Research on Pricing Decision Considering Advertising Benefit and Consumer Psychological Benefit

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Abstract. For perishable goods, the optimal pricing models studied by current scholars seldom consider price effect, psychological benefit and consumption time. Based on the current basic newsboy model, this paper focuses on the price characteristics and consumer psychology of perishable products under the background of single dealer, in order to build a complete optimal price decision model of perishable products. According to the two-stage ladder pricing of perishable products in the pricing stage, this paper constructs the optimal price decision model of dealers in different sales stages by representing consumer demand and dealer profit equation, so as to provide enterprises with the maximum optimal strategy. Moreover, sensitivity analysis of parameters in the model is carried out to ensure the stability of the model.

Keywords: Algorithm; Model Building; Machine Analysis.

1. Introduction

1.1 Background Research

With the continuous improvement of science and technology, the national happiness index is gradually improved, and the enterprise competition trend is strong. Consumer demand for products gradually presents a trend of diversification, so the rate of product update and iteration is significantly and continuously increased, the product life cycle is getting shorter and shorter, more and more products appear the characteristics of perishable products, and the competition around perishable products is becoming increasingly intense. The so-called competitive products, can also be called "timeliness products, life cycle products, seasonal products", such products have a long production cycle, product sales cycle is short, product demand fluctuations, the end of the sale of product prices significantly reduced nature.

For consumers, once the price reduction information is known to them, they will rationally postpone the current purchase decision and expect to get the product at a lower price in the future [1,2]. Du[2] points out the difference between strategic consumers and short-sighted consumers, emphasizing that strategic consumers are able to fully acquire existing information and form rational expectations of future price reduction information, so as to buy special prices at future discounts by delaying purchase decisions. For example, in order to reduce the idle seat rate of flights, many airlines take various promotional activities to increase the demand, and the price reduction strategy is the most common one [3]. However, frequent price cuts have led consumers to come

The more patient they are [4], the more they choose the products they want in advance[5]. Therefore, it is a key issue for dealers to solve the pricing strategy of perishable products. Whitin[6] first introduced the selling price in the construction of the newsboy problem and established the demand function with price correlation. Price became the decision variable of the decision-maker. In solving the model, he first fixed the price to obtain the optimal order quantity and then the optimal selling price. Since then, the issue of joint pricing and subscription has aroused wide interest in the academic world.

1.2 Research Status at Home and Abroad

Many scholars have studied the operation efficiency of the newsboy model. PETRUZZIN[7] et al. studied the newsboy model that simultaneously decides inventory quantity and selling price, and

reviewed the literature on the existing single-issue newsboy model. ABAD[8] studied the pricing and bulk ordering of perishable goods considering fixed productivity, exponential deterioration, partial late delivery and loss of sales. GOYALC[9] considered the production-inventory problem of perishable products, in which demand, productivity and deterioration rate all change with time. GALLEGO et al. [4] considered the continuous strategy and dynamic pricing strategy, assuming that customer arrival follows Poisson distribution and demand is price sensitive and random. Based on the research of GALLEGO et al. [9], ZHAO et al. [10] expanded the model to non-homogeneous Poisson distribution of customer arrival obedience. The above model examines pricing and ordering decisions in continuous time T, but it is difficult to realize continuous dynamic pricing in real life.

Domestic scholar Liu Xiaofeng [11] et al. studied the pricing and inventory decisions of manufacturers under the circumstances of uncertain and uncertain demand, and the results showed that manufacturers could increase the risk of consumers not being able to buy products through appropriate inventory quantity and price setting according to the composition of high value and low value consumers in the market, so as to reduce consumers' waiting behavior. Wang Lei et al. [12] studied the consumer choice model under the influence of price and freshness, and analyzed retailers' optimal pricing and optimal fresh-keeping input when potential market capacity changes or retailers' initial order quantity changes. Guan Zhenzhong et al. [13] used Stackelberg game model to analyze retailers' pricing decisions when there were speculators and strategic consumers. Yang Hui et al. [14] studied the two-stage product pricing problem under the circumstance that the short-sighted and strategic behaviors of consumers were considered and the consumer valuation presented random distribution, and obtained the optimal price path of the product by using the backward derivation method. Dou Jinhu et al. [15] established a dynamic pricing model based on the attenuation of consumer perceived value, and analyzed the impact of the attenuation of consumer perceived value on dynamic pricing and manufacturers' expected revenue.

1.3 Research Route

Based on the comprehensive analysis of the above literature, the optimal pricing models studied by current scholars rarely consider price effect and consumption time. Based on the current basic newsboy model, this paper focuses on the price characteristics and consumer psychology of perishable products under the background of single dealer, in order to build a complete optimal price decision model of perishable products. According to the two-stage ladder pricing of perishable products in the pricing stage, this paper constructs the optimal price decision model of dealers in different sales stages by representing consumer demand and dealer profit equation, thus providing enterprises with the maximum optimal strategy, and carries on the sensitivity analysis of the parameters in the model.

2. Impact of Sales Cycle Pricing on Production Enterprises

2.1 Problem Description

Suppose there is a monopoly production enterprise in the market, which only produces a perishable product P. The sales cycle T of product P can be divided into two stages, namely the full price stage and the price reduction stage, which are called T1 and T2. In the full-price stage, the selling price of product P is P1, and consumers purchase the product at full price according to their own needs. With the increase of product sales cycle, new products of the same kind are constantly put into the market, and the competitive pressure of products becomes greater. Dealers begin to carry out the price reduction strategy, and the sales price of product P is P2, which meets P1>P2. The specific product sales flow chart is shown below

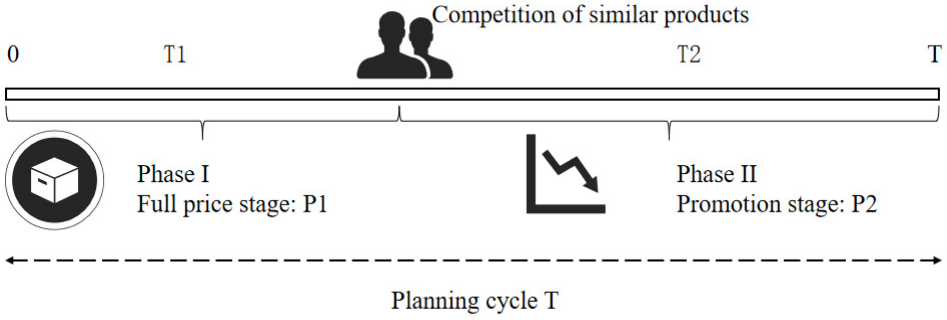

Figure 1. Schematic diagram of product sales process

In order to consider the close to the actual situation, it is assumed that there is heterogeneity among consumers. For customer utility, it can be divided into acquisition utility and transaction utility. It is advisable to set up a customer group with a valuation benefit of v. Whenever it enters the product market, the valuation of the product is v. The market size of the enterprise is set as 1, and the enterprise's valuation v for each consumer is not predictable in advance..

2.2 Research Methods

Therefore, from the above discussion, we can see that the price effect φ It mainly affects the transaction utility of consumers and leads to an increase in the probability of purchasing perishable products. The range of change of this parameter is [0,1]. The psychological impact factor mainly reduces the transaction utility of consumers and leads to a decrease in the probability of purchasing perishable products. The range of change of this parameter is [0,1]. There is an antagonistic effect between the two. According to the above discussion, the life cycle of perishable products can be divided into two phases: the first phase: full price period and the second phase: price reduction period. For monopolistic manufacturing enterprises, because they need to consolidate the product's position in the forefront of the industry, they need to use advertising benefits to increase the sales of products, thus increasing the profits of enterprises. In this paper, we only consider the promotion effect of advertising benefits on the sales volume of products in the first and second stages, without considering the impact of price factors.

3. Establishment and Solution of Model

In view of the above two definitions of the life cycle of perishable products and the definitions of "impulsive" consumers and "rational" consumers.

3.1 Commodity Valuation of "Impulsive" Consumers

For the "impulsive" consumer, if the valuation of the perishable product is v and the first price of the perishable product is p1 during the first full price period of the perishable product, the "impulsive" consumer utility is expressed as Ur1=v-p1.

The second price of the perishable product is p2, and the added value of transaction benefit due to price effect is φ (p1 - p2), the transaction benefit caused by consumers' discount psychology is reduced, which can be expressed as Ur2= δ 1[v+ φ (p1-p2)-p2].

Find the critical point for the commodity valuation of "impulsive" consumers, and make Ur1=Ur2 get the critical point for the commodity valuation of "impulsive" consumers:

$$Vr^* = \frac{1}{1-\delta 1}[(1+\varphi\delta 1)p1 - (1+\varphi)(p1-p2)]$$

3.2 Commodity Valuation of "Rational" Consumers

As for "rational" consumers, as compared with "impulsive" consumers, their purchase behavior is more rational and there is no impulse consumption. If its valuation of the perishable product is v, the first phase of the list price of the perishable product is p1. Because the goods purchased by "rational" consumers in the first phase will be consumed in the second phase, at this time, the quality of the goods has been reduced, so the utility of "rational" consumers in the first phase is Um1= δ 2[v-p1]. For the "ideal" consumers who purchase and choose to consume in the second phase, if the prices of the first and second phases are known to be p1 and p2 respectively, the added value of transaction benefits due to the price effect is φ (p1 - p2), the transaction benefit caused by consumers' discount psychology is reduced, which can be expressed as Um2= δ 1[v+ φ (p1-p2)-p2].

Calculate the critical point of commodity valuation of "rational" consumers, and make Um1=Um2 to get the critical point of commodity valuation of "rational" consumers:

$$Vm^* = \frac{1}{\delta 1 - \delta 2}[(1+\varphi\delta 1)p1 - (1+\varphi)(p1-p2)]$$

3.3 Retailer's Shelf Strategy

For retailers, the sales strategy for this perishable product will be divided into two stages. The quality of perishable products in the first stage is brand new. This stage is called the full price period. During this period, retailers have two strategies to sell goods, including high price and low price. The second stage is the loss period due to the characteristics of perishable product quality loss over time. For the above two stages, the pricing strategy of retailers can be divided into high-price sale or low-price sale. Therefore, there are four strategies, as follows:

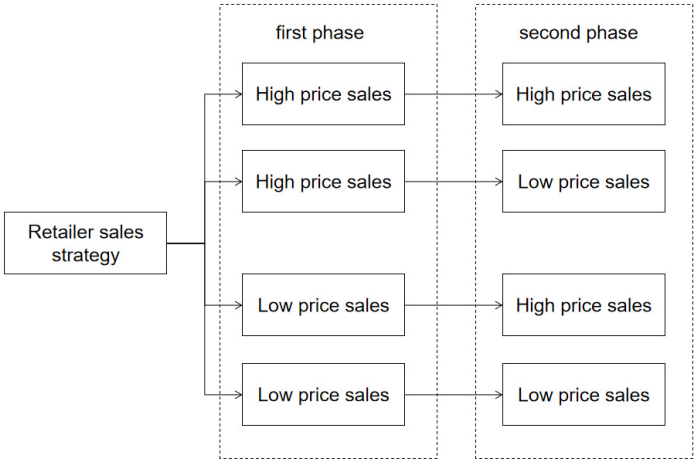

Figure 2. Two-stage process diagram of product sales

According to the analysis of the above figure, retailers have four sales strategies, namely, high-price-high price, high-price-low price, low-price-low price and low-price-high price.

4. The Best Strategy for Enterprises to Order

4.1 Ordering Strategies for All "Impulsive" Consumers

For the corporate profit function of all "impulsive" consumers, the degree of corporate advertising promotion d and product price p1 are calculated. The first-order partial derivative of the corporate profit function of "impulsive" consumers to the degree of corporate advertising promotion d and product price p1 is as follows:

$$\frac{\partial \pi_r(p_1,d)}{\partial d} = p_2 * \theta_2 - d - p_1 * \theta_2 * (\delta_1 - 1)$$

$$\frac{\partial \pi_r(p_1,d)}{\partial p_1}=\frac{(\delta_1+p1*(\varphi*\delta_1+1)}{(\delta_1-1)}-\frac{p2*\delta_1*(\varphi+1)}{(\delta_1-1)}+\frac{d*\theta_1*(\delta_1-1)}{(\delta_1-1)}-\frac{1}{(\delta_1-1)}+\frac{(p1*(\varphi*\delta_1+1))}{(\delta_1-1)}-\frac{(p2*(\delta_1+1))}{\delta_1-1}$$

The second-order partial derivative of the corporate profit function of "impulsive" consumers to the degree of corporate advertising promotion d and product price p1 is as follows:

$$\frac{\partial^2 \pi_r(p_1,d)}{\partial d^2}=-1,\ \frac{\partial^2 \pi_r(p_1,d)}{\partial p_1^2}=\frac{2*(\varphi*\delta_1+1)}{\delta_1-1}$$

$$\frac{\partial^2 \pi_r(p_1,d)}{\partial d\partial p_1}=\theta_1$$

Therefore, according to Hessian matrix theory, the second order partial derivative matrix A of enterprise profit function is constructed, as shown below:

$$A=\begin{bmatrix}\frac{\partial^2 \pi_r(p_1,d)}{\partial p_1^2} & \frac{\partial^2 \pi_r(p_1,d)}{\partial d\partial p_1}\\ \frac{\partial^2 \pi_r(p_1,d)}{\partial p_1\partial d} & \frac{\partial^2 \pi_r(p_1,d)}{\partial d^2}\end{bmatrix}=\begin{bmatrix}\frac{2*(\varphi*\delta_1+1)}{\delta_1-1} & \theta_1\\ \theta_1 & -1\end{bmatrix}$$

The first-order principal and sub-formula is

$$\left|\frac{2*(\varphi*\delta_1+1)}{\delta_1-1}\right|<0,\delta_1\in[0,1)$$

The second order principal and sub-formula is

$$\begin{vmatrix}\frac{2*(\varphi*\delta_1+1)}{\delta_1-1} & \theta_1\\ \theta_1 & -1\end{vmatrix}=\frac{2*(\varphi*\delta_1+1)}{\delta_1-1}-\theta_1^2,\varphi\in[0,1),\theta_1\in[0,1),$$

$$\delta_1+1>\varphi*\delta_1+1>\delta_1-1,\frac{2*(\varphi*\delta_1+1)}{\delta_1-1}>2>\theta_1^2,\frac{2*(\varphi*\delta_1+1)}{\delta_1-1}-\theta_1^2>0$$

4.2 Ordering Strategy of All "Rational" Consumers

The enterprise profit function of all "rational" consumers is used to calculate the degree of enterprise advertising promotion d and the product price p1. The first-order partial derivative of the corporate profit function of "rational" consumers to the degree of corporate advertising promotion d and product price p1 is as follows:

$$\frac{\partial \pi_r(p_1,d)}{\partial d}=\frac{1}{(\delta_1-\delta_2)}(p_2*(\varphi+1)-p_1*(\varphi*\delta_1+1)-\delta_1-p_1*(\varphi*\delta_1+1)-p_2*\delta_1*(\varphi+1)+d*\theta_1*(\delta_1-1)+1)$$

$$\frac{\partial \pi_r(p_1,d)}{\partial p_1}=\frac{1}{(\delta_1-\delta_2)}[d+(p1*\theta1+p2*\theta2)*(\delta_1-1)]$$

The second-order partial derivative of the corporate profit function of "rational" consumers to the degree of corporate advertising promotion d and product price p1 is as follows:

$$\frac{\partial^2 \pi_m(p_1,d)}{\partial d^2}=-1,\ \frac{\partial^2 \pi_m(p_1,d)}{\partial p_1^2}=-\frac{2*(\varphi*\delta_1+1)}{\delta_1-\delta_2}$$

$$\frac{\partial^2 \pi_m(p_1,d)}{\partial d\partial p_1}=-\frac{\theta_1*(\delta_1-1)}{\delta_1-\delta_2}$$

Therefore, according to Hessian matrix theory, the second order partial derivative matrix A of enterprise profit function is constructed, as shown below:

$$B=\begin{bmatrix}-\frac{2^*(\varphi^*\delta_1+1)}{\delta_1-\delta_2} & -\frac{\theta_1^*(\delta_1-1)}{\delta_1-\delta_2}\\ -\frac{\theta_1^*(\delta_1-1)}{\delta_1-\delta_2} & -1\end{bmatrix}$$

5. Numerical Simulation Analysis

Based on the above analysis, in this chapter, we will conduct numerical simulation analysis on the above optimal investment strategy. It may be said that the advertising promotion coefficient at the full price stage is θ1=0.2, the advertising promotion coefficient at the price reduction stage is θ2=0.15, psychological effect parameter δ1=0.8, price effect parameter φ= 0.7, the price at the price reduction stage is 0.1

Therefore, set the product price p2=0.1 during the price reduction period, set the initial value of product price p1 and advertising effort d to be 0.1, increase the step length to 0.01, and the maximum iteration threshold is 0.99. This paper uses MATLAB R2021a, and the system environment is Intel (R) Core (TM) i5-8250U CPU @ 1.60GHz, 1800 Mhz. The results are as follows:

Table 1. Profit parameter of enterprise function when p2 is 0.1

Price reduction p2:0.1		
Product price p1	Promotion degree d	Enterprise profit
0.1000	0.1000	0.088500
0.2000	0.2000	0.099999
0.3000	0.3000	-0.05050
0.4000	0.4000	-0.36300
0.5000	0.5000	-0.83750
0.6000	0.6000	-1.47400
0.7000	0.7000	-2.27250
0.8000	0.8000	-3.23300
0.9000	0.9	-4.35550

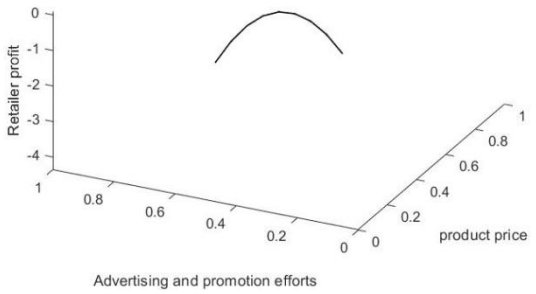

Figure 3. Enterprise function profit curve when p2 is 0.1

Table 2. Profit parameters of enterprise function when p2 is 0.2

Price reduction p2:0.2		
Product price p1	Promotion degree d	Enterprise profit
0.2	0.2	0.1540
0.3	0.3	0.1580
0.4	0.4	0.0001
0.5	0.5	-0.3200
0.6	0.6	-0.8020
0.7	0.7	-1.446
0.8	0.8	-2.252
0.9	0.9	-3.220

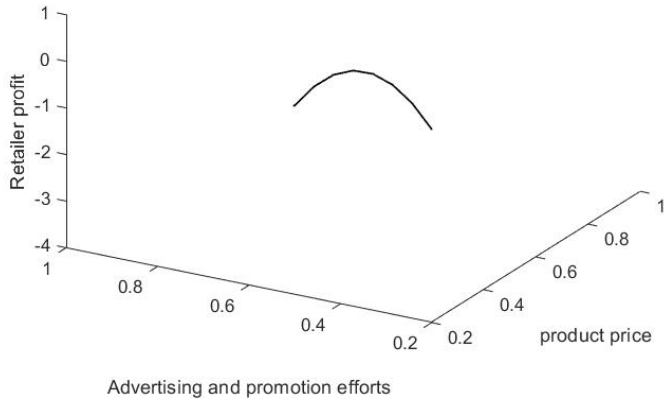

Figure 4. Enterprise function profit curve when p2 is 0.2

According to the above illustration, whether the product price p2=0.1 during the price reduction period or p2=0.2 during the price reduction period, the retailer has an optimal strategy to maximize the enterprise profit function. Therefore, it can be concluded that the enterprise profit function is a binary joint concave function of advertising promotion effort and product price. There is an optimal strategy p1 * in the definition field of this function, d * makes the enterprise retailer profit the highest.

According to the analysis of the results at p2=0.1 and p2=0.2, when retailers implement the price reduction strategy, if the price reduction rate is too high in the second stage, it will lead to more consumers choosing to wait, leading to more purchases during the price reduction period, and the retailer's profit will be reduced, thus breaking the previous inherent impact: not "the higher the price reduction rate, the higher the profit the enterprise will gain".

6. Conclusion

In the previous literature, there is little discussion on the effect of advertising promotion, psychological effect, and the impact of price reduction range in the price reduction stage on the optimal promotion strategy of enterprise retailers. Under the premise of previous research, this paper introduces the influence of advertising benefits and psychological effects on the optimal strategy of enterprise retailers, divides the sales stage of perishable products into full price cycle and price reduction cycle, and deduces the product mathematically according to the price benefits and psychological benefits, thus solving the two-stage demand function of "impulsive" consumers and "rational" consumers, and solving the problem together to obtain the enterprise profit function. Based on the above mathematical derivation, this paper conducts a numerical simulation analysis, and demonstrates that there is a unique optimal product price for enterprise retailers, and the degree of advertising and promotion efforts makes the enterprise profit have the maximum value.

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