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Research on Inventory Sharing and Pricing Strategy of Multi-channel Retailer with Channel Preference in Internet Environment

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Abstract

With the development of the computer technology, many retailers sale the products not only in the entity shop, but also in the online shop. The network channel brings a lot of convenience. However, it also produces the channel conflict. In the dual channel supply chain, the retailers are in a passive position. Therefore, they begin to use the optimal dynamical pricing strategy to determine the price of the products. At the same time, the retailers obtain the greater benefits according to reduce the inventory cost. Thereby, in this paper, considering the online channel preference, we study the inventory strategy and the pricing strategy of the products in the dual channel. And then we propose a shared inventory and a dynamical pricing strategy. In addition, we study the influence of the related parameters on the profit of the retailers. At last, the numerical analysis shows that the shared inventory and the dynamical pricing strategy can bring more profits for the retailers.

Keywords: *Dual-channel, shared inventory, channel preference*

1. Introduction

Due to the development of the Internet, many merchants begin to increase the product sales by the strategy of the entity shop and the online shop. In addition, this kind of channel strategy has brought the increasing sales and the extensive market share for the merchants. However, there is a problem which cannot be ignored. That is the channel conflict. Merchants can sell products not only by traditional channel but also through the establishment of network channel. Many companies, such as Compaq, HP, IBM, Samsung and Sony, have two channels and multiple sales channels.

The conflict of dual channel has attracted the attention of many scholars. Mukhopadhyay *et al.* argued that retailers were able to differentiate their products through the network channels by adding value to on-the-shelf goods [1]. Yue studied the retailers pricing problem in dual channel supply chain [2]. Hua *et al.* examined a dual-channel supply chain and considered the factor of delivery lead time in the pricing decisions [3]. Xie found that the simple contracts, such as the wholesale price, buyback, revenue-sharing and Vendor Managed Inventory (VMI) contracts, cannot coordinate the dual-supply chain with inventory decisions [4]. Cai *et al.* showed that the price discount contracts perform well in a dual-channel supply chain [5]. Yao and Liu discussed Bertrand and Stackelberg equilibrium pricing policies and compared the profit gains under these two types of competition in a dual channel [6]. Cai investigated the influence of the channel structures and the channel coordination on the supplier, the retailer, and the entire supply chain in a dual-channel supply chain [7]. Karray and Zaccour discussed the products retailers, the sales of private brand products and the manufacturers [8]. From the two channels, Xie analyzed the cost and the price of the market demand which were influenced by the advertising though optimal decision level. And he pointed out that the cooperative game can improve the system [9]. Szmerekovsky and Zhangon thought that the

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advertising costs will affected the decision problems of manufacturers and retailers. In above study, the study about the advertising decision-making and the strategy of cooperative advertising into the research in dual channel supply chain are less [10].

The research shows that the price of the products in electronic retailers with zero-inventory was lower than the price of retailers own its own inventory. But the different price would decrease with time in the rapid expansion market [11]. Chaing W, Monahan G E thought that customers would transfer to another channel to buy goods in a certain percentage [12]. Boycai studied the distribution system of the dual channel conditions. He also discussed the impact on channel efficiency of channel order quantity decision problem and the ratio of substitution [13]. Geng and Mallik discussed the inventory competition and the double channel assignment problem. They also proposed the game equilibrium of the conditions that the manufacturer capacity was not limited. The study found that even in capacity limited circumstances, the manufacturers may also refuse to the retailer orders [14]. Yongbo Xiao discussed two subjects and each subject had four different customer group situations on the basis of the model of Frank [15]. Frank studied two subjects on the basis of this model. And each subject had two different customer group situations [16]. Zhang and Cooper researched the special problems of parallel flight in multi -product and multi-resource dynamic pricing problem. They structured this problem as a Markov decision process [17]. Chen F Y, Chen Jian, Xiao Yongbo researched the Dynamic inventory ration control strategy [18, 19]

This paper attempts to establish a model which can contact the dynamic pricing and revenue management with considering the channel preference. We try to research inventory strategy and dynamic pricing problem in dual channel supply chain. And we examine the profits of retailers under different inventory strategies. In addition, we study the effects of the parametric variable and the channel preference on the profits of the retailers. The construction of this paper is as follows. The first part is the introduction. The second part is the establishment of the model. The third part is the numerical analysis and the last part is the conclusion.

2. Establishment of the Model

2.1. Description and Assumption

The online shop and the entity shop sale the same product. The pricing of the entity shop is p_1. The price in the entity shop is stable during a specific period. We assume that the price in the sales cycle is fixed. Firstly, we consider that the sales cycle is short. Secondly, changing the product price needs cost and it is not convenient. Therefore, it is reasonable to assume that the price is fixed in a period. Finally, we assume the pricing of the online shop is p_2. And it can be changed.

The price of the online shop not only influences reversely the demand of the online products for the customers but also effects the demand of the entity shop positively. Similarly, the price of the entity shop can influence the demand of the online shop positively. The higher the price of the online shop, the demand of the online shop decreases and the demand of the entity shop increases. The lower the price of the online shop, the demand of the online shop increases and the demand of the entity shop decreases. We use $\lambda_1(p_1)$ to represent the arrival rate of the online shop. And we use $\lambda_2(p_2)$ to express the arrival rate of the entity shop. We suppose that a customer only buy one product and the arrival of the two customers is independent. Therefore, we can use the following functions to express the relation between the arrival rate and the pricing.

$$\lambda_1(p_1) = \alpha A_1 - B_1 p_1, A_1 > 0, B_1 > 0$$

$$\lambda_2(p_2) = (1-\alpha)A_2 + B_2 p_2, A_2 > 0, B_2 > 0$$

We make the following assumptions.

The hypothesis 1: $B_1 < B_2$ that is , for its demand, the influence of the online price is bigger than the entity shop. This is obvious because the online shop can treat as the substitutes to the entity shop.

The hypothesis 2: $A_1/B_1 \geq p_2$. When the price of the online shop is the same to the entity shop, the online shop has certain requirement. When the price is bigger than A_1/B_1 , the demand of the online shop is zero.

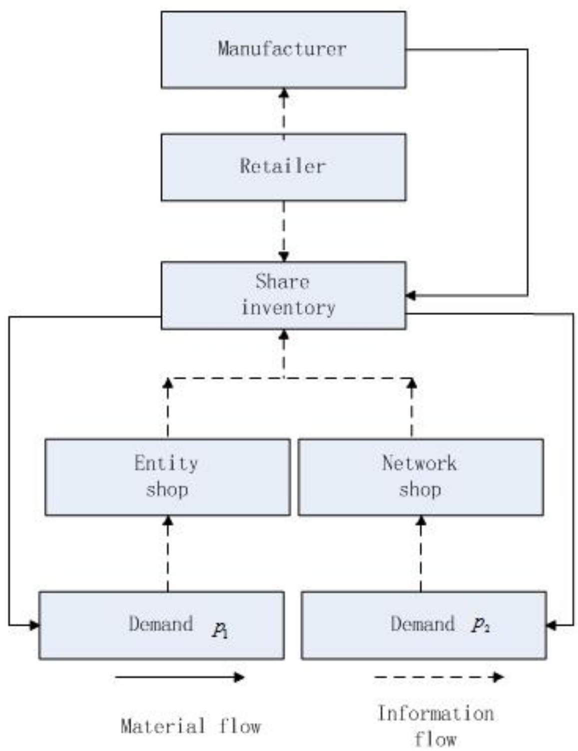

Figure 1. The Share Inventory

In addition, we divide the sell period into several equal intervals Δt . Every Δt is a stage and is very small. Therefore, the probability of appearing two or more than two customer arrivals is zero in a intervals. The whole sales cycle is $[0,T]$ and $\Delta t = 1, t = 1,2,\cdots,T$.

Because the customer arrival obeys the Poisson distribution, the rate of customer arrival is equal to the exception arrival number in Δt . $\lambda_1(p_1)/T$ is equal to the number of the exception customer arrival number in network shop in Δt .

The exception customer arrival numbers in network channel are as follows.

$$\lambda_1(p_1)/T = 1P(1) + 2P(2) + 3P(3) + \cdots$$

As the probability of the two or more customer arrivals can be ignored, $\lambda_1(p_1)/T = 1p(1)$ .We set $\lambda_1(p_1)/T = \lambda_1$, namely the probability of one customer arrives in network channel is equal to the exception value of Poisson distribution. The probability of one customer arrives in entity shop is equal to $\lambda_1(p_1)/T$ in Δt. We set it as λ_2.The probability of none customer arrives is $1-\lambda_1-\lambda_2$.We can get $0<\lambda_1+\lambda_2<1$ and:

$$\lambda_1(p_1)=\alpha\frac{A_1}{T}-\frac{B_1p_1}{T}=\alpha a_1-b_1p_1, a_1>0, b_1>0 \tag{1}$$

$$\lambda_2(p_2)=(1-\alpha)\frac{A_2}{T}+\frac{B_2p_2}{T}=\alpha a_2-b_2p_2, a_2>0, b_2>0 \tag{2}$$

2.2. The Optimal Pricing Strategy

We use a three dimensional vector (t,n_1,n_2) to describe the state of the whole sales system. Among them, t is the current state which belongs to the section $[0,T]$. n_1 is the inventory level of the online store and n_2 is the inventory level of the entity shop. The first situation is to use a two dimensional vector (t,n_2) to describe the state of the system. From the start of the stage t to the end of the sales, when the inventory of the entity shop is n_2, the total maximum expected future income in the sales period is $R_t(n_2)$. Then we can write the dynamic recursive equations. The second situation is to use three dimensional vector (t,n_1,n_2) to describe the state of system. From the start of the stage t to the end of the sales, when the inventory level of the online store is n_1 and the inventory level of the entity shop is n_2, the total maximum expected future income in the sales period $[t,T]$ is $R_t(n_1,n_2)$. Then we can write the dynamic recursive equations.

In addition, because the inventory of the entity shop is not specifically provided for the demand of the online shop, it only provides the temporary supplement when the network channel is not the inventory in the second situation. Therefore, we need to establish a specific cost to perform the network orders and we hypothesis it as d.

At last, in order to analyze the optimal initial inventory of the two situations, the network channel and the entity channel belong to the same seller, we assume the purchasing cost of the two channels is the same. We denote it as c. The revenue function is a increasing function about the remaining inventory n. In addition, it is a decreasing function about the time t.

Theorem 1: The revenue function $R_t(n_2)$ has the following characteristics.

(1) $R_t(n_2)$ increases with the increasing of n_2 and it decreases with the increasing of t.

(2) $R_t(n_2)-R_t(n_2-1)$ decreases with the increasing of n_2 and it decreases with the increasing of t.

Theorem 2 The revenue function $R_t(n_1,n_2)$ has the following characteristics.

(1) $R_t(n_1,n_2)$ increases with the increasing of n_1 and n_2. And it decreases with the increasing of t.

(2) $R_t(n_1+1,n_2)-R_t(n_1,n_2)$ decreases with the increasing of n_1 and n_2.

(3) $R_t(n_1,n_2+1)-R_t(n_1,n_2)$ decreases with the increasing of n_1 and n_2.

(4) $R_t(n_1+1,n_2)-R_t(n_1,n_2+1)$ decreases with the increasing of n_1. And it increases with the increasing of n_2.

(5) $R_{t+1}(n_1,n_2)-R_t(n_1,n_2)$ decreases with the increasing of n_1 and n_2. And it decreases with the increasing of t.

2.2.1. The First Situation (the entity shop and the online shop share the inventory of the entity shop): In the stage of t, the maximum future expectation income for the retailer is as follows.

$$R_t(n_2) = \max_{p_1}\{\lambda_1[p_1 + R_{t+1}(n_2 - 1)] + \lambda_2[p_2 + R_{t+1}(n_2 - 1)] + (1 - \lambda_1 - \lambda_2)R_{t+1}(n_2)\} \quad (3)$$

Among them, $R_t(0) = 0, R_{T+1}(n) = 0$. Putting the formula (1) and (2) into the formula (3), we can obtain the following conclusion.

$$\begin{aligned} & R_t(n_2) = \max_{p_1}\{(\alpha a_1 - b_1 p_1)[p_1 + R_{t+1}(n_2 - 1)] + ((1-\alpha)a_2 - b_2 p_1)[p_2 + R_{t+1}(n_2 - 1)] \\ & +[1 - \alpha a_1 - (1-\alpha)a_2 + (b_1 - b_2)p_1]R_{t+1}(n_2)\} \\ & \Rightarrow \frac{dR_t(n_2)}{dp_1} = [\alpha a_1 - b_1 R_{t+1}(n_2 - 1)] - 2b_1 p_1 + b_2[p_2 + R_{t+1}(n_2 - 1)] + (b_1 - b_2)R_{t+1}(n_2) = 0 \\ & \frac{d^2 R_t(n_2)}{dp_1{}^2} = -2b_1 < 0 \Rightarrow p_{1t}^*(n_2) = \\ & \frac{\alpha a_1 + b_2 p_2 (b_1 - b_2)[R_{t+1}(n_2) - R_{t+1}(n_2 - 1)]}{2b_1} \end{aligned} \quad (4)$$

According to the analysis of the structure characteristics for the revenue function, from the optimal dynamic pricing (4), we can launch the related conclusions of the first situation. These conclusions are as follows.

The conclusion 1: When α is a constant value, the optimal dynamic pricing $p_{1t}{}^*(n_2)$ is a series of price series. And it decreases with the increasing of the remaining inventory n_2. In addition, it decreases with the increasing of t.

The conclusion 2: When α is a constant value, the relation between the optimal dynamic pricing $p_{1t}{}^*(n_2)$ and the coefficients is that it increases with the increasing of a_1 and b_1.

The conclusion 3: When α is a constant value, the optimal dynamic pricing is larger than the optimal static pricing.

The static process is as follows. p_1 is fixed. Therefore, the whole process is given and it needs not to use the dynamic recursive process. So we can directly obtain the maximum benefits p_1. That is,

$$\begin{aligned} & \max_{p_1}\{R_1(Q)\} = \lambda_1 p_1 + \lambda_2 p_2 = (\alpha A_1 - B_1 p_1)p_1 + ((1-\alpha)A_2 - B_2 p_1)p_2 \\ & \Rightarrow p_1^{\#} = \frac{\alpha A_1 + B_2 p_2}{2B_1} = \frac{\alpha a_1 + b_2 p_2}{2b_1} \end{aligned}$$

The static process is as follows. Each state (t, n_2) corresponds to an optimal pricing. Moreover, the range of the optimal pricing has the following relation. Due to the range of $R_t(n_2) - R_t(n_2 - 1)$ is $[0, p_2]$, we inference the following conclusion.

$$\begin{aligned} & \frac{\alpha a_1 + b_2 p_2}{2b_1} \le p_{1t}^*(n_2) \\ & = \frac{\alpha a_1 + b_2 p_2 + (b_1 - b_2)[R_{t+1}(n_2) - R_{t+1}(n_2 - 1)]}{2b_1} \le \frac{\alpha a_1 + b_1 p_2}{2b_1} \end{aligned}$$

Therefore, the optimal dynamic pricing is larger than the optimal static pricing. Because of the range of p_1, and in order to ensure to have the optimal solution, we need the following constraints.

$$\frac{\alpha a_1 + b_2 p_2}{2b_1} \le p_2 .$$

Then we can get

$$\frac{\alpha a_1 + b_2 p_2}{2 p_1} \le b_1 \le \frac{a_1}{p_2} \tag{5}$$

2.2.2. The Second Situation (the entity shop and the online shop have their own inventories): The entity shop and the online shop respectively have one inventory. If the online shop has not the inventory, we allow the entity shop to perform the network order. However, if the entity shop has not the inventory, we will lose the customers. This is accorded with the reality.

The total maximum future expected revenue for the retailers is discussed as follows.

$$\begin{aligned} & R_t(n_1, n_2) = \\ & \begin{cases} 0, (n_1 = 0, n_2 = 0) \\ \max_{p_1}\{\lambda_1[p_1 + R_{t+1}(n-1,0)] + (1-\lambda_1)R_{t+1} \\ (n_1, 0)\}, (n_1 > 0, n_2 = 0) \\ \max_{p_1}\{\lambda_1[p_1 - d + R_{t+1}(0, n_2 - 1)] + \lambda_2[p_2 + \\ R_{t+1}(0, n_2 - 1)] + (1-\lambda_1-\lambda_2)R_{t+1}(0.n_2)\}, \\ (n_1 = 0, n_2 > 0) \\ \max_{p_1}\{\lambda_1[p_1 + R_{t+1}(n_1 - 1, n_2)] + \lambda_2[p_2 + \\ R_{t+1}(n_1, n_2 - 1)] + (1-\lambda_1-\lambda_2)R_{t+1}(n_1, n_2)\}, \\ (n_1 > 0, n_2 > 0) \end{cases} \end{aligned}$$

Among them, $R_t(0,0) = 0, R_{T+1}(n_1, n_2) = 0$. We put the formula (1) and (2) into the formula (6).

(1) When $n_1 > 0, n_2 = 0$

$$\begin{aligned} & R_t(n_1) = \max\{(\alpha a_1 - b_1 p_1)[p_1 + R_{t+1}(n_1 - 1)] \\ & +[1 - \alpha a_1 + b_1 p_1]R_{t+1}(n_1)\} \\ & \Rightarrow \frac{dR_t(n_1)}{dp_1} = [\alpha a_1 - b_1 R_{t+1}(n_1 - 1)] - 2b_1 p_1 + \\ & b_1 R_{t+1}(n_1) = 0 \\ & \frac{d^2 R_t(n_1)}{dp_1^2} = -2b_1 < 0 \\ & \Rightarrow p_{1t}^*(n_1) = \frac{\alpha a_1 + b_1[R_{t+1}(n_1) - R_{t+1}(n_1 - 1)]}{2b_1} \end{aligned}$$

Due to $b_1 > 0$, the optimal pricing and $R_t(n_1) - R_t(n_1 - 1)$ have a positive relationship. From the theorem 2, we can know the optimal dynamic pricing $p_{1t}^*(n_1)$ is a series of price series. And it decreases with the increasing of n_1. It decreases with the increasing of t.

(2) When $n_1 = 0, n_2 > 0$

$$R_t(n_2) = \max\{(\alpha a_1 - b_1 p_1)[p_1 - d + R_{t+1}(n_2-1)]$$
$$+((1-\alpha)a_2 + b_2 p_1)[p_2 + R_{t+1}(n_2-1)] + [1-\alpha a_1 - (1-\alpha)a_2 +$$
$$(b_1 - b_2)p_1]R_{t+1}(n_2)\}$$
$$\Rightarrow \frac{dR_t(n_2)}{dp_1} = [\alpha a_1 - b_1 R_{t+1}(n_2-1)] + b_1 d - 2b_1 p_1 +$$
$$b_2 R_{t+1}(n_2-1) + (b_1 - b_2)R_{t+1}(n_2) = 0$$
$$\frac{d^2 R_t(n_2)}{dp_1^{\ 2}} = -2b_1 < 0$$
$$\Rightarrow p_{1t}^*(n_2) = \frac{\alpha a_1 + b_2 p_2 + b_1 d + (b_1 - b_2)[R_{t+1}(n_2) - R_{t+1}(n_2-1)]}{2b_1}$$

Due to $b_1 > b_2$, the optimal pricing and $R_{t+1}(n_2) - R_{t+1}(n_2-1)$ have a positive relationship. From the theorem 1, we can know the optimal dynamic pricing $p_{1t}^*(n_2)$ is a series of price series. And it decreases with the increasing of n_2. It decreases with the increasing of t.

(3)When $n_1 > 0, n_2 > 0$

$$R_t(n_1, n_2) = \max_{p_1}\{(\alpha a_1 - b_1 p_1)[p_1 + R_{t+1}(n_1-1, n_2)]$$
$$+((1-\alpha)a_2 + b_2 p_1)[p_2 + R_{t+1}(n_1, n_2-1)] + [1-\alpha a_1 - (1-\alpha)a_2 +$$
$$(b_1 - b_2)p_1]R_{t+1}(n_1, n_2)\}$$
$$\Rightarrow \frac{dR_t(n_1, n_2)}{dp_1} = \alpha a_1 - b_1 R_{t+1}(n_1-1, n_2)] - 2b_1 p_1 + b_2 p_2$$
$$b_2 R_{t+1}(n_1, n_2-1) + (b_1 - b_2)R_{t+1}(n_1, n_2) = 0$$
$$\frac{d^2 R_t(n_2)}{dp_1^{\ 2}} = -2b_1 < 0$$

And

$$p_{1t}^*(n_1, n_2) = \frac{\alpha a_1 + b_2 p_2 + b_1[R_{t+1}(n_1, n_2) - R_{t+1}(n_1-1, n_2)]}{2b_1}$$
$$- \frac{b_2[R_{t+1}(n_1, n_2) - R_{t+1}(n_1, n_2-1)]}{2b_1}$$
$$= \frac{\alpha a_1 + b_2 p_2 + (b_1 - b_2)R_{t+1}(n_1, n_2)}{2b_1}$$
$$+ \frac{-b_1 R_{t+1}(n_1-1, n_2) + b_2 R_{t+1}(n_1, n_2-1)}{2b_1}$$
$$= \frac{\alpha a_1 + b_2 p_2 + (b_1 - b_2)[R_{t+1}(n_1, n_2) - R_{t+1}(n_1-1, n_2)]}{2b_1}$$
$$+ \frac{b_2 p_2[R_{t+1}(n_1, n_2\text{-}1) - R_{t+1}(n_1-1, n_2)]}{2b_1}$$

From the theorem 1, we can know that the optimal dynamic pricing $p_{1t}^*(n_1, n_2)$ is a series of price series. And it decreases with the increasing of n_1. It decreases with the increasing of t.

3. Numerical Analysis

We assume that the arrival rate is consistent between the online shop and the entity shop. And the total inventory of the online shop is the same to the entity shop. $T = 100$, the total inventory is 1000($n_1 + n_2 = 1000$), the price of the entity shop is $p_2 = 50$, the price of the network shop is p_1 and it is dynamic adjustment .

$$a_1 = 80/T \text{ , } a_2 = 30/T \text{ , } b_1 = 4/T \text{ , } b_2 = 2/T \quad d = 2/T \text{ .}$$

The online shop adjusts the price dynamically to effect the demand of the entity shop and the online shop according to the remaining inventory of the entity shop and the time state. Then we can make the income maximum for the retailer. This is the revenue management according to adjust the price dynamically.

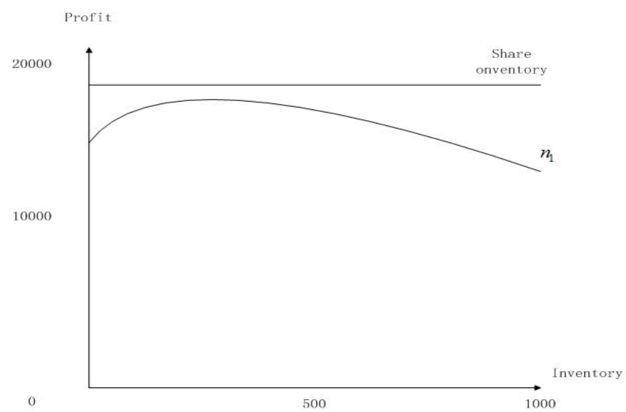

Figure 2. The Profits of Two Inventory Strategies

Due to $n_1 + n_2 = 1000$, with the increasing of n_1, n_2 decreases. But from the Figure 2, we can find that with the increasing of n_1, the revenue of the retailers increases firstly ,then the revenue begin to decrease. However, no matter how n_1 changes, the profit of the retailers in the shared inventory strategy is higher than that in the separate inventory strategy.

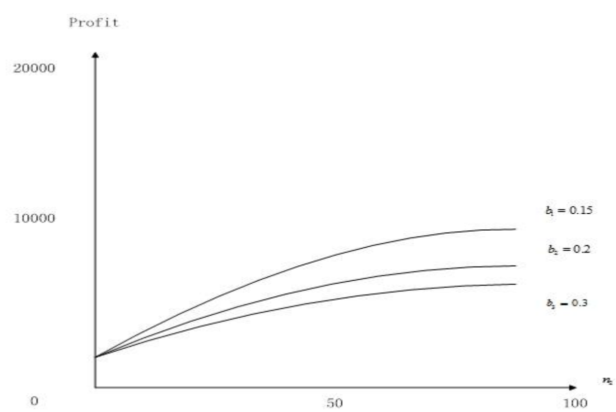

Figure 3. The Influence of b_1 on the Profit

From the Figure 3, we can see the relation between the profit of the retailer and the coefficient b_1. With the increasing of b_1, the revenue increases. At the same time, we find that the larger values of the b_1, the growth rate of the retailer's profit is smaller. Conversely, when the value b_1 becomes small, the profit of the retailer is bigger.

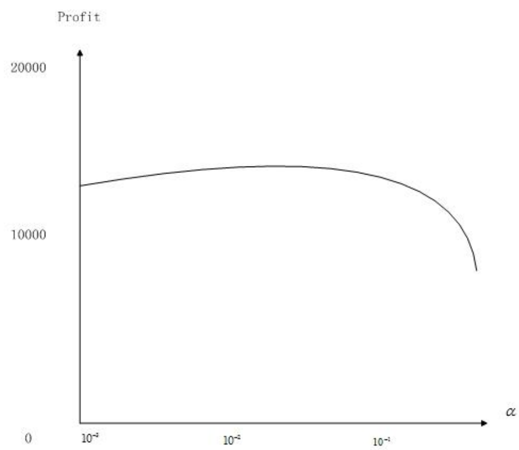

Figure 4. The Influence of α on the Profit

From Figure 4, we can find that with the increasing of the online channel preference rate α, the profit of the retailer increases. However, the profit of the retailer begins to decrease when α increases continuously. Because the increase of the online channel preference rate, the inventory of the entity inventory decreases. And the price increases. At the same time, the retailers need to conduct the market research to obtain the market information. And then they also need to pay a high cost.

4. Conclusion

In the dual channel supply chain environment, the channel conflict is an urgent problem to be solved. In the traditional dual channel supply chain, the online shop and the entity shop have their own inventory respectively. It makes the inventory increase, then the inventory cost increases. Therefore, the profits of the retailers decrease. In order to solve the above problem, we combine the online inventory and the entity shop. That is, the online shop and the entity shop use the same inventory. According to share one inventory, it can reduce the inventory cost. It can make the profits of the retailers maximum. In addition, for one product, the pricing of the entity shop is higher than the online shop. For one product, the demand rate in the entity shop and the demand rate in the online demand are inversely proportional. If the price of the online shop is higher, the demand rate is lower. Then the demand rate in the entity shop increases.

In the past literature, it adopts the static pricing strategy to price products. In this paper, we use the dynamical pricing strategy to adjust the price in the online shop and the entity shop. Then we can get an optimal pricing strategy. It makes the total profits of the retailers maximum. Therefore, the innovation of this paper is as follows. (1) According to merge the inventories of the online shop and the entity shop, we get a new shared inventory model. This shared inventory model can reduces the inventory cost and make the profits of the retailers increase. (2) We study the pricing problem in the online shop and the entity shop. We use the dynamical pricing strategy to study the relation between the online shop and the entity shop. Then we get an optimal dynamical pricing. It makes the profits of the retailer maximum.

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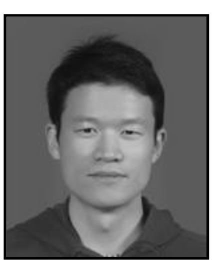

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