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# Application of Evolutionary Game to Analyze Dual-Channel Decisions: Taking Consumer Loss Aversion into Consideration

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**Abstract:** Manufacturers and consumers are boundedly rational and ultimately seek evolutionarily stable strategies through trial and error, imitation, and learning. It is important to study the pricing strategies of manufacturers and the purchasing channel decisions of consumers in the context of increasingly fierce competition in online channels, in addition to consumers' loss aversion due to increasingly confusing promotional strategies; accordingly, in this paper, an evolutionary game including both parties is constructed, and the loss aversion factor from prospect theory is introduced. Based on data from Chinese media reports on the cosmetics industry, simulation and sensitivity analyses were conducted using Matlab R2024a. The results indicate that—in addition to channel services affecting the evolutionarily stable strategy for purchasing channel selection—a decrease in consumer loss aversion will help consumers reach the evolutionarily stable strategy faster. For manufacturers, channel services do not affect their evolution to a unified pricing strategy; however, when consumer loss aversion increases, manufacturers' evolutionarily stable strategy will shift from a unified pricing strategy to a differentiated pricing strategy.

**Keywords:** loss aversion; price strategy; evolutionary game; dual channel; Hotelling

**MSC:** 91-10

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## 1. Introduction

The Internet is changing suppliers' distribution channel decisions and the corresponding logistical networks [1]; this context is accompanied by the booming development of e-commerce globally. According to Statista (2024) [2], Amazon generated approximately USD 135 billion via retail e-commerce sales in the United States, compared to Walmart, which generated about USD 65 million. Foreign companies (such as Temu and Shein from China) are also taking on the U.S. market. The growing e-commerce market is estimated to have generated USD 1.2 trillion in revenue in 2024; by 2029, U.S. consumers' appetite for online shopping is forecasted to bring in USD 1.8 trillion. In addition, according to the "China New E-commerce Development Report 2024", the total online retail sales in China reached CNY 15.42 trillion in 2023, reflecting a year-on-year increase of 11 percent.

In addition to the growth in scale, e-commerce has increasingly diverse sales channels. In order to adapt to changes in consumers' lifestyles, an increasing number of retailers are widely utilizing online channels, including social media, to promote their products and marketing activities, especially since the outbreak of COVID-19. Amazon and Taobao have launched Amazon Live [3] and Taobao Live [4] to display and sell products. Amazon has also announced partnerships with Facebook, Instagram, and Snapchat to allow buyers to associate their social media accounts with Amazon, enabling the sharing of advertising targeting data.

The diversification of sales channels poses challenges in channel management for manufacturers and suppliers. In addition to the new forms mentioned above, there are other ways in which e-commerce functions. Firstly, manufacturers can sell directly through a proprietary website, such as Nike, HP, Apple, or Mattel. Secondly, manufacturers can involve specialized third-party online platforms, acting as a marketplace through which they sell their goods by paying a fee for a service; this is the strategy that Microsoft and Samsung have undertaken with Best Buy. Thirdly, manufacturers can opt to distribute their goods to specialized (or non-specialized) online players. An example of this is the way in which Crocs, Inc. works with Amazon and Zappos, which resell to the final consumers. This approach entails standard B2B dynamics [5].

As for the price, many products have lower online prices than offline prices because of different channel costs; this is consistent with the trend of the price index from China, shown in Figure 1, in which 'iCPI' is the 'Internet-based Consumer Price Index'. There are many reports about online prices being lower than offline prices, such as drugs, electronic products, and clothing, and even the emergence of online price-comparison services. With the rapid development of e-commerce, the problem of pricing conflicts between online and offline channels has become increasingly prominent. With numerous price-comparison websites and applications, consumers today are frequently conducting price-comparison shopping. As a result, retailers face an increasing challenge in predicting consumer demand and determining the optimal product price and inventory level accordingly [6]. As online product price competition intensifies, some manufacturers have chosen a strategy of offering the same price both online and offline. Chen [7] recently found that uniform pricing can be optimal for a monopoly retailer even though consumers have different costs for shopping online versus offline; additionally, there is no intrinsic disutility against price discrimination by consumers. For consumers, in order to obtain lower online prices, they have to pay more than before because of the increasingly complex promotion rules. The complex rules of promotion, fake discounts, compelling marketing, and disadvantages of goods/services might have caused consumers' aversion to the Double Eleven shopping festival on Tmall [8].

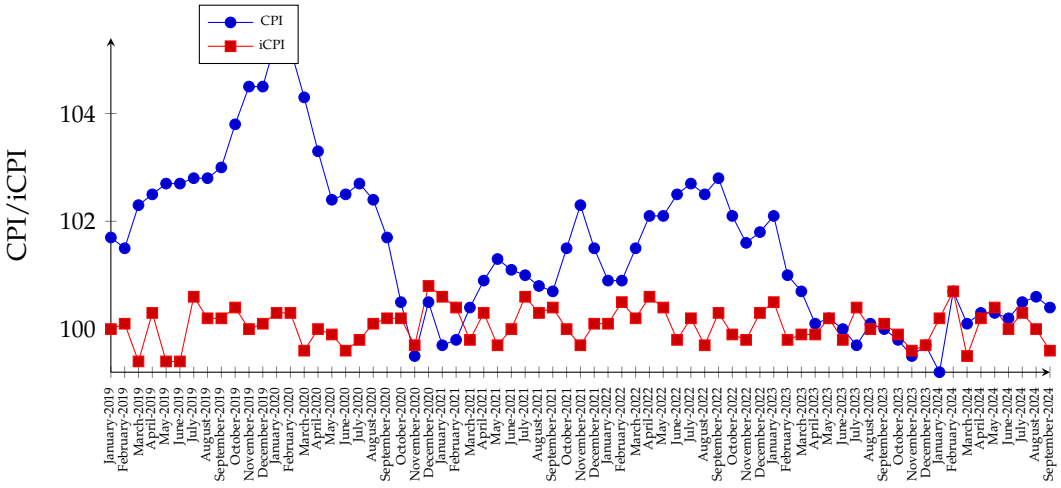



**Figure 1.** The (Internet-based) consumer price index from China.

Both the consumer group and the manufacturer group are boundedly rational, and their decisions are influenced by the environment, which is a dynamic evolutionary process. Thus, the purpose of this article is to investigate the following questions: Do manufacturers still need to adhere to a strategy of lower online pricing in the increasingly fierce competition of online channels? Or, should manufacturers draw on existing precedents and develop unified pricing strategies for both online and offline channels? How will consumers choose

their purchasing channels when they are increasingly loss-averse in the face of some online promotional tactics? Will the decisions of consumers and manufacturers evolve into other stable states?

To address these issues, this paper constructed an evolutionary game model for dual-channel manufacturers and consumers, and the consumer loss aversion factor from prospect theory was introduced. Manufacturers can choose between a dual-channel unified pricing strategy or a dual-channel differential pricing strategy, which means that the pricing of online channel products is the same or different from that of offline channels. Then, consumers choose to purchase products from online or offline channels. The evolutionarily stable strategies for manufacturers and consumers can be obtained by solving the replicated dynamic equations.

This paper contributes to the literature on pricing decisions for manufacturers by bridging ideas from dual-channel management and evolutionary game theory, contributing to the former by introducing consumer irrational factor-loss aversion, analyzing the stable strategies of manufacturers and consumers, and contributing to the latter by demonstrating its practical application in the field of e-commerce. The methodology is shown in Figure 2.

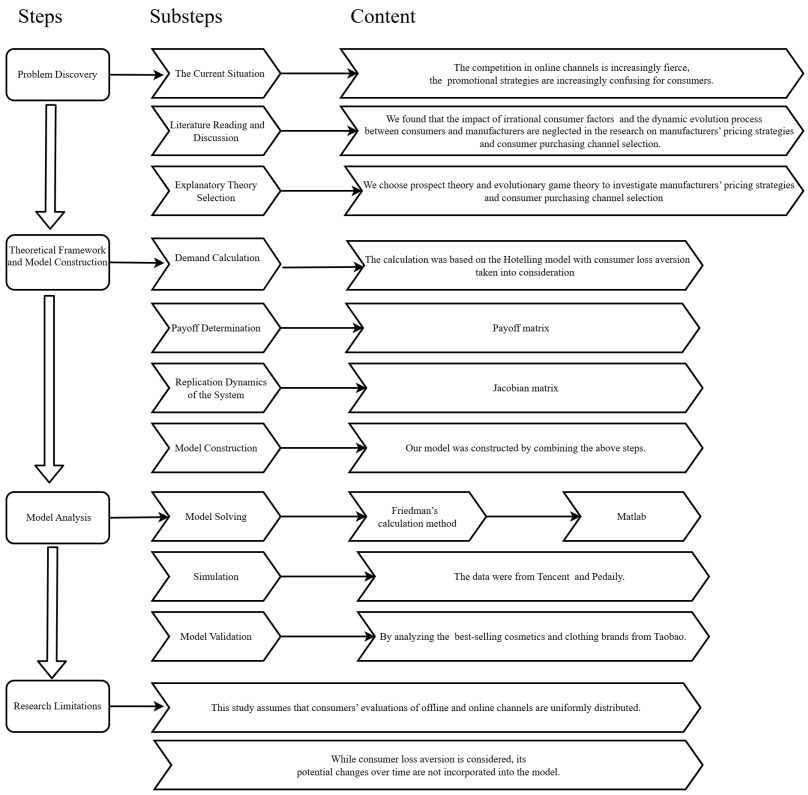



**Figure 2.** The methodology.

The remainder of this paper is organized as follows: Section 2 reviews the literature on manufacturers' pricing decisions as well as consumers' purchasing channel decisions and identifies research gaps. Section 3 describes the research problem and constructs an evolutionary game model that innovatively considers the factor of consumer loss aversion, in which the Friedman's calculation method is used to solve the stable strategy of each party in the game. Section 4 presents the results and discussion using a numerical example, in which the Matlab R2024a was employed for calculation, simulation, and visualization. Section 5 concludes with implications for management and directions for future research.

## 2. Literature Review

First, we review the research on the dual-channel pricing decisions of manufacturers and dual-channel retailers, as well as consumers' channel selection decisions.

On the one hand, there are channel conflicts and coordination issues. Manufacturers are addressing this issue through four routes of differentiation and price discrimination. First, the spatial separation method is a way of applying price discrimination depending on selling areas or regions. This approach can be used when consumers recognize the value of the product differently based on the place of purchase. Second, the temporal separation method is a solution where online and offline stores' selling prices differ depending on the point of purchase. Third, situational separation is a solution where online and offline selling prices differ depending on the quantity purchased, the transaction conditions, and the relationship with the consumer. Fourth, separation by the whole and the part involves maintaining the same price for all products sold by online and offline stores; this approach sometimes partially uses a different price policy [9]. Some scholars have studied the effectiveness of dual-channel differentiation strategies, which are widely used by manufacturers to resolve channel conflicts; researchers have found that the impact of quality differentiation depends on the distribution strategy, encroachment strategy, contract form, level of product competition, inventory risks, etc. [10–14].

On the other hand, some scholars have argued that—whether one looks at a single retailer–manufacturer channel or a multi-retailer vs. manufacturers channel—it is inefficient for the manufacturer to focus on differentiation in product distribution between channels to secure profits [15,16]. The operating costs associated with this choice are often overwhelming. More specifically, Zhang et al. [17] found that, if the product differentiation level exceeds a particular threshold, the product quality distribution strategy can negatively influence the retailer to abandon the hybrid retailing mode. Therefore, some manufacturers have chosen omnichannel retailing and abandoned differentiation strategies. As the line between online and physical channels is blurred, the omnichannel strategy has emerged for channel integration, which aims to deliver a seamless customer experience regardless of the channel [18]. A typical form is retailers offering consumers the option to buy online and pick up in-store (BOPS). The BOPS option affects consumer choice in two ways: by providing real-time information about inventory availability and by reducing the hassle cost of shopping. However, not all products are well suited for in-store pickup; specifically, it may not be profitable to implement BOPS on products that sell well in stores [19].

In addition to channel competition and cooperation strategies, manufacturers and dual-channel retailers often need to consider consumer-related factors when pricing: First, one must consider the different types and preferences of consumers—when strategic consumers have high levels of patience, or when consumers are more overconfident, all manufacturers prefer to decrease prices in both periods [20,21]. Second, one must consider consumer behaviors under a dual-channel retailing strategy—this strategy allows customers who find a purchase unsatisfactory to obtain a full refund through a same-channel return or a cross-channel return. Radhi et al. took note of such cross-channel returns behavior and studied their impacts on optimal pricing decisions [22]. Some scholars have also investigated the impact of consumer-generated online reviews and the free-rider problem on pricing in a dual-channel context [23,24].

The research on consumers' channel selection is generally conducted through studying consumer preferences. Factors such as consumers' Internet experience [25], the channel's delivery lead time [26], the channel's service level [27], interactivity mode [28], online product presentation videos [29], and consumer relationship investment [30] can affect consumers' channel preferences, which in turn affect their choice of purchasing channels.

In the second place, we reviewed the supply chain structures in different e-commerce studies. Sun et al. [31] proposed a robust closed-loop e-commerce supply chain network structure based on research over the past two decades; here, suppliers provide raw materials, manufacturers produce products, the e-commerce platform and distribution centers process orders from consumers, and consumers place orders or return products. Accordingly, referring to keywords in this structure, we continued to review the manufacturers' and consumers' decisions as they relate to this structure.

Manufacturers' revenue can be affected by their channel decisions, including selling only online, selling both online and offline, and having offline showrooms with online purchases [32]. When there are relatively many manufacturers but relatively few retail channels, the competitive relationship between manufacturers will affect their delivery decisions [33].

E-commerce platforms have a direct impact on manufacturers' decisions. Wan and Fan [34] formed an e-commerce supply chain that includes a manufacturer providing products and an online platform providing service to investigate the reselling platform mode and the agent platform mode under different channel power structures. Specifically, the extended warranty service—which is an increasingly significant after-sale value-added service of e-commerce platforms—and ancillary services or products provided by manufacturers have been demonstrated to play a pivotal role in online market dynamics and manufacturers' selling pattern decisions [35,36]. An issue that cannot be ignored in e-commerce platforms is the continuous risk of network attacks. Zhang and Yang [37] studied a dual-channel supply chain where manufacturers can earn revenue through online channels (i.e., manufacturers sell products through e-retailers) and offline channels (i.e., manufacturers sell products directly to consumers), showing that manufacturers and retailers can simultaneously mount cyber defenses seeking to maximize profits.

Consumer-centric supply chain management has also received research attention. A common practice for brand manufacturers is to operate dual distribution channels in which they offer an online channel for direct sales to end consumers and an independently managed retail channel for sales in physical stores. Jafar and Ozgunthe studied the impact of the consumers' sales channel preferences and product compatibility with online shopping on pricing decisions in such a dual-channel supply chain [38]. Factors related to the distribution channel are found to influence supply chain management in articles on consumer-centric logistics and consumer-centric marketing, and they influence every phase of the customer journey. In consumer-centric marketing studies, the integration and interaction among distribution channels is a factor that drives purchase and subsequent return decisions [39].

In general, the research on manufacturers' pricing strategies and consumer purchasing channel selection mainly focuses on channel conflicts and coordination, the influence of consumer types and preference factors, and the influence of some consumer behavior factors. However, the decisions of manufacturers and consumers will dynamically evolve with changes in conditions. Moreover, consumers may be affected by loss aversion, which was proposed by Kahneman and Tversky in 1979 [40] in their prospect theory: here, the value function is concave for gains, convex for losses, and steeper for losses than for gains. As far as the authors know, there is little research concerning the dynamic evolution of behavioral strategies between manufacturers and consumers in dual-channel pricing and channel selection, and there is no research that considers both the former and consumer loss aversion simultaneously. Thus, in this paper, evolutionary game analysis is applied to dual-channel decisions made by manufacturers and consumers, and consumer loss aversion is taken into consideration; the goal is to explore the impact of consumer loss aversion on manufacturers' pricing decisions and consumers' purchasing channel decisions.

## 3. Research Methods

A real supply chain structure involves many stakeholders, including raw material suppliers, e-commerce platforms, logistics providers, after-sales service providers, cybersecurity stakeholders, consumers, and even regulatory departments. The supply chain structure can generally be summarized as shown in Figure 3, according to the literature review section [31–39], in which the blue part is the focus of this paper.

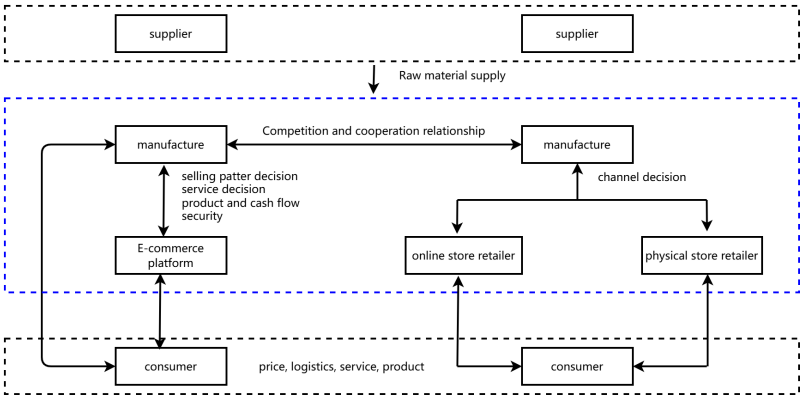



**Figure 3.** The dual-channel supply chain structure.

This study focuses on the part from manufacturers to retailers and then to consumers, as shown in the blue part in Figure 3; here, the left side of the blue part focuses on manufacturers' direct online sales and agent online sales, and the other part is focused on the relevant decisions of online store retailers and physical store retailers. This paper describes the problem based on the latter, as shown in Figure 4; here, retailers, e-platforms, and other stakeholders are seen as intermediaries in the game between manufacturers and consumers.

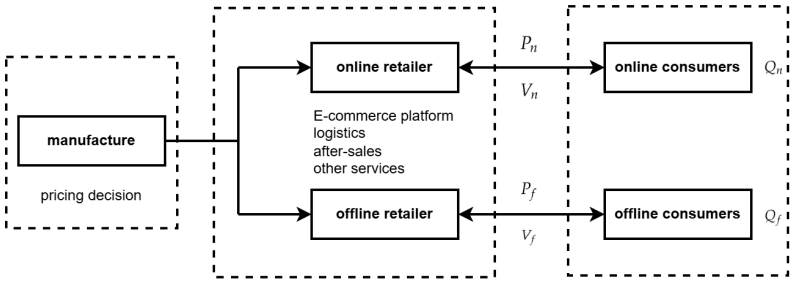



**Figure 4.** The problem focus.

### *3.1. Model Descriptions and Assumptions*

In evolutionary game theory, the players are assumed to be boundedly rational and to ultimately seek evolutionarily stable strategies through trial and error, imitation, and learning. The decisions of dual-channel manufacturers and consumers form a dynamic process. Each participant in the process formulates a self-prioritized decision strategy based on its own costs and benefits. The stakeholders related to the dual-channel supply chain exhibit bounded rationality. This section provides a detailed discussion of the evolutionary game process among the manufacturers and consumers.

Faced with intensified competition in online channels and the complexity of online promotion rules, consumers are attracted by the convenience and low prices of online channels while also becoming increasingly dissatisfied with sales tactics. To cope with this challenge, some manufacturers choose to invest more financially and adopt price differentiation management, but we have also noticed that some manufacturers choose

to adopt a unified pricing strategy both online and offline. In order to discuss the stable strategies that consumers and manufacturers may form in the evolutionary game process, the following assumptions are made:

(1) Manufacturers determine pricing policies, with a proportion of $x$ choosing a dual-channel unified pricing strategy and a proportion of $1 - x$ choosing differential prices; consumers choose purchasing channels, with a proportion of $y$ choosing the offline channel and a proportion of $1 - y$ choosing the online channel.

(2) When manufacturers choose a dual-channel unified pricing strategy, a portion of consumers who cannot accept the price increase may choose not to buy and will leave the online market, with a proportion of $\omega$. $Q_f$ and $Q_n$, respectively, represent the offline and online market shares.

(3) Given that consumers have more uncertainty when purchasing online, consumers are more susceptible to loss aversion in online channels. $\lambda$ represents the utility loss caused by consumer loss aversion.

(4) If the prices and quality of the products are the same online and offline, then product utility for consumers is also the same; that is to say, $V_f = V_n$ and $P_f = P_n$. Consumers will naturally choose online or offline channels based on their preferences.

(5) If the online and offline prices are different, then $\alpha$ represents the price discount of the online product, and $\beta$ represents the quality discount of the online product. If consumers choose to purchase online, on the one hand, they will enjoy a price discount, $\alpha$, and the benefits of convenience, $S_n$, which represents online service quality, including logistics, returns, and exchanges. However, on the other hand, they will be affected by loss aversion, $\lambda$, caused by more uncertainty in online channels. If consumers choose to purchase offline, they cannot enjoy price discounts, but they can experience traditional offline services, $S_f$, which are influenced by investment costs.

(6) If manufacturers choose a dual-channel unified pricing strategy, they will benefit from simplified management, prevention of price erosion, brand enhancement, and so on. Meanwhile, due to the different management costs between online and offline channels—assuming that the benefit gained by manufacturers when consumers tend to prefer offline channels is $R$—the benefit gained by manufacturers when they tend to prefer online channels is $M$.

(7) If manufacturers choose a differential pricing strategy, they need to choose between fixed or dynamic adjustments based on market demand to cope with price erosion, manage free-riding behavior between online and offline channels, increase cooperation or competition management through dual channels, and so on, leading to an increase in management costs. Similarly, due to the differences between online and offline management, using $F$ represents the increased management cost when consumers tend to purchase offline, and using $N$ represents the increased management cost when consumers tend to purchase online.

Based on the above assumptions, each player has two strategies to choose from. In reality, the utility or profit of two participating entities will be influenced by each other's choices.

### *3.2. The Payoff for Each Player*

Table 1 displays the symbols and their corresponding descriptions for parameters in the evolutionary game.

**Table 1.** Summary of symbols.

| Parameters | Descriptions |
|---|---|
| $P_f$ | The product price for offline retail. |
| $P_n$ | The product price for online retail. |
| $\omega$ | The proportion of online consumers lost due to a price increase. |
| $V_f$ | The product utility for offline retail. |
| $V_n$ | The product utility for online retail. |
| $\alpha$ | The price discount for the online product, $P_n = \alpha P_f$. |
| $\beta$ | The quality discount for the online product, $V_n = \beta V_f$. |
| $\lambda$ | The consumer loss aversion coefficient. Consumers are more loss-averse when $\lambda$ is larger. |
| $T$ | The unit mismatch cost caused by choice. |
| $S_f$ | The service utility of offline retail. |
| $S_n$ | The service utility of online retail. |
| $R$ | Benefits to manufacturers caused by simplifying management, preventing price erosion issues, improving brand positioning, etc., when manufacturers choose a dual-channel unified pricing strategy and consumers tend to prefer an offline purchasing channel. |
| $M$ | Benefits to manufacturers caused by simplifying management, preventing price erosion issues, improving brand positioning, etc., when manufacturers choose a dual-channel unified pricing strategy and consumers tend to prefer an online purchasing channel. |
| $F$ | The increased cost to manufacturers caused by increased management for price erosion problems, the free-riding effect, etc., when manufacturers choose a dual-channel differential pricing strategy and consumers tend to prefer an offline purchasing channel. |
| $N$ | The increased cost to manufacturers caused by increased management for price erosion problems, the free-riding effect, etc., when manufacturers choose a dual-channel differential pricing strategy and consumers tend to prefer an online purchasing channel. |
| $x$ | The proportion of consumers choosing a dual-channel unified pricing strategy. |
| $y$ | The proportion of manufacturers choosing offline channels for purchase. |
| $Q_f$ | The market share of offline retail. |
| $Q_n$ | The market share of online retail. |
| $u_f$ | The total utility for consumers by buying the product offline. |
| $u_n$ | The total utility for consumers by buying the product online. |
| $\pi_f$ | The manufacturer's profit when consumers buy the product offline. |
| $\pi_n$ | The manufacturer's profit when consumers buy the product online. |
| $X$ | The marginal consumer with the same evaluations in the two channels. |

Next, we use the Hotelling model and consider online consumer loss aversion in calculating online and offline market share; further, we calculate the manufacturer's profit and consumer utility to determine the payoff for both parties.

#### 3.2.1. Market Share and Profit Calculation Based on Consumer Loss Aversion and the Hotelling Model

The Hotelling model is a linear (linear segment) market duopoly location model proposed by Harold Hotelling in 1929, and it operates from different space locations. It is one of the important models that we used to solve the problem of site selection. The Hotelling model has been previously applied to various spatial position competition problems. In this study, consumers' evaluations for offline channels and online channels are set in a linear space from 0 to 1; then, the corresponding market share can be calculated based on the Hotelling model by calculating the position of consumers without an evaluation difference.

Assume that consumers' evaluations of offline and online channels are uniformly distributed. Here, 0 represents the highest evaluation of the offline channel, and 1 represents the highest evaluation of the online channel, as shown in Figure 5. $X$ is a marginal consumer with the same evaluations as used in the two channels.

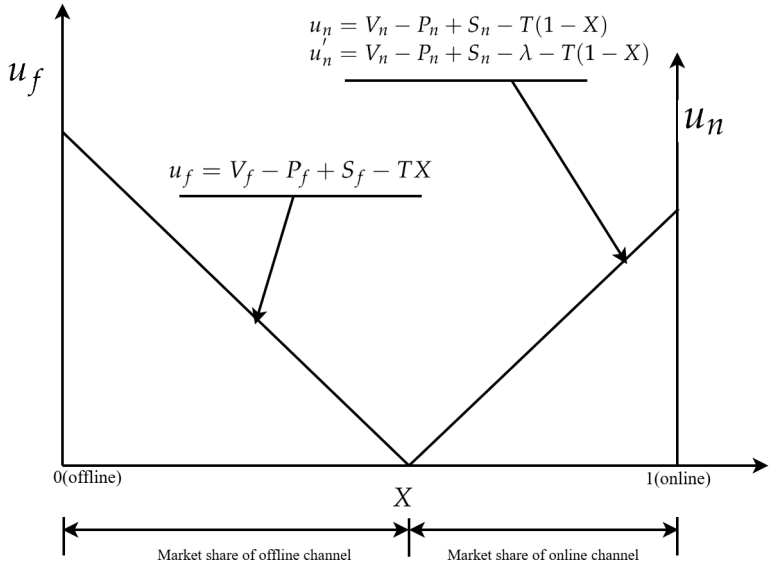



**Figure 5.** The market share of the two channels based on Hotelling demand.

(1) When manufacturers choose a dual-channel unified pricing strategy, the price and quality of dual-channel products are the same, and consumers will choose purchasing channels based on their preferences and the quality of online and offline services, represented by parameters $S_f$ and $S_n$. Consumers with a proportion of $\omega$ will leave the online market due to the price increase. Additionally, consumers choosing channels that do not match their preferences will incur mismatch costs. Here, $T$ is used to represent the unit mismatch cost. Thus, overall consumer utility is shown in Equation (1):

$$\begin{aligned} u_f &= V_f - P_f + S_f - TX \\ u_n &= V_n - P_n + S_n - T(1-X) \end{aligned} \tag{1}$$

Let $u_f = u_n$; that is, if $V_f - P_f + S_f - TX = V_n - P_n + S_n - T(1-X)$, the following results can be calculated:

$$\begin{aligned} X &= \frac{S_f - S_n + T}{2T} \\ 1 - X &= 1 - \frac{S_n - S_f + T}{2T} \end{aligned}$$

Considering the proportion of online consumers lost due to price increase $\omega$, the market shares of the two channels are shown in Equation (2):

$$\begin{aligned} Q_f &= X = \frac{S_f - S_n + T}{2T} \\ Q_n &= (1-X)(1-\omega) = \frac{(1-\omega)(S_n - S_f + T)}{2T} \end{aligned} \tag{2}$$

Furthermore, note the following: (a) When consumers tend to prefer an offline purchasing channel, manufacturers will benefit from simplified management, prevention of erosion issues, improvement in brand positioning, and so on, which are represented by parameter $R$. Thus, the utility for consumers and the profit for manufacturers can be calculated, as shown in Equation (3):

$$u_f = V_f - P_f + S_f$$
$$\pi_f = P_f \times Q_f + P_n \times Q_n + R = P_f \times Q_f + P_f \times Q_n + R = \frac{\omega \times P_f \times S_f - \omega \times P_f \times S_n + (2-\omega) \times P_f \times T + 2R \times T}{2T} \quad (3)$$

(b) When consumers tend to prefer an online purchasing channel, manufacturers will benefit as well, as represented by parameter $M$. Thus, the utility for consumers and the profit for manufacturers can be calculated, as shown in Equation (4):

$$u_n = V_n - P_n + S_n = V_f - P_f + S_n$$
$$\pi_n = P_f \times Q_f + P_n \times Q_n + M = P_f \times Q_f + P_f \times Q_n + M = \frac{\omega \times P_f \times S_f - \omega \times P_f \times S_n + (2-\omega) \times P_f \times T + 2M \times T}{2T} \quad (4)$$

(2) When manufacturers choose the dual-channel price differentiation strategy, they have to pay for increased management for price erosion problems, the free-riding effect, and so on. The increased management costs caused by different channel structures are represented by $F$ and $N$, respectively. When consumers choose online channels, they will obtain a price discount, $\alpha$, but at the same time, they also have to accept the decrease in product quality, represented by $\beta$, and the loss aversion caused by the risk of not being able to feel the actual product in a timely manner, represented by $\lambda$. Similar to the process in (1) above, the market share under this condition can be calculated by letting $u_f = u_n$; that is, $V_f - P_f + S_f - TX = V_n - P_n + S_n - \lambda - T(1-X)$, in which $P_n = \alpha P_f$, $V_n = \beta V_f$. The results are shown in Equation (5):

$$Q_f = \frac{(1-\beta)V_f - (1-\alpha)P_f + S_f - S_n + \lambda + T}{2T}$$
$$Q_n = \frac{(\beta-1)V_f + (1-\alpha)P_f - S_f + S_n - \lambda + T}{2T} \quad (5)$$

Furthermore, note the following: (a) When consumers tend to prefer an offline purchasing channel, the utility for consumers and the profit for manufacturers can be calculated, as shown in Equation (6):

$$u_f = V_f - P_f + S_f$$
$$\pi_f = \frac{(1-\alpha)(1-\beta)P_f \times V_f - (1-\alpha)^2 \times P_f^2 + (1-\alpha)P_f \times S_f - (1-\alpha)P_f \times S_n + (1-\alpha)\lambda \times P_f + (1+\alpha) \times P_f \times T - 2F \times T}{2T} \quad (6)$$

(b) When consumers tend to prefer an online purchasing channel, the utility for consumers and the profit for manufacturers can be calculated, as shown in Equation (7):

$$u_n = \beta V_f - \alpha P_f + S_n$$
$$\pi_n = \frac{(1-\alpha)(1-\beta)P_f \times V_f - (1-\alpha)^2 \times P_f^2 + (1-\alpha)P_f \times S_f - (1-\alpha)P_f \times S_n + (1-\alpha)\lambda \times P_f + (1+\alpha) \times P_f \times T - 2N \times T}{2T} \quad (7)$$

#### 3.2.2. The Payoff of the Evolutionary Game Between Manufacturers and Consumers

Based on the above assumptions and analysis, the game tree of the manufacturers and consumers is shown in Figure 6.

$a_1$, $a_2$, $a_3$, and $a_4$ represent the consumer's utility, and $b_1$, $b_2$, $b_3$, and $b_4$ represent the manufacturer's profit.

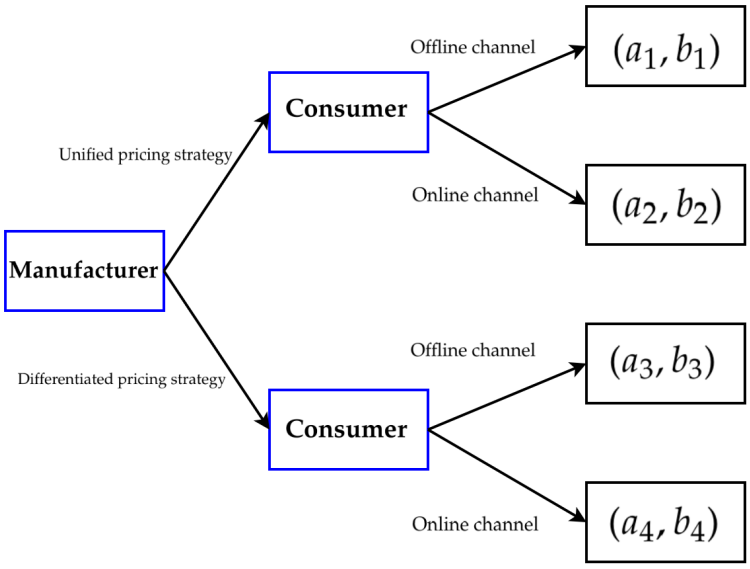



**Figure 6.** The game tree.

The payoff matrix is shown in Table 2.

**Table 2.** The payoff matrix.

| Consumer \ Manufacturer | Unified Pricing Strategy $y$ | Differentiated Pricing Strategy $1-y$ |
|---|---|---|
| Offline channel $x$ | $a_1 = V_f - P_f + S_f$, $b_1 = \frac{\omega * P_f * S_f - \omega * P_f * S_n + (2-\omega) * P_f * T + 2R * T}{2T}$ | $a_3 = V_f - P_f + S_f$, $b_3 = \frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 * P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda * P_f + (1+\alpha) * P_f * T - 2F * T}{2T}$ |
| Online channel $1-x$ | $a_2 = V_f - P_f + S_n$ $b_2 = \frac{\omega * P_f * S_f - \omega * P_f * S_n + (2-\omega) * P_f * T + 2M * T}{2T}$ | $a_4 = \beta V_f - \alpha P_f + S_n$ $b_4 = \frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 * P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda * P_f + (1+\alpha) * P_f * T - 2N * T}{2T}$ |

### *3.3. Solutions and Analysis of the Evolutionary Game*

(1) Consumer-replicated dynamic equations:

Suppose that $U_e(x)$ represents the expected utility for the consumer that adopts a strategy of offline channel. Then,

$$U_e(x) = y(V_f - P_f + S_f) + (1-y)(V_f - P_f + S_f) = V_f - P_f + S_f \tag{8}$$

Suppose that $U_e(1-x)$ represents the expected utility for the consumer that adopts an online channel strategy. Then,

$$U_e(1-x) = y(V_f - P_f + S_n) + (1-y)(\beta V_f - \alpha P_f + S_n) \tag{9}$$

The expected utility for the consumer that adopts both strategies is

$$\overline{U_c} = xU_e(x) + (1-x)U_e(1-x) \tag{10}$$

Thus, the replicator dynamics equation of the proportion x for the consumer is

$$F(x) = \frac{dx}{dt} = x(U_e(x) - \overline{U_c}) = x(1-x)[V_f - P_f + S_f - y(V_f - P_f + S_n) - (1-y)(\beta V_f - \alpha P_f + S_n)] \tag{11}$$

(2) Manufacturer replicated dynamic equations:

Suppose that $U_e(y)$ represents the expected profit for the manufacturer that adopts a strategy of unified pricing. Then,

$$U_e(y) = x\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2R * T}{2T} + (1-x)\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2M * T}{2T} \quad (12)$$

Suppose that $U_e(1-y)$ represents the expected profit for the manufacturer that adopts a strategy of differentiated pricing. Then,

$$\begin{aligned} U_e(1-y) = x&\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2F * T}{2T} \\ +(1-x)&\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2N * T}{2T} \end{aligned} \quad (13)$$

The expected utility for the manufacturer that adopts both strategies is

$$\overline{U_m} = yU_e(y) + (1-y)U_e(1-y) \quad (14)$$

Thus, the replicator dynamics equation of the proportion y for the manufacturer is

$$\begin{aligned} F(y) &= \frac{dy}{dt} = y(U_e(y) - \overline{U_m}) = y(1-y)(U_e(y) - U_e(1-y)) \\ &= y(1-y)[x\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2R * T}{2T} + (1-x)\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2M * T}{2T} \\ &- x\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2F * T}{2T} \\ &- (1-x)\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2N * T}{2T}] \end{aligned} \quad (15)$$

According to Equations (11) and (15), the replicated dynamic equations of the whole system can be written as follows:

$$\begin{cases} F_x = x(1-x)[V_f - P_f + S_f - y(V_f - P_f + S_n) - (1-y)(\beta V_f - \alpha P_f + S_n)] \\ F_y = y(1-y)[x\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2R * T}{2T} + (1-x)\frac{\omega P_f * S_f - \omega P_f * S_n + (2-\omega)P_f * T + 2M * T}{2T} \\ -x\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2F * T}{2T} \\ -(1-x)\frac{(1-\alpha)(1-\beta)P_f * V_f - (1-\alpha)^2 P_f^2 + (1-\alpha)P_f * S_f - (1-\alpha)P_f * S_n + (1-\alpha)\lambda P_f + (1+\alpha)P_f * T - 2N * T}{2T}] \end{cases} \quad (16)$$

The Jacobian matrix can be constructed accordingly, as follows:

$$\begin{aligned} J &= \begin{bmatrix} \frac{\partial F(x)}{dx} & \frac{\partial F(x)}{dy} \\ \frac{\partial F(y)}{dx} & \frac{\partial F(y)}{dy} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \\ a_{11} &= (2x-1)(P_f - S_f + S_n - V_f - \alpha P_f + \beta V_f - yP_f + \alpha yP_f - \beta yV_f) \\ a_{12} &= -x(x-1)(P_f - V_f - \alpha P_f + \beta V_f) \\ a_{21} &= 0 \\ a_{22} &= (1-2y)\frac{P_f * (P_f - S_f + S_n + 2T - V_f - \lambda - 2\alpha P_f + \alpha S_f - \alpha S_n + \alpha V_f + \beta V_f + \omega S_f - \omega S_n - \omega T + \alpha\lambda + \alpha^2 P_f - \alpha\beta V_f)}{2T} \end{aligned} \quad (17)$$

According to Friedman's calculation method for the evolutionary stability strategy [41], an evolutionary stability strategy can be obtained based on a local stability analysis of a Jacobian matrix. The judgment conditions for the Jacobian matrix stability are that, when $Det(J) > 0$ and $Tr(J) < 0$, the equilibrium point has asymptotic stability properties, which can become an evolutionarily stable strategy (ESS).

Let $Det_{00}$, $Det_{01}$, $Det_{10}$, and $Det_{11}$ represent the sign of $Det(J)$ for different points, and let $Tr_{00}$, $Tr_{01}$, $Tr_{10}$, and $Tr_{11}$ represent the sign of $Tr(J)$ for different points, where

$$
\begin{aligned}
Det_{00} &= (S_f - P_f - S_n + V_f + \alpha P_f - \beta V_f) * \frac{\begin{array}{r}(2MT + 2NT - P_fS_f + P_fS_n + TP_f - P_fV_f - \lambda P_f - 2\alpha P_f^2 + P_f^2 + \alpha^2 P_f^2 + \alpha P_fS_f \\ - \alpha P_fS_n - \alpha P_fT + \alpha P_fV_f + \beta P_fV_f + \omega P_fS_f - \omega P_fS_n - \omega P_fT + \alpha\lambda P_f - \alpha\beta P_fV_f)\end{array}}{2T} \\
Tr_{00} &= (S_f - P_f - S_n + V_f + \alpha P_f - \beta V_f) + \frac{\begin{array}{r}(2MT + 2NT - P_fS_f + P_fS_n + TP_f - P_fV_f - \lambda P_f - 2\alpha P_f^2 + P_f^2 + \alpha^2 P_f^2 + \alpha P_fS_f \\ - \alpha P_fS_n - \alpha P_fT + \alpha P_fV_f + \beta P_fV_f + \omega P_fS_f - \omega P_fS_n - \omega P_fT + \alpha\lambda P_f - \alpha\beta P_fV_f)\end{array}}{2T} \\
Det_{01} &= (S_f - S_n) * \frac{\begin{array}{r}(-2MT - 2NT + P_fS_f - P_fS_n - TP_f + P_fV_f + \lambda P_f + 2\alpha P_f^2 - P_f^2 - \alpha^2 P_f^2 - \alpha P_fS_f \\ + \alpha P_fS_n + \alpha TP_f - \alpha P_fV_f - \beta P_fV_f - \omega P_fS_f + \omega TP_f - \alpha\lambda P_f + \alpha\beta P_fV_f)\end{array}}{2T} \\
Tr_{01} &= (S_f - S_n) + \frac{\begin{array}{r}(-2MT - 2NT + P_fS_f - P_fS_n - TP_f + P_fV_f + \lambda P_f + 2\alpha P_f^2 - P_f^2 - \alpha^2 P_f^2 - \alpha P_fS_f + \alpha P_fS_n \\ + \alpha TP_f - \alpha P_fV_f - \beta P_fV_f - \omega P_fS_f + \omega TP_f - \alpha\lambda P_f + \alpha\beta P_fV_f)\end{array}}{2T} \\
Det_{10} &= (-S_f + P_f + S_n - V_f - \alpha P_f + \beta V_f) * \frac{\begin{array}{r}(P_fS_n - P_fS_f + TP_f + 2RT - P_fV_f - \lambda P_f - 2\alpha P_f^2 + P_f^2 + \alpha^2 P_f^2 + 2FT + \alpha P_fS_f \\ - \alpha P_fS_n - \alpha TP_f + \alpha P_fV_f + \beta P_fV_f + \omega P_fS_f - \omega P_fS_n - \omega TP_f + \alpha\lambda P_f - \alpha\beta P_fV_f)\end{array}}{2T} \\
Tr_{10} &= (-S_f + P_f + S_n - V_f - \alpha P_f + \beta V_f) + \frac{\begin{array}{r}(P_fS_n - P_fS_f + TP_f + 2RT - P_fV_f - \lambda P_f - 2\alpha P_f^2 + P_f^2 + \alpha^2 P_f^2 + 2FT + \alpha P_fS_f \\ - \alpha P_fS_n - \alpha TP_f + \alpha P_fV_f + \beta P_fV_f + \omega P_fS_f - \omega P_fS_n - \omega TP_f + \alpha\lambda P_f - \alpha\beta P_fV_f)\end{array}}{2T} \\
Det_{11} &= (-S_f + S_n) * \frac{\begin{array}{r}(-P_fS_n + P_fS_f - TP_f - 2RT + P_fV_f + \lambda P_f + 2\alpha P_f^2 - P_f^2 - \alpha^2 P_f^2 - 2FT - \alpha P_fS_f + \alpha P_fS_n \\ + \alpha TP_f - \alpha P_fV_f - \beta P_fV_f - \omega P_fS_f + \omega P_fS_n + \omega TP_f - \alpha\lambda P_f + \alpha\beta P_fV_f)\end{array}}{2T} \\
Tr_{11} &= (-S_f + S_n) + \frac{\begin{array}{r}(-P_fS_n + P_fS_f - TP_f - 2RT + P_fV_f + \lambda P_f + 2\alpha P_f^2 - P_f^2 - \alpha^2 P_f^2 - 2FT - \alpha P_fS_f + \alpha P_fS_n \\ + \alpha TP_f - \alpha P_fV_f - \beta P_fV_f - \omega P_fS_f + \omega P_fS_n + \omega TP_f - \alpha\lambda P_f + \alpha\beta P_fV_f)\end{array}}{2T}
\end{aligned}
\tag{18}
$$

By calculating the determinant and the trace of the Jacobian matrix in Equation (17), the five situations shown in Table 3 can be obtained.

**Table 3.** The determinant and trace of the Jacobian matrix.

| Local Equilibrium Point | Sign of $Det(J)$ | Sign of $Tr(J)$ | Results |
|---|---|---|---|
| $(0,0)$ | $Det_{00}$ | $Tr_{00}$ | ESS ① |
| $(0,1)$ | $Det_{01}$ | $Tr_{01}$ | ESS ② |
| $(1,0)$ | $Det_{10}$ | $Tr_{10}$ | ESS ③ |
| $(1,1)$ | $Det_{11}$ | $Tr_{11}$ | ESS ④ |
| $(x^*, y^*)$ | 0 | 0 | Saddle point |

Condition ①: $Det_{00} > 0$ and $Tr_{00} < 0$. Condition ②: $Det_{01} > 0$ and $Tr_{01} < 0$. Condition ③: $Det_{10} > 0$ and $Tr_{10} < 0$. Condition ④: $Det_{11} > 0$ and $Tr_{11} < 0$.

It can be seen that different conditions will lead to different evolutionarily stable strategies, and $S_f - S_n$ directly determines whether the determinant is greater than 0, which in turn affects whether the point can become an ESS; further sensitivity analysis is needed to investigate the impact of other parameters.

## 4. Results and Discussion

To verify the rationality of the model and derived ESS established in Section 3.3, we simulated the evolution process of the game between manufacturers and consumers under different initial conditions. This work discusses the impact of various factors on the game results, including consumer loss aversion, price discount, quality discount, and services. Matlab was applied for the simulation.

### *4.1. Simulation*

Multiple Chinese media outlets, including Tencent (https://news.qq.com/, accessed on 20 November 2024) and Pedaily (https://www.pedaily.cn/, accessed on 20 November

2024), released industry analyses on cosmetics in 2024, stating that CNY 350 will become the most important competitive price band for cosmetics in China. On this basis, other parameters are reasonably set according to investigation and discussion. That is, $P_f = 350$, $\omega = 0.2$, $V_f = 550$, $\alpha = 0.7$, $\beta = 0.7$,$T = 5$, $\lambda = 20$, $S_f = 50$, and $S_n = 10$.

Combining Equation (18) and Table 3, it can be concluded that $Det_{11} > 0$ and $Tr_{11} < 0$; thus, point $(1, 1)$ can become an ESS. Figure 7 shows the dynamic evolution tree of the game between manufacturers and consumers when offline services are better, in which different lines represent different initial probability points.

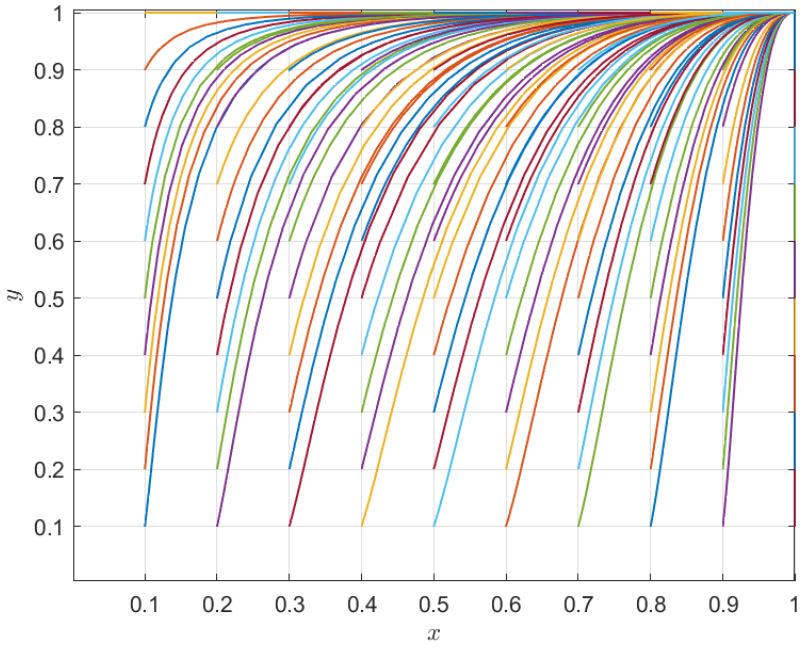



**Figure 7.** Dynamic evolution tree of the game when offline services are better.

Figure 7 shows that the curve converges to (1,1) and reveals that it is easier to achieve stability if manufacturers prefer to adopt a unified pricing strategy; here, consumers tend to purchase more through offline channels when the offline service is better. Although face-to-face and timely offline services cannot be replaced at present, with the application of AI technologies—and the improvement of live streaming interactions, logistics services, after-sales returns, and exchanges—these services might be replicated in an online setting. Accordingly, it is assumed that, for consumers, the utility of online services may exceed that of offline services. Therefore, a higher online service parameter ($S_n = 85$) is set to explore the ESS when online services exceed offline services. Figure 8 shows the dynamic evolution tree of the game between manufacturers and consumers when online services are better, in which different lines represent different initial probability points.

Figure 8 shows that the curve converges to (0,1) and reveals that it is easier to achieve stability if manufacturers prefer to adopt a unified pricing strategy; here, consumers tend to purchase more through online channels when online services are better.

Combining Figures 7 and 8 reveals that, with other conditions constant, channel services will affect the evolution process of the game for manufacturers and consumers, and different service quality parameters will evolve to different ESSs. Interestingly, the comparison of services can affect consumers' evolutionarily stable strategies, and consumers are more inclined to choose which purchasing channel has better service to a certain extent; however, regardless of the differences between online and offline services, manufacturers will evolve to an evolutionarily stable unified pricing strategy (ESS).

### *4.2. Parameter Sensitivity Analysis*

#### 4.2.1. The Effect of Consumer Loss Aversion on Evolution

To further observe the influences of consumer loss aversion on the evolution of the game, we examine the evolution paths of the strategies of manufacturers and consumers over time, allowing only the consumer loss aversion parameter, $\lambda$, to vary; the others remain constant at the initial value ($S_n = 10$). Figure 9 shows the dynamic evolution paths for consumers and manufacturers when $\lambda$ takes different values.

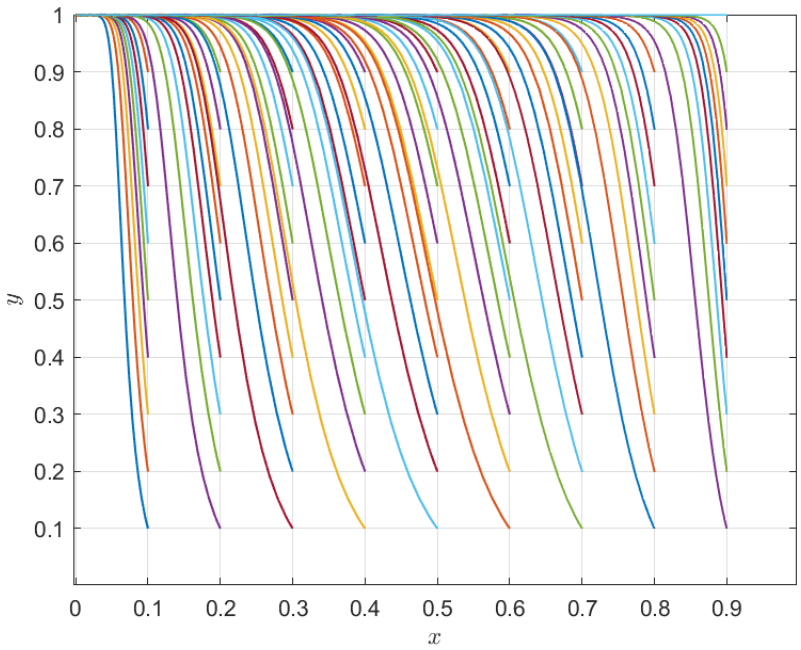
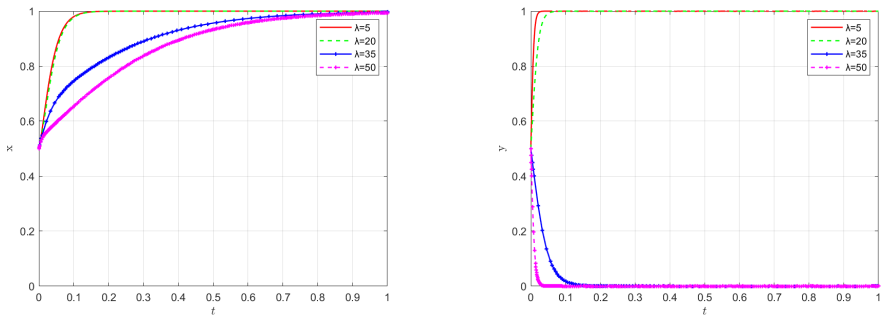



**Figure 8.** Dynamic evolution tree of the game when online services are better.




(**a**) Consumer (**b**) Manufacturer

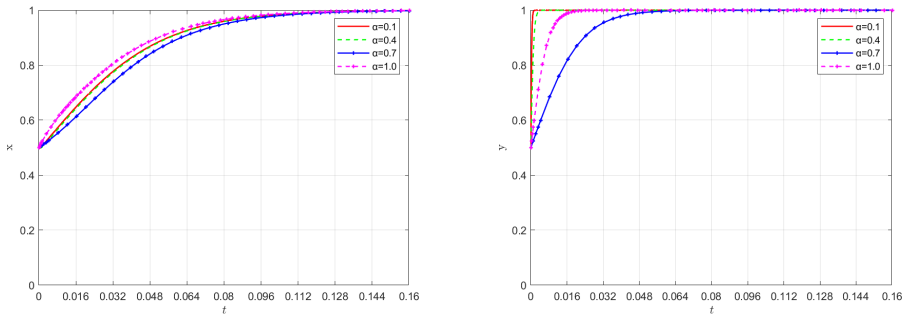
**Figure 9.** The impact of consumer loss aversion on the dynamic evolution paths for two parties.

As seen in Figure 9a, with the rest of the parameters unchanged, when $\lambda$ = 5, 20, 35, or 50, the times required for consumers to reach stability increase. Thus, the stronger the role of $\lambda$, the more time it requires to achieve stability. That is to say, with the decrease in $\lambda$, consumers are increasingly inclined to adopt an offline purchasing strategy. This may be because, when $\lambda$ decreases, manufacturers first notice an increase in online channel demand; then, in order to obtain more profits, they may raise the online price, which in turn leads to a decrease in online demand. Finally, consumers gradually evolve to choose offline channels for purchasing, forming an ESS; meanwhile, when $\lambda$ increases, manufacturers may notice a rapid decrease in online demand and may adopt price differentiation strategies, while consumers may evolve to choose offline channels for purchasing due to their aversion to online channel risks, once again forming such an ESS. According to Figure 9b, when $\lambda$ = 5 or

20, the times required for manufacturers to reach a stable unified pricing strategy increase. When $\lambda$ = 35 or 50, the times required for manufacturers to reach a stable differentiated pricing strategy decrease. Thus, with the decrease in $\lambda$, the manufacturers' ESS changed from a differentiated pricing strategy to a unified pricing strategy. This may be because, when $\lambda$ decreases, the online channel demand becomes greater, and manufacturers are more likely to set high online prices in order to maximize profits. That is, a unified pricing strategy forms an ESS; meanwhile, when $\lambda$ increases, the online channel demand will decrease, and manufacturers will choose differentiated pricing strategies to form a different ESS.

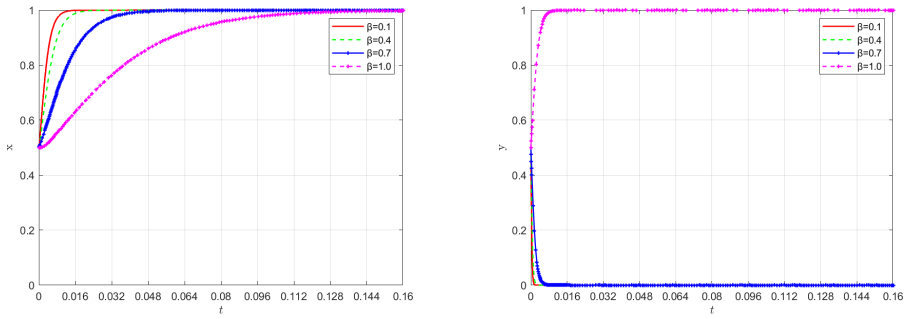
4.2.2. The Impact of Other Parameters on Evolution

This paper further examines the evolution paths of the strategies of consumers and manufacturers over time, allowing only $\alpha$ or $\beta$ to vary while the others remain constant at the initial value ($S_n = 10$). Figures 10 and 11 show the impact of price discount and quality discount on the dynamic evolution paths for consumers and manufacturers when $\alpha$ or $\beta$ take different values.




(**a**) Consumer (**b**) Manufacturer

**Figure 10.** The impact of price discount on the dynamic evolution paths for two parties.




(**a**) Consumer (**b**) Manufacture

**Figure 11.** The impact of quality discount on the dynamic evolution paths for two parties.

It can be seen from Figure 10 that, as $\alpha$ reaches its maximum value of 1.0, the time that a consumer requires to achieve stability is at a minimum; as $\alpha$ reaches its minimum value of 0.1, the time that a manufacturer requires to achieve stability is at a maximum. Therefore, as $\alpha$ increases, consumers are increasingly inclined to adopt an offline purchasing channel strategy. With a decrease in $\alpha$, manufacturers are increasingly inclined to adopt a unified pricing strategy.

Similarly, Figure 11 shows that, as $\beta$ reaches its minimum value of 0.1, the time that a consumer requires to achieve stability is at a minimum. Therefore, as $\beta$ decreases, consumers are increasingly inclined to adopt an offline purchasing channel strategy. Mean-

while, as $\beta$ increases, the ESS of manufacturers shifts from a differentiated pricing strategy to a unified pricing strategy.

### *4.3. Model Validation and Verification*

We obtained the prices and sales of best-selling cosmetics and clothing brands from Taobao, one of the largest e-commerce platforms in China, as shown in Tables 4 and 5, respectively.

The counter prices in Table 4 are based on the price data published by Intime Department Store, and the sales data are the monthly sales displayed on the product page of Taobao.

**Table 4.** Sales data of skincare products.

| Product Registration Number | Brand | Prices on Taobao | Sales on Taobao | Counter Prices in Shopping Malls |
|---|---|---|---|---|
| 2024004383 | Lancome | 1120 | 60,000+ | 1120 |
| 2023001769 | LA MER | 1060 | 70,000+ | 1060 |
| 2022006890 | Clarins | 1030 | 20,000+ | 1030 |
| 2020003600 | Estee Lauder | 990 | 100,000+ | 990 |
| 2023000066 | Guerlain | 780 | 50,000+ | 780 |
| 2020007702 | SK-II | 610 | 100,000+ | 610 |
| 2024005718 | Lancome | 500 | 100,000+ | 500 |
| 2023006081 | Elizabeth Arden | 410 | 10,000+ | 410 |
| 2023009305 | Kiehl's | 395 | 100,000+ | 395 |
| 2024000651 | Origins | 380 | 30,000+ | 380 |
| 2023005172 | L'oreal | 359 | 100,000+ | 370 |
| 2023001147 | PROYA | 349 | 500,000+ | 349 |
| G20202048 | OLAY | 339 | 400,000+ | 339 |
| 2022000473 | Winona | 338 | 100,000+ | 338 |
| 2023001593 | Clinique | 310 | 20,000+ | 310 |

It can be seen that the sales of these products have all exceeded 10 thousand, with products priced around CNY 350 having the highest sales, reaching 500 thousand. Even though international first-tier brands have higher prices, their sales are still impressive. We also found that regardless of the price, brands usually offer high-value gifts, which can often reach or even exceed the content of the main product in the form of samples, while shopping malls often cannot provide such generous gifts.

So, the authors argue that these brands have higher online service, and more consumers are choosing to purchase online. We also found that best-selling products are usually classic products from various brands, and consumers do not need to personally experience them to have sufficient knowledge of the products, because the ingredients and efficacy of these products have become increasingly transparent. If offline channels only focus on product explanations, while online channels offer more favorable gifts, then consumers are more likely to choose online purchases when they have a full understanding of the product.

This is consistent with the simulation result in Figure 8, in which the curve converges to (0,1) and reveals that it is easier to achieve stability if manufacturers adopt a unified pricing strategy and consumers tend to purchase more through online channels when online service is better.

At the same time, we also found that mature brands are increasingly providing consumers with free, immersive, exclusive services offline, which may be an important way for offline channels to retain customers in the future. However, providing better services inevitably leads to an increase in channel costs, so many brands still choose to focus on

online channels, while mature brands that can afford the costs are actively joining the exploration of offline service improvement.

Table 5 lists the clothing products that we found on Taobao using the keyword "same as the mall", which means the product is sold both online and offline. The tag prices were obtained through the pictures in the product details on the platform.

**Table 5.** Sales data of clothing products.

| Product Registration Number | Brand | Prices on Taobao | Sales on Taobao | Tag Price |
|---|---|---|---|---|
| N23101A01007 | NEELY | 339 | 16 | 339 |
| BDS1MD1184 | broadcast | 798 | 5 | 798 |
| JLFGM253 | jessie | 671 | 7 | 1499 |
| JWCD31302 | JZ | 394 | 34 | 1580 |
| 5P1113980 | JNBY | 695 | 87 | 695 |
| A3EEE3422 | PEACEBIRD | 599 | 1 | 599 |
| 1EA332241 | Eifini | 596 | 8 | 596 |
| 89124370104 | HOPESHOW | 449 | 9 | 449 |
| 3F8331781 | SEIFINI | 539 | 33 | 598 |
| 124420TC348 | LILY | 719 | 0 | 719 |
| FR470034043 | FeiNiao&XinJiu | 899 | 0 | 899 |
| LWT009177C0B | Lee | 629 | 26 | 629 |
| S23483523 | sdeer | 549 | 6 | 599 |
| C2EEE420439 | LEDiN | 499 | 17 | 499 |
| 112401102049 | H's | 614 | 4 | 614 |

When searching, it was found that many brands do not offer the same products as in the mall but instead provide a wide range of styles that are only sold online. The prices of products that are the same as those in the mall are also the same as the tag price, with only two products launched in 2022 having significant discounts on their online prices.

The online sales of these products are not high, many of which are within 10 pieces. So, the authors believe that these brands actually choose a unified pricing strategy, with products sold through dual channels at the same price, and consumers choose to purchase offline because of the better services that are on offer.

Unlike classic cosmetics products, clothing products are updated quickly, and consumers cannot feel the fabric, witness any color difference, or feel any differences in any other details of the product through the screen. Therefore, offline services are irreplaceable and can help consumers choose more satisfactory products, while consumers who do not have high requirements for these details can purchase low-priced products sold only online.

This is consistent with the simulation result in Figure 7, in which the curve converges to (1,1), and reveals that it is easier to achieve stability if manufacturers adopt a unified pricing strategy and consumers tend to purchase more through offline channels when the offline service is better.

## 5. Conclusions

### *5.1. Main Findings*

The competition of online channels is increasingly fierce, and consumers are increasingly loss-averse to some confusing online promotional tactics. It is necessary to study the pricing strategy of manufacturers and the purchasing channel strategy of consumers under dual-channel sales in the face of more uncertainty.

The current research on manufacturers' pricing strategies and consumer purchasing channel selection mainly focuses on channel conflicts and coordination, the influence of consumer types and preference factors, and the influence of some consumer behavior factors. However, the decisions of manufacturers and consumers will dynamically evolve

with changes in conditions. Moreover, consumers would be influenced by irrational factors, such as loss aversion from prospect theory.

Thus, this paper constructed an evolutionary game model for manufacturers and consumers, with consumer loss aversion taken into consideration. We identified four potential strategies for evolutionary stability and examined the effects of changes in parameters related to online and offline channel services, consumer loss aversion, and online price discounts. The results indicate that—in addition to channel services, $S_n$ and $S_f$, which affect the ESS for purchasing channel selection—a decrease in consumer loss aversion, $\lambda$, an increase in price discount, $\alpha$, or a decrease in quality discount, $\beta$, will help consumers reach the equilibrium faster. For manufacturers, channel services do not affect their evolution to a unified pricing strategy (ESS), and a decrease in price discount, $\alpha$, will make manufacturers reach the ESS faster. However, when consumer loss aversion, $\lambda$, increases, a manufacturer's ESS will shift from a unified pricing strategy to a differentiated pricing strategy; when quality discount, $\beta$, increases, a manufacturer's ESS will shift from a differentiated pricing strategy to a unified pricing strategy.

### *5.2. Implications and Limitations*

This paper provides new insights for scholars in dual-channel management by constructing dynamic evolution models of consumers and manufacturers and introducing a consumer loss aversion parameter. For manufacturers, under a certain cost structure, choosing dual-channel unified pricing is stable. The unified pricing strategy is simple to operate, easy to manage, and can leave a fair impression on consumers, giving them stable price expectations. At this point, the service quality of channels directly affects consumers' channel choices. Manufacturers can guide consumers to choose channels with lower costs or higher incomes through service quality to obtain higher profits. While, assuming all other conditions remain constant, when consumer loss aversion increases to a certain extent, choosing dual-channel differentiated pricing is stable. This strategy can attract more price-sensitive consumers and expand sales scope, but it also brings complexity.

This work has the following limitations: Firstly, although the model introduces consumer loss aversion and investigates the impact of its different values on the results, it does not take into account that this parameter may dynamically change over time. Thus, a temporal dimension to this parameter to reflect its potential variation over time could be included in future research. Secondly, more relevant parameters were not investigated, and additional stakeholders based on actual situations were not included, such as platform, logistics, and after-sales service. These limitations represent future research directions.

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