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Full Research Paper

The Pricing Strategy of Extended Warranty Services in Supply Chain Considering Response Time

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Abstract: To study the impact of response time on extended warranty services (EWS), the pricing strategy of EWS is discussed with different response time in a competitive environment. Considering of a two-level supply chain composed of one manufacturer, one self-owned retailer (SR) and one franchise retailer (FR), there exists the differentiated response time in EWS provided by SR and FR. Based on the consumer demand function in two cases, the optimal pricing strategy of EWS for supply chain members is analyzed. Research shows that: (1) The EWS price of SR increases with the increasing of the differential response time, but which of FR decreases and changing faster. (2) The manufacturer is more profitable when the differential response time is smaller, and two retailers' profits continue to increase as the differential response time increasing. (3) The retailers' profits are always higher than the manufacturer's, and both supply chain members will choose the market that consumers are more sensitive to differentiated response time to realize their respective benefits. The conclusion provides enlightenment and reference for enterprises to make decision of EWS.

Keywords: extended warranty service, supply chain, response time, pricing strategy

1. INTRODUCTION

Consumers will reduce the perceived risk of products by purchasing extended warranty services (EWS)[1], which is regarded as an important part of after sales service guarantee system, especially in durable products such as automobiles and household appliances[2]. According to market research data, the profit from sales of EWS is as high as 18 times compared to the profit from sales of products, and the average profit margin is usually 50-60% [3]. EWS price directly affects the market share and the market competition [4], and EWS responsiveness is also one of the market competition points under the leadership of the time-sensitive consumers [5]. Moreover, the responsiveness of EWS is often closely related to the price, for example, in Boeing, they set service pricing and response time standards according to the level of service, i.e. significant requests, emergent requests and routine requests. But what exactly is the relationship between EWS pricing and EWS response time? How do we make optimal pricing strategy based on response time?

The current research mainly focuses on the pricing decisions of EWS with profit maximization of supply chain, such as Peng et al.[6]studied the online shopping supply chain coordination strategy of extended warranty services by building a two-stage dynamic game model. Zhang[7] analyzed whether manufacturers offering extended warranty services engage in channel intrusions and the impact of channel intrusions on other members of the supply chain. Chen et al.[8]constructed two competing retailer supply chains to study different pricing strategies of manufacturers in the context of a separate negotiation strategy, average cost, and actual cost negotiation strategy. Mart et al.[9]researched the pricing decision of extended warranty services under different

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pricing contracts. According to whether the products are homogeneous, Tang et al.[10]study the supply chain coordination between products and extended warranty services. Zhao et al.[11]built a supply chain network equilibrium model to study the optimal parameters for retailers to provide extended warranty services. Zhang [12]found that retailers chose to provide extended warranty services by themselves as the most favorable decision. Chakraborty et al.[13]analyzed the performance analysis and selection of contracts for the pricing of extended warranty services in competitive markets. Chen et al.[14] discussed the pricing of extended warranty services, product price pricing and joint pricing in the environment of centralized decision and decentralized decision in supply chain.

The current research about service pricing under response time is mainly from the performance maximization of supply chain, such as Shen et al.[15] studied the response time and product price act on the market at the same time, and established a profit model based on the deterministic demand function to find the optimal decision in the two level supply chain market. Lin et al.[16] discussed a two-stage supply chain decision-making problem under the influence of product price sensitivity and response time changes. Xu et al.[17]analyzed the relationship between retailers' order volume and delivery time differences considering of consumers' expectations for different delivery times. Liu et al.[18] established the demand function to discuss the large or small impact on the performance of the entire supply chain under centralized and decentralized conditions. Lu et al.[19]found that considering the same-day response and the next-day response, as the delivery time increases, the retailer's online sales price decreases. Mo et al.[20] constructed price discrimination decisions to support spare parts services under mass customization of manufacturing companies. Tan et al.[21] researched the impact of equity concerns on the lead time of network direct sales. Wu et al.[22]studied the relationship between the price and response time to achieve the greatest benefit.

In summary, the research of service response time and EWS pricing is in two parallel directions. Considering the characteristics of the EWS, this paper adopts the response time as the EWS pricing model of basic performance to provide consumers with a certain warranty service quality, discusses the pricing of EWS with differential response times among competing retailers, and provides a reference basis for enterprise to make EWS pricing decisions.

2. MODELING

2.1 Problem description

There is a supply chain consisting of one manufacturer and two retailers, and the retailers include one self-owned retailer (SR) and one franchise retailer (FR) offers a differential response time in EWS. Manufacturers providing EWS to SR and FR. The smaller the difference between the response time provided by FR and SR, the higher the utility to the consumer. Consumers often consider the utility of EWS to choose FR or SR. The model is shown in Figure 1.

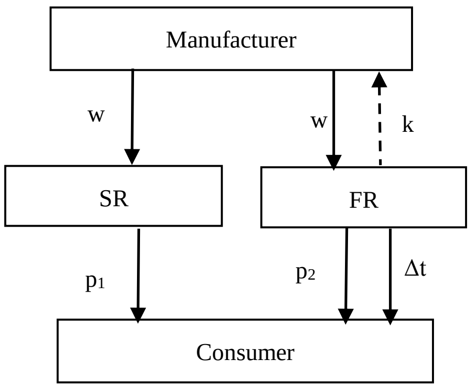

Figure 1. EWS with differential response time

The notations in the text and their meanings are described in Table 1 below.

Table 1. The notations and meanings

Notation	Meaning	Notation	Meaning
m	Manufacturer	α	Consumer price sensitivity to retailers' EWS
r_i	Retailer i(i= 1,2)	β	Consumer sensitivity to differentiated response times
w	Wholesale price of parts and components required for EWS.	Δt	Poor response time for EWS
w*	Optimal EWS pricing.	η	EWS cost factor
p_i	Pricing of EWS for retailer units.	U_i	The utility function for consumers to purchase EWS
p_i *	Pricing for retailers' optimal EWS.	D_1	Demand from SR
k	Referral fee paid by the FR ($k=\lambda p_2 D_2$).	D_2	Demand from FR
v	The basic valuation of consumers for EWS. Evenly distributed on [0,1].	Π_m*	Manufacturer's profit under differential response time
θ	The substitution rate between the two EWS ($0<\theta\le 1$).	Π_r*	Retailer's profit under differential response time

2.2 Demand function

The response time of FR is different from SR, which is expressed in Δt. Then the utility obtained by consumers from SR and FR are:

$$U_1 = v - \alpha p_1 \tag{1}$$

$$U_2 = \theta v - \alpha p_2 + \beta \ln \frac{1}{\Delta t} \tag{2}$$

Consumers will choose the party with the greater utility to purchase the EWS, i.e. choose max ($u_1, u_2, 0$). Using the same idea as above, it can be obtained that consumers face three critical situations when choosing a buyer, namely $u_1 = 0, u_2 = 0, u_1 = u_2$. For the convenience of discussion, the critical valuations are defined as v_1, v_2, v_3 respectively, i.e. $v_1 = \alpha p_1$, $v_2 = \alpha p_2 - \beta \ln \frac{1}{\Delta t} / \theta$, $v_3 = [\alpha(p_1 - p_2) + \beta \ln \frac{1}{\Delta t}] / 1 - \theta$. v_1, v_2, v_3 will get different extended service price ranges when different conditions are met, and the demand function under each range will be obtained. The specific discussion is as follows.

(1)When $v_1 \ge v_2$ and $v_3 \le 1$, both retailers will have demand for EWS, and the unit EWS price meets the following conditions:

$$p_1 - (1-\theta-\beta \ln \frac{1}{\Delta t}) / \alpha \le p_2 \le \theta p_1 + \beta \ln \frac{1}{\Delta t} / \alpha \tag{3}$$

(2)When $v_1 \ge v_2$ and $v_3 \ge 1, u_1 \le u_2$, consumers only choose to purchase EWS from FR, and the unit EWS price meets the following conditions:

$$p_2 \le p_1 - (1-\theta-\beta \ln \frac{1}{\Delta t}) / \alpha \tag{4}$$

(3)When $v_1 \le v_2$, $u_1 \ge u_2$, consumer only chooses to purchase EWS from SR, and the unit EWS price meets the conditions as:

$$p_2 \ge \theta p_1 + (\beta \ln \frac{1}{\Delta t}) / \alpha \tag{5}$$

(4) When $u_1 \le 0, u_2 \le 0$, consumer will not purchase the EWS.

It can be obtained that the specific purchasing behavior of consumers when providing EWS with differential response times is shown in Figure 2.

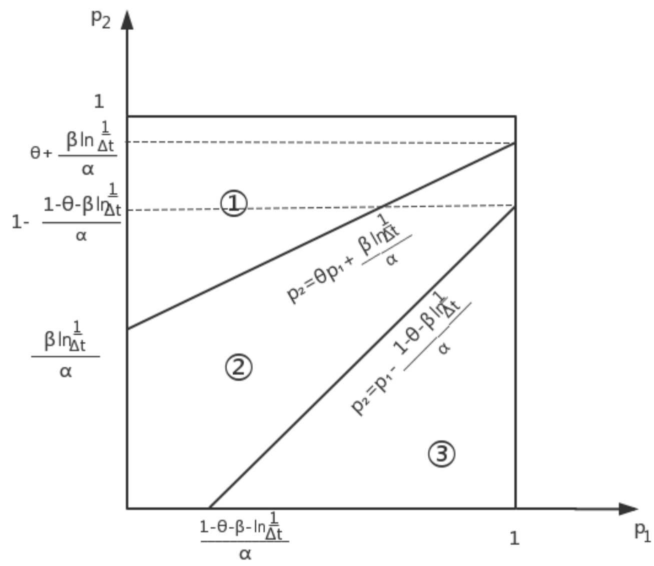

Figure 2. Consumer's choice of EWS

In generally, it is discussed for situations where consumers will have a purchase demand for both retailers, and the demand functions D_1 and D_2 as follows:

$$D_1 = 1-[\alpha(p_1 - p_2)+\beta\ln\frac{1}{\Delta t}]/(1-\theta)\ ;\ D_2 = [\alpha(p_1 - p_2)+\beta\ln\frac{1}{\Delta t}]/(1-\theta)-(\alpha p_2 - \beta\ln\frac{1}{\Delta t})/\theta \qquad (6)$$

3. DECISION ANALYSIS

The manufacturer first determines the wholesale price of EWS, and the two retailers set the price of EWS according to the wholesale price. FR also need to pay a certain introduction fee k in proportion to the income to the manufacturer, $k=\lambda p_2 D_2$ (λ is a fixed value). Draw on the conclusion of Andy (2000) [23], the benefit functions of supply members under decentralized decision are as follow:

$$\underset{w^*}{\text{Max}}\prod\nolimits_{\text{m}}^{*} = w(1-\frac{\alpha(p_1-p_2)+\beta\ln\frac{1}{\Delta t}}{1-\theta})+(w+\lambda p_2)(\frac{\alpha(p_1-p_2)+\beta\ln\frac{1}{\Delta t}}{1-\theta}-\frac{\alpha p_2-\beta\ln\frac{1}{\Delta t}}{\theta}) \qquad (7)$$

$$\underset{p_1^*,p_2^*}{\text{Max}}\prod\nolimits_{\text{r}}^{*} = (p_1-w)(1-\frac{\alpha(p_1-p_2)}{1-\theta})+((1-\lambda)p_2-w-\frac{\eta}{2\Delta t^2})(\frac{\alpha(p_1-p_2)}{1-\theta}-\frac{\alpha p_2-\beta\ln\frac{1}{\Delta t}}{\theta}) \qquad (8)$$

Proposition 1: When two retailers provide EWS with a differential response time, the manufacturer's wholesale price and the two retailers' price optimal solutions are functions (9), (10), and (11).

$$w^* = \frac{\begin{array}{c}(-\alpha\eta(\theta-1)(-4+\theta(\lambda-2)^2)+\theta\Delta t^2(8+12\lambda(\lambda-2)+\theta^2(\lambda-2)^2\\ (2+\lambda(\lambda-4))+2\theta(-8+\lambda(24+\lambda(4\lambda-17))))+\beta\Delta t^2(8(\lambda-1)^2\\ +\theta^2(\lambda-2)^2(2+\lambda(\lambda-4))+2\theta(-8+\lambda(20+\lambda(4\lambda-15))))\ln(\frac{1}{\Delta t}))\end{array}}{8\alpha\Delta t^2(\theta-1)^2(\lambda-2)} \qquad (9)$$

$$p_1^* = \frac{-\alpha\eta(\theta-1)+\Delta t^2(\theta+\beta\ln(\frac{1}{\Delta t}))(4\lambda+\theta(2+\lambda(\lambda-4)))+2\Delta t^2(\theta-\beta\ln(\frac{1}{\Delta t})-2)}{8\alpha\Delta t^2(\theta-1)} \qquad (10)$$

$$p_2^* = -\frac{\alpha\eta(\theta-1)+\Delta t^2(-6+4\lambda+\theta(6+\lambda(\lambda-4)))\left(\theta+\beta\ln\frac{1}{\Delta t}\right)}{4\alpha\Delta t^2(\theta-1)(\lambda-2)} \qquad (11)$$

Firstly, it is proved whether the optimal solution of EWS price exists when the SR and FR provide EWS with different response time under the decentralized decision. For function (2), the second-order Hessian matrix of the income function for prices p_1 and p_2 is:

$$H(p_1*, p_2*) = \begin{pmatrix} \frac{\partial \Pi^2_r *}{\partial p_1^2 *} & \frac{\partial \Pi^2_r *}{\partial p_1 * \partial p_2 *} \\ \frac{\partial \Pi^2_r *}{\partial p_2 * \partial p_1 *} & \frac{\partial \Pi^2_r *}{\partial p_2^2 *} \end{pmatrix} = \begin{pmatrix} \frac{-2\alpha}{1-\theta} & \frac{(2-\lambda)\alpha}{1-\theta} \\ \frac{(2-\lambda)\alpha}{1-\theta} & \frac{2\alpha(\lambda-1)}{\theta(1-\theta)} \end{pmatrix} \tag{12}$$

Since $\frac{\partial \Pi^2_r *}{\partial p_1^2 *} = \frac{-2\alpha}{1-\theta} < 0$, only the conditions $4(1-\lambda) > \theta(2-\lambda)^2$ need to be met, availability $|H_2| > 0$, proves that there is an equilibrium solution that makes the retailer's earnings optimal.

Secondly, p_1 and p_2 are obtained by derivative of p_1 and p_2 in function (8), and solve the system of $\frac{\partial \Pi_r *}{\partial p_1 *} = 0$ and $\frac{\partial \Pi_r *}{\partial p_2 *} = 0$. Through a second derivative of w and $\frac{\partial \Pi^2_m *}{\partial w^2 *} = \frac{8\alpha(\theta-1)^2(\lambda-2)}{\theta(\theta(\lambda-2)^2 + 4(\lambda-1))^2} < 0$, the manufacturer can make the best wholesale price. Let $\frac{\partial \Pi_m *}{\partial w *} = 0$, and w is brought into p_1, p_2, then the complete equilibrium solution (9), (10), (11) can be obtained, QED.

Proposition 2: When two retailers provide EWS with different response time, the optimal price p_1* and p_2* are all decreasing functions of price sensitivity α and increasing functions of response time sensitivity β.

Through the first derivative of p_1* and p_2* with α and β, the follow result is obtained:

$$\frac{\partial p_1 *}{\partial \alpha} = \frac{-4 + (\theta + \beta \ln \frac{1}{\Delta t})(4\lambda + \theta(2 + \lambda(\lambda-4))) + 2(\theta - \beta \ln \frac{1}{\Delta t})}{8\alpha^2(1-\theta)} \tag{13}$$

$$\frac{\partial p_2 *}{\partial \alpha} = \frac{(\theta + \beta \ln \frac{1}{\Delta t})(-6 + 4\lambda + \theta(6 + \lambda(\lambda-4)))}{4\alpha^2(\theta-1)(\lambda-2)} \tag{14}$$

$$\frac{\partial p_1 *}{\partial \beta} = \frac{\ln \frac{1}{\Delta t}(-2 + 4\lambda + \theta(2 + \lambda(\lambda-4)))}{8\alpha(\theta-1)} \tag{15}$$

$$\frac{\partial p_2 *}{\partial \beta} = -\frac{\ln \frac{1}{\Delta t}(-6 + 4\lambda + \theta(6 + \lambda(\lambda-4)))}{4\alpha(\theta-1)(\lambda-2)} \tag{16}$$

Because the denominator in $\frac{\partial p_1 *}{\partial \alpha}$, $\frac{\partial p_2 *}{\partial \alpha}$ and $\frac{\partial p_2 *}{\partial \beta}$ are all greater than 0, and the denominator of $\frac{\partial p_1 *}{\partial \beta}$ is less than 0, it is only necessary to analyze the molecular size of each first derivative. As $(\theta + \beta \ln \frac{1}{\Delta t})(4\lambda + \theta(2 + \lambda(\lambda-4))) + 2(\theta - \beta \ln \frac{1}{\Delta t} - 2) < 0$, then $\frac{\partial p_1 *}{\partial \alpha} < 0$ and $\frac{\partial p_2 *}{\partial \alpha} < 0$. Similarly, as $-2 + 4\lambda + \theta(2 + \lambda(\lambda-4)) < 0$, then $\frac{\partial p_1 *}{\partial \beta}$<0 and $\frac{\partial p_2 *}{\partial \beta}$>0. QED.

Proposition 3: When two retailers provide EWS with different response time, p_1* is the increasing function of differential response time Δt, and p_2* is the decreasing function.

Through the first derivative of p_1* and p_2* with Δt, the follow result is obtained:

$$\frac{\partial p_1*}{\partial \Delta t}=\frac{2\alpha\eta(\theta-1)-\Delta t\beta\ln\frac{1}{\Delta t}(-2+4\lambda+\theta(2+\lambda(\lambda-4)))}{8\alpha\Delta t^3(\theta-1)} \quad (17)$$

$$\frac{\partial p_2*}{\partial \Delta t}=\frac{2\alpha\eta(\theta-1)+\Delta t\beta\ln\frac{1}{\Delta t}(-6+4\lambda+\theta(6+\lambda(\lambda-4)))}{4\alpha\Delta t^3(\theta-1)(\lambda-2)} \quad (18)$$

Since the denominator in $\frac{\partial p_1*}{\partial \Delta t}$ is less than 0, the denominator in $\frac{\partial p_2*}{\partial \Delta t}$ is greater than 0, and only the size of the molecule needs to be analyzed, in the same way as proposition 2, it can be obtained that $\frac{\partial p_1*}{\partial \Delta t}>0$ and $\frac{\partial p_2*}{\partial \Delta t}<0$. QED.

From proposition 2 and proposition 3, it shows that when FR and ER provide differentiated response time EWS and consumers are more sensitive to the price, they should appropriately reduce the EWS price, and the optimal price increases with the sensitivity of differentiated response time, which also prompts FR to choose markets where consumers are more sensitive to differentiated response times. However, for the differentiated response time, the change of the two optimal prices is the opposite, and retailers can cooperate to control the differentiated response time within a certain range to reduce the gap between prices.

4. EXAMPLE ANALYSIS

To analysis EWS prices and profits affected by response times, there are the following basic data: $\eta=0.1$, $\lambda=0.2$, $\theta=0.4$.

(1)When $\alpha=0.2$ and $\beta=0.3$. Figure 3 and 4 describe that when the FR provides differential response time, the optimal price p_1* of SR decreases with the differential response time Δt, while the optimal price p_2* of FR increases with Δt; The manufacturer's optimal wholesale price $w*$ increases first and then decreases with Δt. The manufacturer's profit increases with Δt, and the retailer's total profit decreases with Δt. This shows that the increase of differentiated response time Δt is unfavorable to manufacturers and beneficial to the total profit of retailers. With the increase of Δt, retailers' profits are mainly brought by SR. Therefore, in order to provide EWS for retailers and stabilize the market, FR will strengthen service responsiveness, that is, narrow the gap between response time and avoid large price gap with SR.

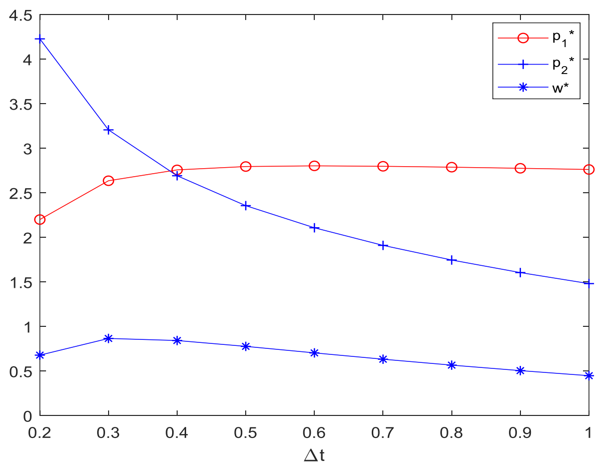

Figure 3. The effect of Δt on p_1*,p_2*,w* under different response time

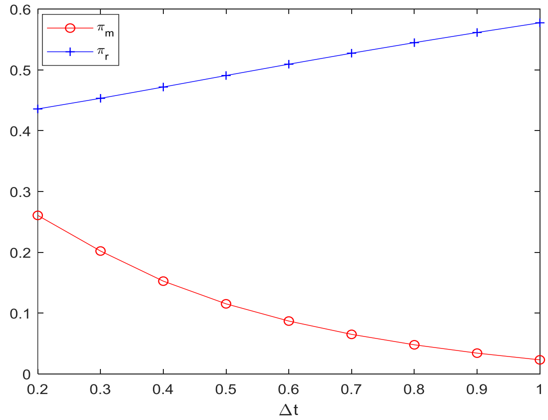

Figure 4. The effect of Δt on Π_m*, Π_r * under different response time

(2)When $\Delta t = 0.6$. Figure 5 and Figure 6 respectively describe that the optimal price of the two retailers decreases with the price sensitivity α and increases with the response time sensitivity β. the optimal price of the retailers changes more violently with the response time sensitivity, and the greater the increase when the price sensitivity is lower. This shows that SR and FR are more willing to choose a market with low price sensitivity and high response time, so as to formulate a higher premium price.

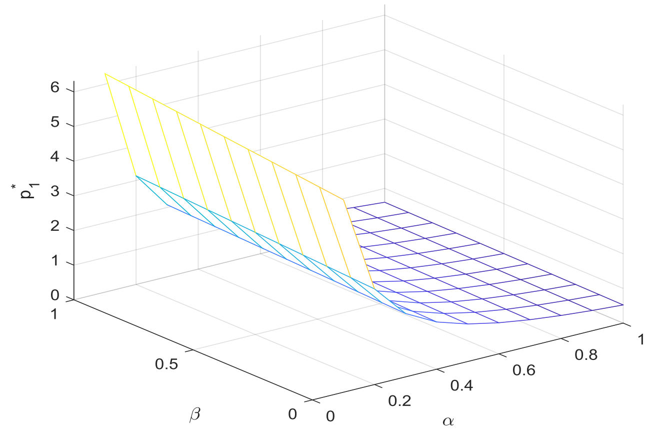

Figure 5. The effect of α β on p_1 * under different response time

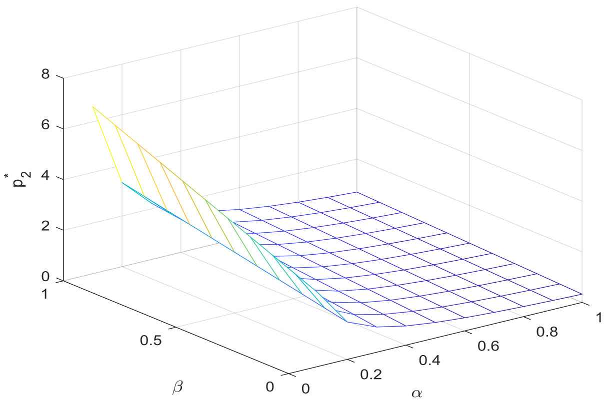

Figure 6. The effect of α β on p_2 * under different response time

(3)When $\Delta t = 0.6$. Figure 7 and 8 respectively describe that the manufacturer's profit and the retailer's total profit decrease with the price sensitivity α, while the manufacturer's profit increases with the response time sensitivity β, and the retailer's total profit first decreases and then increases. Moreover, the impact of β on the total profits of manufacturers and retailers in the supply chain is affected by α. When t α is low, the profits of both sides of the supply chain change more strongly with β . This shows that it is beneficial for retailers to choose markets with low price sensitivity and low or high response time. For manufacturers, they can only choose the market with low price sensitivity and high responsiveness of extended warranty service. Therefore, when FR provide EWS with different response time, manufacturers will encourage FR to shorten the difference in response time and enter the market with high response time, so as to achieve a win-win situation for manufacturers and retailers and obtain greater profits.

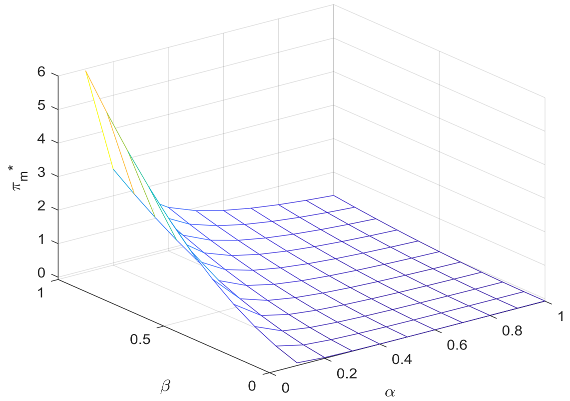

Figure 7. The effect of α β on Π_m * under different response time

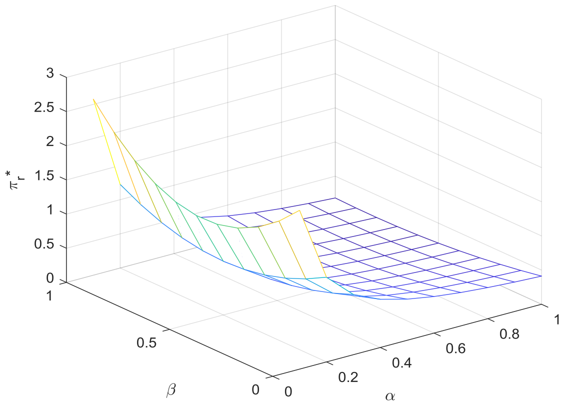

Figure 8. The effect of α β on Π_r * under different response time

5. CONCLUSION

By introducing the response time into the pricing decision of EWS, the pricing strategy of EWS provided by competing retailers with differential response time is studied, and the following conclusions are mainly formed:

(1)The optimal EWS price of SR increases with the differentiated response time, while the optimal EWS price of the FR decreases with the differentiated response time.

(2)With the increase of differentiated response time of EWS, it is unfavorable to benefit the manufacturer's profit and the retailer's total profit.

(3)For retailers and manufacturers, the choice of market pricing strategies where consumers are less price sensitive to EWS and have higher response time of EWS can get greater benefits.

The study also found that the change in the differential response time of FR will lead to changes in the price of SR, the greater the differential response time, the higher the price of SR, while the FR should appropriately reduce the EWS price of to attract consumers because the response time is not dominant. Retailers are always more profitable than manufacturers, and both supply chain members will opt for differentiated response time-sensitive markets to maximize their interests.

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