

Pricing Model of Fresh Supply Chain Based on Reference Price Effect

Rongrong Pu

School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing 400065, China.

Abstract

In this paper, aiming at the O2O fresh supply chain system composed of a manufacturer's network channel and a traditional retail channel, starting from the reference price effect of fresh products, the pricing problem of fresh e-commerce supply chain was studied. Based on the reference price effect, a two-stage pricing model for fresh products was developed. The effects of reference price effect, memory coefficient and reference price coefficient on the long-term earnings of product manufacturers, retailers and supply chains in different decision situations are analyzed by numerical simulation of the assignment of exogenous variables.

Keywords

Fresh supply chain ;Reference price; Memory parameter; Price strategy.

1. Introduction

In the process of shopping, consumers tend to set a psychological expected price ^[1] according to the product's past price, that is, the reference price. For consumers with high price sensitivity, the reference price plays a great role in guiding consumer behavior ^[2]. If the actual price is higher than the reference price, consumers will have a psychological perception of "aversion", and will not necessarily produce purchase behavior; If the actual price is lower than the reference price, consumers will have a psychological perception of "joy" and purchase behavior will occur directly ^[3]. The study of reference price theory not only plays an important role in the study of consumer behavior, but also provides a theoretical basis for the pricing strategy based on consumer behavior ^[4].

The reference price theory is widely used to make the decision model of upstream and downstream pricing and coordination in the supply chain. Li rongxi et al. ^[3] established consumer demand function and product pricing model based on price reference effect with the goal of maximizing enterprise profits, and proved that reference price is related to consumer behavior and enterprise pricing. Popescu et al. ^[5] divided consumers into two types: risk-neutral and risk-preference, and studied the influence of reference prices under consumers' different risk perceptions on the product prices of enterprises. According to the behavioral preference of consumers, cao fang et al. ^[6] established the decision-making model of the internal reference price of consumers, and proposed the price optimization method for improving the stickiness of users. Lou gaoxiang et al. ^[7] considered the dynamic pricing strategy and emission reduction strategy developed by manufacturers under the mechanism of reference effect. Shen et al. ^[8] applied the reference price effect to the actual enterprise management, and made the corresponding strategy research according to the current customer behavior. Bi wenjie et al. ^[9] established a two-cycle dynamic pricing model from the impact of consumers' dual-channel psychological accounts and reference-dependent behaviors on corporate profits, and studied the profit changes and impacts of different payment methods on consumers. However, due to the perishability and damage of fresh products, the article on fresh supply chain did not consider the change of product freshness with time. Bai shizhen et al. ^[10] considered the reference

price effect in the fresh supply chain, and formulated a revenue sharing contract model between suppliers and retailers when product freshness was fixed. Zhang et al. ^[11] introduced the reference price into the product pricing problem of durable goods, and the results showed that the reference price effect was conducive to the overall revenue of the supply chain.

Such as price discount and related price reference not only provide consumers with a variety of choices, but also activate the consumer's strategic behavior, become a powerful reference for consumers to purchase decisions. Therefore, based on the reference dependency theory, this paper introduces the consumer reference price effect and considers the change of freshness of fresh products ^[12]. Through the construction of single-stage pricing model and two-stage pricing model, the paper studies the pricing problem of fresh supply chain from a dynamic perspective, so as to provide a theoretical basis for retailers and manufacturers. It is of practical significance to study the pricing strategy of abundant fresh supply chain.

2. Problem description and model hypothesis

2.1 Problem description

This paper considers the O2O fresh supply chain system composed of a manufacturer's network channel and a traditional retail channel. Due to the instantaneous loss of fresh product freshness, this paper focuses on the two-stage pricing of products at different time points. Assume that the manufacturer and the offline retailer are in a limited time frame $[0, T]$ To sell a monopolistic fresh product to a consumer and the consumer has repeated browsing or buying behavior towards the product. According to the channel richness theory, the convenience and information richness of network channels will increase the possibility of consumers' "price comparison" behavior, and the reference price can be obtained by means of search, price comparison website and crawler. If in a shopping festival during the promotion, consumers observed a shopping site at the current point of the fresh product price p . The reference price is formed according to the price memory of previous shopping browsing or different time points. By comparing with the reference price, consumers will have a value perception of "gain" or "loss". Here, Monroe^[12]'s description of the reference price effect is used $R = 1 - \frac{p}{r}$ to quantify the reference price effect. According to the theory of consumer adaptation level, $R > 0$ it means that consumers feel "earned" to stimulate demand, that is, the positive reference price effect; Indicates that the consumer feels "loss" and thus suppresses the demand, $R < 0$, that is, the negative reference price effect. Therefore, considering the raw product freshness gradually decay over time, fresh supply chain to ensure that different point to maximize profits, based on consumers' sensitivity to the different time fresh price and consumer reference price formation mechanism, key research network channel reference price effect on O2O fresh dynamic pricing strategy of supply chain, the influence of income.

2.2 Symbol description

symbol	The physical meaning	symbol	The physical meaning
p_r	Traditional channels of fresh product sales price	κ	Consumer sensitivity to reference prices
p_e	Network channels of fresh product sales prices	c	Production cost per unit of fresh produce

p_{rt}	Traditional channels two stages of fresh product sales price ($t = 1, 2$)	λ	Cross price elasticity coefficient between two channels
p_{et}	Network channels two stages of fresh product sales price ($t = 1, 2$)	β	The profit discount factor resulting from the second stage pricing
w	Wholesale price of fresh produce	π_e	Net direct channel profit
w_t	Two stages of fresh wholesale prices ($t = 1, 2$)	π_r	Profits from traditional retail channels
θa	Potential market demand for traditional retail channels	π_c	The overall profit of the fresh supply chain
$(1 - \theta)a$	The potential market demand of network direct channel	π_{et}	Network channel profits under the two-stage situation ($t = 1, 2$)
R	The reference price mechanism of network direct channel	π_{rt}	Retail channel profits in the two-stage scenario ($t = 1, 2$)
r_e	Network direct channel reference price effect	μ	Memory parameters of consumers after shopping, namely product loyalty
r_{et}	The reference price effect in two-stage pricing ($t = 1, 2$)		

2.3 Model assumes

In order to simplify the model and ensure that the research content is closer to the reality, the following conditional assumptions are made in this paper in combination with the existing research results.

Hypothesis 1: all members of the O2O fresh supply chain are risk-neutral, and their risk tolerance is limited. Moreover, the supply chain participants make rational decisions and make decisions with the goal of maximizing their own profits.

Hypothesis 2: empirical studies such as Zeng and Yue show that consumers are less sensitive to the reference price of traditional channels and have a short memory of purchasing experience. Therefore, it is assumed that the reference price effect of traditional retail channels is not considered here, and only the influence of reference price effect of network channels on consumers' purchasing decisions is considered.

Hypothesis 3: the effects of reference price formation mechanism of research, research point of view of scholars both at home and abroad can be summarized as the following three: (1) based on the memory reference price effect model, reference price formed in the consumer price of different point

memory, such as when a shopping festival, Tmall, jingdong, suning and other shopping sites, commodity the price of different points in the past have been changing over time, consumers by measuring the price of the different point, decide whether to buy; (2) based on the stimulus reference price effect model, the reference price is generated in the external environment of consumers, such as the external reference price producer through advertising, alternative product price and brand effect to convey market price information; (3) the reference price effect model combining memory and stimulus, this kind of model covers the characteristics of the previous two models, more comprehensive description of the reference price effect model. Therefore, this paper assumes that the reference price is constantly changing at different time points, and the deformation of the reference price function with reference to Monroe's research literature, and the formation process of the reference price is described by the following equation.

$$R_{e(t-1)}^* = \mu \left(1 - \frac{P_{e(t-1)}}{r_{e(t-1)}} \right)$$

$$s.t. \ r_{et} = (1 - \mu)r_{e(t-1)} + \mu p_{e(t-1)} \quad (t = 1, 2)$$

Where, r_{et} refers to the reference price of online channel products by consumers at a certain time, and $r_e(0) = r_{e0}$ to the initial reference price of online channel products by consumers at time 0 (r_{e0} affected by various factors, such as consumers' cognition of product quality, understanding of technology and price of alternative products). $\mu \left(1 - \frac{P_{e(t-1)}}{r_{e(t-1)}} \right)$ reflects the influence of consumers' purchasing

experience in online channels on the formation of the reference price mechanism. The memory parameter μ ($0 \leq \mu \leq 1$) represents the purchase frequency of a certain product, and also represents the loyalty to the product. The higher the memory is μ , the shorter the consumers' memory of past purchase experience is, that is, the lower their loyalty to the product is.

Hypothesis 4 in this paper, the manufacturer is assumed to be the leader in the Stackelberg game. Firstly, the manufacturer decides the wholesale price w of products in the retail channel and determines the selling price p_e of products in the direct channel. Then, the retailer sets the selling price w of products in the retail channel according to the known wholesale price p_r .

Hypothesis 5: assumes that consumers' purchasing decisions are not only affected by the selling price of fresh products and the cross-price between channels, but also affected by the reference price effect of network channels. It is assumed that the market demand of both the producer network channel and the retailer's traditional channel is a linear demand function related to price. The simplified demand function is described as follows.

$$D_r = \theta a - p_r + \lambda p_e$$

$$D_e = (1 - \theta)a - p_e + \lambda p_r + \kappa \left(1 - \frac{p_e}{r_e} \right)$$

Among them: θa and $(1 - \theta)a$ respectively network channels and traditional retail channels of the potential market demand, to simplify the analysis, the price elasticity coefficient of normalized processing, price elasticity coefficient is set to 1, λ according to the traditional retail channels and network channels between the cross price elasticity coefficient, κ said consumer reference price sensitivity of network channels, namely reference price sensitive coefficient.

3. Basic model

3.1 Single stage fresh pricing model

In the limited time interval $[0, T]$, because the life cycle of fresh products is short, its sales cycle will be shorter, it is not allowed to adjust the price for many times to sell. Considering the number of price adjustments, price changes have important effects on consumer loyalty and variable cost. Therefore, this paper assumes that there is an ideal sales cycle, and the pricing decision of fresh products in a single stage is adopted, and the pricing decision problem of fresh supply chain in a single stage is described as follows without considering the pricing problem of products in stages.

$$\pi_r = (p_r - w)(\theta a - p_r + \lambda p_e)$$

$$\pi_e = (w - c)(\theta a - p_r + \lambda p_e) + (p_e - c) \left[(1 - \theta)a - p_e + \lambda p_r + \kappa \left(1 - \frac{p_e}{r_e}\right) \right]$$

Where, π_r represents the profit function of traditional retailers, and π_e represents the profit function of manufacturers' network channels.

Theorem 1: In the case of single stage pricing, the optimal wholesale price of fresh supply chain manufacturer, the optimal direct price and the optimal retail price of fresh supply chain retailer are respectively:

$$w^* = \frac{\theta a + c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa] \lambda r_e}{2(r_e + \kappa - \lambda^2 r_e)}$$

$$p_e^* = \frac{c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa] r_e}{2(r_e + \kappa - \lambda^2 r_e)}$$

$$p_r^* = \frac{3\theta a + (\lambda + 1)c}{4} + \frac{[a + (\lambda - 1)\theta a + \kappa] \lambda r_e}{2(r_e + \kappa - \lambda^2 r_e)}$$

Theorem 2 in the case of single stage pricing, the long-term optimal profit of fresh supply chain manufacturers, retailers and O2O fresh supply chain as a whole is:

$$\pi_r^* = (p_r^* - w^*)(\theta a - p_r^* + \lambda p_e^*)$$

$$\pi_e^* = (w^* - c)(\theta a - p_r^* + \lambda p_e^*) + (p_e^* - c) \left[(1 - \theta)a - p_e^* + \lambda p_r^* + \kappa \left(1 - \frac{p_e^*}{r_e}\right) \right]$$

$$\pi_c^* = (p_r^* - c)(\theta a - p_r^* + \lambda p_e^*) + (p_e^* - c) \left[(1 - \theta)a - p_e^* + \lambda p_r^* + \kappa \left(1 - \frac{p_e^*}{r_e}\right) \right]$$

3.2 A two-stage fresh pricing model is considered

Pricing situation based on the single phase, considering the raw product value changing with time, the price of the different point should also be dynamically adjusted, such as fresh market AM session stage of product pricing is higher than the PM session of product price, the pricing strategy can be thought of as a two-phase pricing based on product value changes. According to the price observed in the period of time and the price of the period of comparison of consumers with the past price memory t_1, t_2 to form a reference price mechanism. Considering the influence of reference price effect on consumers' purchasing decision, this paper constructs a two-stage pricing model for fresh products considering reference price effect, and studies the dynamic pricing of fresh supply chain.

On the basis of the basic assumptions, it is assumed that the manufacturer decides the wholesale price of products in the retail channel w_1 and determines the selling price of products p_{e1} in the direct

channel, and the retailer formulates the selling price w_1 of products in the retail channel according to the known wholesale price p_{r1} . The price of fresh products changes dynamically with the time of sale in a limited sales period. In order to maximize their respective interests, the manufacturer will take the lead in adjusting the product price strategy (w_2, p_{e2}) , and then the retailer will set the retail price p_{r2} of products according to the manufacturer's price strategy.

In the case of two-stage pricing, manufacturers and retailers take profit maximization as the decision objective at each stage. A two-stage Stackelberg game equilibrium pricing strategy is solved by backward induction. First, the Stackelberg equilibrium solution of the second stage is solved, and then the optimal equilibrium solution of the second stage is taken into the profit function of the whole fresh product sales period. Therefore, the profit function of the retailer and the producer in the second stage is respectively:

$$\pi_{r2} = (p_{r2} - w_2)(\theta a - p_{r2} + \lambda p_{e2})$$

$$\pi_{e2} = (w_2 - c)(\theta a - p_{r2} + \lambda p_{e2}) + (p_{e2} - c) \left[(1 - \theta)a - p_{e2} + \lambda p_{r2} + \kappa \left(1 - \frac{p_{e2}}{r_{e2}}\right) \right]$$

Theorem 3: In the case of two-stage pricing, the wholesale price, direct price and retail price of fresh products determined by the producer and retailer in the first and second stages are respectively.

The pricing strategy of the first stage:

$$p_{e1}^* = \frac{c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa]r_{e1}}{2(r_{e1} + \kappa - \lambda^2 r_{e1})}$$

$$w_1^* = \frac{\theta a + c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa]\lambda r_{e1}}{2(r_{e1} + \kappa - \lambda^2 r_{e1})} \quad p_{r1}^* = \frac{3\theta a + (\lambda + 1)c}{4} + \frac{[a + (\lambda - 1)\theta a + \kappa]\lambda r_{e1}}{2(r_{e1} + \kappa - \lambda^2 r_{e1})}$$

Pricing strategy in the second stage:

$$p_{e2}^* = \frac{c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa]r_{e2}^*}{2(r_{e2}^* + \kappa - \lambda^2 r_{e2}^*)}$$

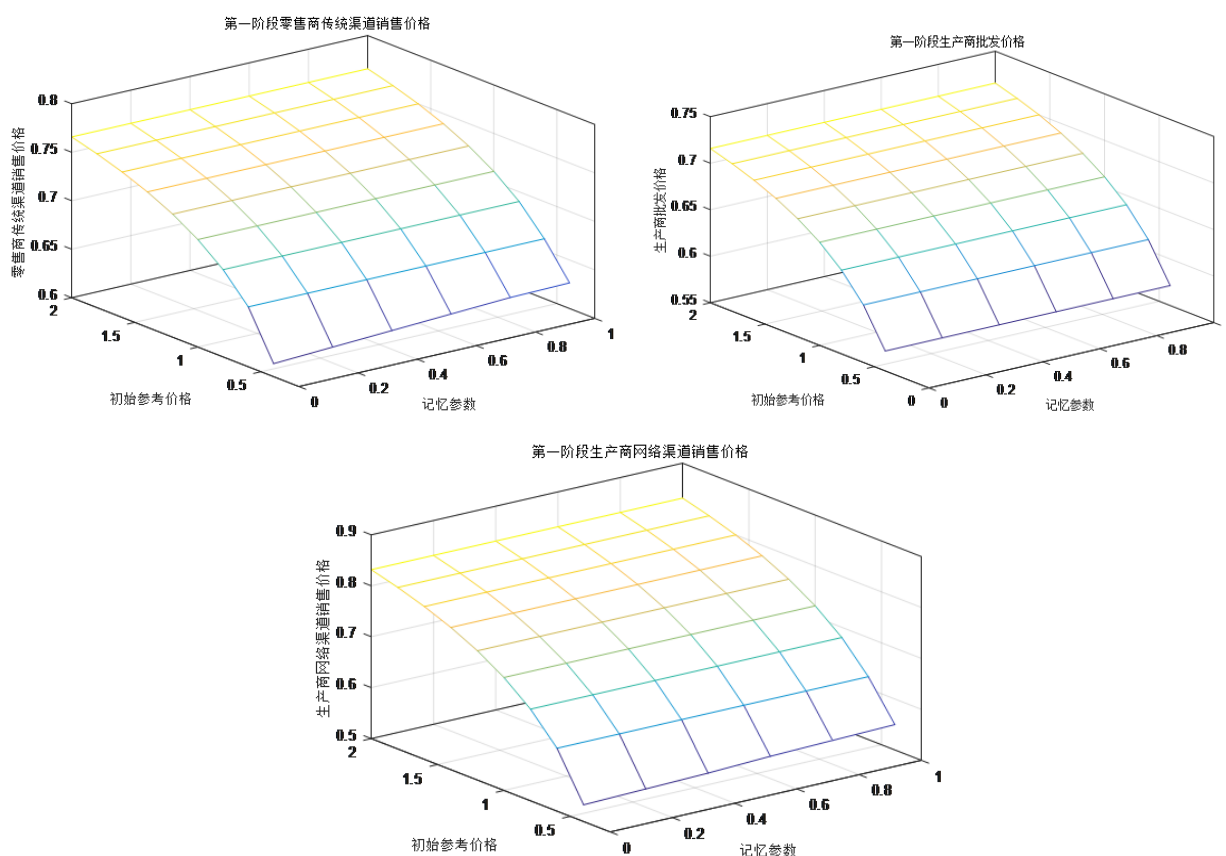
$$w_2^* = \frac{\theta a + c}{2} + \frac{[a + (\lambda - 1)\theta a + \kappa]\lambda r_{e2}^*}{2(r_{e2}^* + \kappa - \lambda^2 r_{e2}^*)}$$

$$p_{r2}^* = \frac{3\theta a}{4} + \frac{(\lambda + 1)c}{4} + \frac{[a + (\lambda - 1)\theta a + \kappa]\lambda r_{e2}^*}{2(r_{e2}^* + \kappa - \lambda^2 r_{e2}^*)}$$

4. The example analysis

Above analysis of the single pricing model and two-phase pricing model under the condition of the corresponding pricing strategy, consumer demand and profit function, to test a single pricing decision and pricing decision and the relevant conclusions on the accuracy of the two phase, numerical simulation by an exogenous variable assignment, more intuitive analysis of the coefficient of the reference price effect under different decision situations, memory and reference price coefficient for product manufacturers, retailers and the supply chain as a whole the influence of long-term returns. With the help of software MATLAB R2015a, data mapping was carried out to observe the change trend of price, demand and profit under different parameter conditions. The benchmark parameters of the model are as follows: $a = 1$ 、 $\theta = 0.4$ 、 $c = 0.2$ 、 $\lambda = 0.5$ 、 $\kappa = 0.4$ 、 $\beta = 0.95$ 、 $\mu \in [0, 1]$ 、 $r_{e1} \in [0, 2]$ 。

The benchmark parameters are substituted into the single-stage pricing model, and the influence of consumer memory parameters and different initial reference prices on the principal pricing strategies of each party in the single-stage supply chain system is mainly discussed. Thus, we can observe the changes of fresh producer's optimal wholesale price, network channel price μ and retailer's optimal pricing strategy under different initial reference prices r_{e1} of consumer memory parameters at different times.



According to figure 2, figure 3 and figure 4, the wholesale price of manufacturers, online channel pricing and traditional channel pricing of retailers in the first stage are more inclined to choose higher pricing strategies with the increase of consumer memory parameters μ , and the traditional channel pricing of retailers is consistent with the trend of online channel pricing of manufacturers.

Similar to Ali box 7 fresh horses, Jingdong and Su Xian raw fresh retail enterprise, at the beginning of the new fresh products have high barriers to entry, because of its unique fresh service experience to meet the personalized needs of consumer, which would increase the memory time of consumers on product service experience, namely the consumer loyalty of product is higher, so fresh electric business enterprise can choose a higher price.

5. Conclusion

Aiming at the O2O fresh supply chain system composed of a producer network channel and a traditional retail channel, this paper introduces the reference price effect of fresh products and studies the pricing problem of fresh e-commerce supply chain. Firstly, the pricing model of the first stage is established, and the long-term optimal profit of fresh supply chain manufacturers, retailers and O2O fresh supply chain as a whole is determined. Under the optimal profit of fresh supply chain manufacturers, the optimal wholesale price, the optimal direct price and the optimal retail price of fresh products of retailers are determined. Secondly, by introducing the reference price mechanism and considering the influence of the reference price effect on consumers' purchasing decisions, a two-stage pricing model of fresh products with reference price effect is constructed to study the dynamic

pricing of fresh supply chain. The wholesale price, direct price and retail price of fresh products made by producers and retailers in the first stage and the second stage are respectively constructed under the decision-making goal of maximizing their own profits at each stage. Finally, the effects of reference price effect, memory coefficient and reference price coefficient on the long-term earnings of product manufacturers, retailers and the supply chain in different decision-making situations are analyzed by numerical simulation with exogenous variable assignment.

The relevant research conclusions are as follows: 1) in single-stage pricing, consumers have a deep memory of purchase and generate customer loyalty. In order to improve revenue, wholesale price, network channel pricing and retailers' traditional channel pricing will gradually increase. 2) in two-stage pricing, the higher the memory parameter of consumers is, the higher the wholesale price, network channel pricing and traditional channel pricing will increase in the second stage, no matter the manufacturer or the retailer. The higher the memory parameter, the higher the channel profit of both manufacturers and retailers in the second stage. In the second stage, the wholesale prices of manufacturers tend to be higher with the increase of memory parameters. 3) the higher the reference price coefficient is, the higher the price of the first stage will be and the lower the price of the second stage will be. For retailers, it raises prices in two phases. Therefore, it can promote the overall revenue of the channel. In the process of constructing the function, this paper does not consider the efforts made by retailers and manufacturers to improve the channel revenue. Therefore, in the future research, it will consider the decision problem of the preservation efforts invested by retailers and manufacturers under the influence of the freshness of fresh products changing with time.

References

- [1] Shen Z J M, Su X. Customer Behavior Modeling in Revenue Management and Auctions: A Review and New Research Opportunities[J]. *Production & Operations Management*. 2010, 16(6): 713-728.
- [2] Bai Shizhen, Xie Shuang, Wu Rong, et al. Research on coordination strategy of fresh e-commerce supply chain based on price reference effect [J]. *Preservation and processing*. 2018 (01) : 118-124.
- [3] Zhang J, Chiang W Y K, Liang L. Strategic pricing with reference effects in a competitive supply chain[J]. *Omega*. 2014, 44(2): 126-135.
- [4] Duan Y, Liu J. Optimal dynamic pricing for perishable foods with quality and quantity deteriorating simultaneously under reference price effects[J]. *International Journal of Systems Science: Operations & Logistics*. 2018: 1-10.
- [5] Wang Lei, Dan Bin. Research on fresh agricultural product preservation and pricing strategy based on consumer choice behavior [J]. *Journal of management*. 2014, 11 (03) : 449-454.
- [6] Tang Yuewu, fan Tijun, Liu sha. Pricing and inventory decision of fresh agricultural products considering strategic consumers [J]. *China management science*. 2018, 26 (11) : 105-113.
- [7] Li Lin, Fan Tijun. Comparative study on the pricing strategy of fresh agricultural products supply chain under the leadership of retailers [J]. *China management science*. 2015, 23 (12) : 113-123.
- [8] Shia J, Fungb R Y K, Guoa J. Optimal ordering and pricing policies for seasonal products: impacts of demand uncertainty and capital constraint[J]. *Discrete Dynamics in Nature and Society*,2016,(2016-11-23). 2016, 2016(2): 1-13.
- [9] Dye C Y, Hsiehb T P. An optimal replenishment policy for deteriorating items with effective investment in preservation technology[J]. *European Journal of Operational Research*. 2012, 218(1): 106-112.
- [10] Shulman J D, Savaskan R C. Managing Consumer Returns in a Competitive Environment.[J]. *Management Science*. 2011, 57(2): 347-362.
- [11] Cao Yu, li Yemei, wan Guangyu. Research on incentive mechanism of freshness of fresh agricultural products supply chain based on consumer utility [J]. *China management science*. 2018 (02) : 160-174.
- [12] Monroe K B. Buyers' Subjective Perceptions of Price[J]. *Journal of Marketing Research*. 1973, 10(1): 70-80.