T_1$ stage, controlling purchase-restriction strategy is expressed as a value between 0 and 1. Therefore, it is essential to control the purchase-restriction strategy within a specific range to achieve optimal results.

Figure 5. The influence of strategic consumer ratio $k$ on the optimal profit in the $T_1$ period (a–d) show the relationship between the ratio of strategic consumers and optimal profits during the normal and discount periods.

Figure 6. The influence of the proportion of strategic consumers $k$ on the optimal profit in the $T_2$ period (a–d) show the relationship between the ratio of strategic consumers and optimal profits during the normal and discount periods.
5.2. The Effect of Purchase-Restriction Coefficient on Supply-Chain Pricing and Profit

Strategic consumers have the option to either buy products at regular prices or delay their purchases and wait for discounted prices. Although purchasing at regular prices allows consumers to enjoy products right away, waiting for non-perishable products may lead to strategic consumers obtaining higher consumer surplus at lower prices. However, this waiting behavior also comes with the risk of uncertainty. In the $T_1$ stage, controlling the difficulty of consumers’ acquisition through a purchase-restriction policy weakens the influence of strategic consumer behavior. This study focuses on the impact of the purchase-restriction coefficient ($h$) on price and profits during the $T_2$ stage. The proportion of strategic consumers in online channels is higher than that in traditional channels, with $k_1 = 0.4$, $k_2 = 0.4$, $k_3 = 0.3$, while the values of other parameters remain the same as in $T_1$. Assuming that only the purchase-restriction strategy is implemented in the $T_2$ stage, with consumers having an equal probability of obtaining goods in each channel, $h$ is expressed as a value between 0 and 1.

Figure 7 depicts the impact of parameter $h$ on the optimal price of each channel during the $T_2$ period. During the $T_2$ discount period, the product availability coefficient affects the optimal price of each channel, with the optimal price decreasing as the product availability ($h$) during the discount period increases. The more challenging it is to obtain the product, the higher the price, following the order of $p_1 < p_2 < p_m$. Retailers’ online channels offer a significant price advantage, with the dual-channel price changing more slowly when $h \in [0, 0.8]$. However, when $h \in (0.8, 1]$, the price of each channel decreases considerably. Therefore, it is essential to control the purchase-restriction strategy within a specific range to achieve optimal results.

![Figure 7. The impact of h on the optimal price in the $T_2$ period.](image)

Figures 8 and 9 demonstrate that both the retailer’s and the manufacturer’s profits are negatively correlated with $h$. Despite the higher demand in the $T_2$ stage compared to the $T_1$ stage, the overall supply-chain profit exhibits a downward trend due to the lower prices during the discount period. Moreover, as the possibility of acquisition increases, profits gradually decrease, and the slope of the profit curve gradually increases. Although an appropriate purchase-restriction strategy can help increase profits during the discount period, the possibility of acquisition is often too low to curb the impact of consumer strategic behavior. In addition, strategic consumers constitute a larger proportion of consumers in the $T_2$ stage, and a suitable purchase-restriction coefficient can help reduce the impact of some strategic consumers’ waiting behavior and narrow the profit gap with the $T_1$ stage.
5.3. The Impact of Pre-Announced Discounts on Supply-Chain Pricing and Profits

To better illustrate the impact of the optimal price in the $T_2$ period and the optimal price in the $T_1$ period, we set the following parameters: $A = 1000$, $w_1 = 2$, $w_2 = 2$, $v^* = 30$, $h = 0.8$, $k_1 = 0.4$, $k_2 = 0.4$, and $k_3 = 0.3$. It should be noted that pre-announcement discount strategies are commonly used by some e-commerce platforms such as Taobao and JD. Even if no official announcement is made, consumers can use historical information to predict possible future prices. Therefore, assuming that strategic consumers make predictions based on previous discount information, we introduce the pre-discount rate announced in stage $T_1$, denoted by $s$.

Figure 10 depicts the impact of the $T_2$ discount rate relative to $T_1$ on the optimal price in $T_1$. As $S$ approaches zero, the price difference between the two periods becomes larger, and strategic consumers are more likely to wait for the discount in $T_2$. However, this behavior is not advantageous for the overall performance of channel merchants and the supply chain.
As shown in Figure 11, there is a positive correlation between the discount coefficient \( S \) and the optimal price in \( T_1 \). When the values of \( s_m, s_1, \) and \( s_2 \) approach 1, the price gap between \( T_2 \) and \( s_m \) becomes smaller, and most consumers choose to purchase at \( T_1 \). On the other hand, smaller values of \( s \) indicate a larger price difference between the two stages, making more consumers inclined to wait for the discount period to purchase. However, relying solely on price cuts to compete intensifies the two-stage competition and forces merchants to lower prices during the normal sales period. In the long run, this approach is not the most effective means of competition. As consumers compare prices more conveniently, merchants should consider enhancing the user experience of the regular price period and use measures to enhance consumer utility to minimize the adverse effects of channel intertemporal competition.

**Figure 10.** The Influence of \( S \) on Optimal Price in the \( T_1 \) Period ((a–c) show the impact of the \( T_2 \) discount rate relative to \( T_1 \) on the optimal price in \( T_1 \)).

**Figure 11.** The Influence of \( s \) on profit in the \( T_1 \) period ((a–d) show correlation between the discount coefficient \( S \) and the optimal price in \( T_1 \)).
5.4. The Influence of Combination Strategy on Supply-Chain Pricing and Profit

The current decision-making environment is becoming increasingly complex, and relying on a single index to reflect the actual situation may not suffice. Therefore, it is important to integrate the impact of strategic consumers, purchase restrictions, and pre-release discount information on price. To study the influence of the h value on profit in stage $T_2$, we set $s = 0.8$ and keep the other parameters consistent with the initial setting.

From Figure 12, we observe that the profit of the manufacturer’s direct sales channel is negatively correlated with h, and it exhibits a downward trend as the value of h increases. In contrast, the retailer’s dual-channel profit first rises and then falls. When $h = 0.8$, the profits of the retailer and the supply chain reach their highest point, which is significantly higher than that achieved without considering the forecast discount.

Figure 12. The Influence of h on profit in the $T_2$ period ((a–d) show the profit of the manufacturer’s direct sales channel with h).

Figure 13 illustrates the impact of the proportion of strategic consumers, denoted by $k$, on supply-chain pricing and profits when $s = 0.8$ and $h = 0.8$. As shown in the figure, the retailer’s profit increases with the proportion of strategic consumers and reaches a maximum at the critical point, beyond which the profit decreases. Similarly, the total profit of the supply chain also exhibits an optimal value. By considering the results from Figures 12 and 13, there exists an optimal combination of $k$ and $h$ that maximizes the profit under the condition of pre-announced discounts. Furthermore, the overall optimal profit of channels and the supply chain is significantly higher than the profit obtained by considering only a single strategy. These findings emphasize the importance of considering multiple factors in decision-making processes in complex environments.
Figure 13. The influence of pre-discount information and \( k \) on the profit in the \( T_2 \) period ((a-d) show the impact of the proportion of strategic consumers).

The mixed-channel model examines the impact of pre-release discount information and purchase-restriction strategies in a multi-channel setting. The simulation results demonstrate that strategic consumer behavior has a significant effect on the pricing and profits of each channel in the retailer-led two-cycle mixed-channel model. As shown in Figures 3 and 4, the optimal price of both manufacturers and retailers is negatively correlated with the proportion of strategic consumers \( k \) in both cycles. Furthermore, comparing Figures 11 and 12 with Figure 6 reveals that, in the presence of strategic consumers, pre-release discount information and purchase restrictions can mitigate strategic consumer behavior, and both can help to improve the overall profits of the channel and supply chain. Additionally, a Pareto region exists among the combination of pre-release discounts, purchase limit coefficients, and proportion of strategic consumers in a specific situation, where an appropriate price can generate higher profits for the supply chain. In general, appropriate combinations should be determined based on the actual situation in the application.

6. Conclusions

As more and more purchasing festivals are held, the influence of consumers’ strategic behavior becomes increasingly apparent. This paper constructs a retailer-led mixed-channel supply-chain pricing model based on the heterogeneous behavior of consumers and discusses the impact of purchase restriction, the proportion of strategic consumers, and the early release of discount information on supply-chain pricing and profit in light of the coexistence of strategic consumers and short-sighted consumers in the market. Simulation and comparative analysis have led to the following conclusions:

1. Heterogeneous consumer behavior and utility theory impact consumer purchasing opportunities. Considering the pre-announced discount, the greater the difference between the two phases of pricing, the more strategic consumers tend to wait until...
the discount period to make a purchase, and the resulting intertemporal effect intensifies channel competition. However, this competition decreases the profit margin of businesses and supply chains and increases the surplus of consumers, which is not advantageous for all channel merchants and the entire supply chain.

2. It is now indisputable that consumers pay close attention to historical discount information and potential future commodity prices. According to research, the proportion of strategic consumers is constant, and consumers refer to past or forthcoming reductions that have been announced. There is a minimum purchase-restriction coefficient value. If the purchase limit coefficient is less than or equal to this value, it is positively correlated with the overall profit of the retailer and the supply chain, and if it exceeds this value, it is negatively correlated. Therefore, a suitable purchase-restriction strategy contributes to increased profits for retailers and the supply chain.

3. Considering the history and pre-announced discount information, there exists a Pareto region for the combination of the ratio purchase restriction factors of strategic consumers. Reasonable combinations within this region can result in higher profits for retailers and manufacturers.

This paper examines the optimal price of the supply chain based on the market for durable products and derives the following management implications through simulation: Strategic consumers have a direct impact on the pricing strategy and future profits of supply chain enterprises. The guiding strategies of purchase restriction and discount are advantageous for mitigating the negative effects of delayed purchases and increasing supply-chain enterprises’ profits. The model implies that there is only one manufacturer on the market and that all products in all distribution channels are identical. In reality, there are numerous businesses in the supply chain, and consumer returns are common. The environment for manufacturers and retailers is becoming more complex and volatile. The next stage is to examine the following three factors: (1) The influence of strategic consumer behavior on the pricing of upstream and downstream enterprises in the supply chain when many manufacturers are in a competitive environment; (2) Whether the conclusion of the article is still valid in the perishable market; and (3) How can the supply chain protect its own interests through guiding strategies such as discounts and pricing when online shopping frequently returns?

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