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RESEARCH ON JOINT DYNAMIC PRICING WITH CONSIDERATION OF CONSUMER STRATEGIC BEHAVIOR AND RISK PERCEPTION

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Abstract. *This paper studies the joint dynamic pricing problem with the coexistence of myopic and strategic behavior and strategic consumers with different risk perceptions. Based on the behavioral characteristics of consumers, consumers are divided into myopic consumers and strategic consumers. The strategic consumers are further divided into optimistic consumers and pessimistic consumers. The paper studied the optimal pricing problem of retailers under different consumer types and different risk perceptions. The numerical experiments show that when the myopic consumers reach a certain proportion, the retailers can take the high price strategy, otherwise take the low price strategy; when the proportion of myopic and strategic type is certain, with the increase of optimistic consumers in strategic consumers, retailers should take the high price strategy, otherwise adopt low price strategy.*
Keywords: Joint pricing, Myopic consumers, Strategic consumers, Risk perception

1. **Introduction.** For the same kind of goods, different consumers have different valuations; enterprises can set different prices to meet the needs of different consumers, to maximize profits. However, with the information open, consumers become more and more intelligent, they will not buy products immediately, but wait patiently for a price cut. Electronic business Best Buy calls these consumers "demons" [1]. Consumers, called "angel angels", choose to buy as long as the price is lower than the willingness to pay. "Angel" consumers, "Devil" consumers are the myopic consumers and strategic consumers. When Coase [2] first studied consumer strategy behavior, he found that when strategic customers realized that the price of durable goods would decline in the future and chose to wait, the monopoly would be forced to set the price at the marginal cost of the product. Shen and Su [3], Aviv and Pazgal [4] and Levin et al. [5] also prove that consumer's strategic behavior leads to the decrease of revenue.

Dynamic pricing studies first appeared in the hotel industry, the aviation industry and other relatively stable supply of industries. Wilson et al. [6], Jerath et al. [7] and Kim [8] studied the impact of consumer's strategic behavior on airline pricing and revenue. Levin et al. [9] mentioned that in recent years, the research of dynamic pricing strategy has not only been limited to these industries, but also applied in the retail industry. Yang et al. [10] studied the two stage dynamic pricing decision problem of products under market environment with different characteristics of strategy or myopic on the behavior rule, and put forward the definition of critical valuation; Li and Wang [11] studied the pricing strategy of retailers facing strategic customers and myopic customers. It is found that the price guarantee mechanism can be used to realize the retailer's unified pricing; Bi et al. [12] studied the dynamic pricing problems when monopolistic firms sell two

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alternative products at the same time; Guan and Li [13] further studied how retailers can decide the optimal price when the consumer's evaluation changes with time and faces the risk of stock-outs, and analyzed the influence of the proportion of strategic consumers on the retailer's dynamic pricing and earnings; Yang et al. [14] had studied the pricing strategy of "product + services" integrated system for consumer strategy behavior.

The above studies are aimed at single consumers, that is, only strategic consumers exist in the market. Actually, consumers in the market tend to be a mixture of myopic and strategic. The pricing of enterprises should take account of the different behavioral characteristics of consumers. Although Su [15] considered both myopic and strategic consumers, he only divided his customer's willingness to pay into two categories. This paper studies the consumers in addition to myopic and strategy, and strategic consumers have different risk perceptions. "Risk perception" refers to the individual's feelings and perceptions of various objective risks existing in the external environment, and emphasizes the individual's cognitive influence on the individual's experiences obtained from the intuitive judgment and subjective feelings. In this paper optimistic consumers think the possibility of future large, so willing to postpone buying, while pessimistic consumers believe that the future of goods is very low, willing to buy immediately.

To sum up, this paper studies the optimal pricing strategy of the retailer when the myopic and strategic consumers coexist, and the strategic consumers have different risk perceptions. Using the newsboy model and numerical analysis, this paper draws the following conclusions: (1) When myopic consumers more than a certain percentage of the market, the retailer should take a high price strategy; (2) When the proportion of consumers is determined, the optimists in strategic consumers reach a certain percentage, and the retailer should also take a high price strategy.

2. Problem Description and Hypothesis.

Considering a sales market with both strategic and myopic consumers, and strategic consumers with different risk perceptions, retailers aim to maximize profitability. The unit cost of goods is c. The selling price of the unit product is p. After the sales period, there is a large enough processing market, and the remaining products are dealt with at the price of s, s is fixed and $s < c$. Consumers have the same retention value v for all products. Strategic consumers believe that the future possibility of obtaining goods is ξ. The retailer's decision variables are sales price p and order quantity Q. The market demand X is a non-negative, continuous random variable, whose distribution function is $F(x)$, and the probability density function is $f(x)$. There are both strategic and myopic consumers in the market, among which the proportion of myopic consumers is β $(0 \leq \beta \leq 1)$. E is on behalf of expectations. Each customer only buys one product and does not consider the retailer's shortage cost.

3. Mathematical Model.

3.1. Product pricing analysis.

As long as the consumer surplus of myopic consumers is not negative, that is $(v-p) \geq 0$, they will choose to buy immediately, rather than waiting for purchase during processing period. Strategic consumers estimate the likelihood of future price reductions and decide whether to buy immediately. The remainder of the regular purchase of the consumer is $v - p$. Consumers' surplus after purchasing goods during the treatment period is $\xi(v - s)$. By comparing the consumer surplus in the two periods, the strategic consumers choose to buy now or wait. When and only if the consumer surplus in the regular period is large, that is $(v - p) \geq \xi(v - s)$, the strategic consumers will buy immediately, otherwise they will choose to wait. Myopic consumers can accept the highest price is $p = v$. Strategic consumers can accept the highest price for $p = v - \xi(v - s)$. If retailers want strategic consumers to buy on regular period, they are priced at $p = v - \xi(v - s)$, at this point, myopic consumers will also buy. When

the retailer is priced at v, it can take over the remainder of all myopic consumers, and strategic consumers will choose to wait.

3.2. **Pricing of strategic consumers.** When a retailer wants a strategic consumer to buy during the sales period, the product price should be the consumer's retained value $p_t = v - \xi(v - s)$. Retailers expect profit to be:

$$\begin{aligned}\pi_{t(Q_t,p_t)} &= p_t E\min(X, Q_t) + s[Q_t - E\min(X, Q_t)] - cQ_t \\ &= (p_t - s)E\min(X, Q_t) - (c - s)Q_t \\ &= (p_t - s)\left[\int_0^{Q_t} xf(x)dx - \int_0^{Q_t} Q_t f(x)dx + Q_t\right] - (c - s)Q_t\end{aligned}$$

Revenue function $\pi_{t(Q_t,p_t)}$ finds the first derivative of Q_t and let $\frac{\partial \pi_t}{\partial Q_t} = 0$: $\frac{\partial \pi_t}{\partial Q_t} = (p_t - s)\overline{F(Q_t)} - c - s = 0$, so $Q_t = F^{-1}\left(\frac{p_t - c}{p_t - s}\right)$.

3.3. **Pricing of myopic consumers.** When retailers only consider myopic consumers, the optimal pricing is $p_m = v$, and retailers expect profit:

$$\begin{aligned}&\pi_{m(Q_m,\beta)} \\ &= vE\min(\beta x, Q_m) + s[Q_m - E\min(\beta x, Q_m)] - cQ_m \\ &= (v - s)E\min(\beta x, Q_m) - (c - s)Q_m \\ &= \beta(v - s)E\min\left(x, \frac{Q_m}{\beta}\right) - \beta(c - s)\frac{Q_m}{\beta} \\ &= \beta(v - s)\left[\int_0^{\frac{Q_m}{\beta}} xf(x)dx + \int_{\frac{Q_m}{\beta}}^{+\infty} \frac{Q_m}{\beta} f(x)dx\right] - \beta(c - s)\frac{Q_m}{\beta} \\ &= \beta(v - s)\left[\int_0^{\frac{Q_m}{\beta}} xf(x)dx + \int_0^{\frac{Q_m}{\beta}} \frac{Q_m}{\beta} f(x)dx + \int_{\frac{Q_m}{\beta}}^{+\infty} \frac{Q_m}{\beta} f(x)dx - \int_0^{\frac{Q_m}{\beta}} \frac{Q_m}{\beta} f(x)dx\right] \\ &\quad - \beta(c - s)\frac{Q_m}{\beta} \\ &= \beta(v - s)\left[\int_0^{\frac{Q_m}{\beta}} xf(x)dx - \int_0^{\frac{Q_m}{\beta}} \frac{Q_m}{\beta} f(x)dx + \frac{Q_m}{\beta}\right] - \beta(c - s)\frac{Q_m}{\beta}\end{aligned}$$

Revenue function π_m finds the first derivative of Q_m,

$$\begin{aligned}&\frac{\partial \pi_m}{\partial Q_m} \\ &= \beta(v - s)\left[\frac{1}{\beta} \cdot \frac{Q_m}{\beta} \cdot f\left(\frac{Q_m}{\beta}\right) + \frac{1}{\beta} - \frac{1}{\beta}\int_0^{\frac{Q_m}{\beta}} f(x)dx - \frac{Q_m}{\beta} \cdot \frac{1}{\beta} \cdot f\left(\frac{Q_m}{\beta}\right)\right] - (c - s) \\ &= \beta(v - s)\left(\frac{1}{\beta} - \frac{1}{\beta}\int_0^{\frac{Q_m}{\beta}} f(x)dx\right) - (c - s) \\ &= (v - s)\left[1 - \int_0^{\frac{Q_m}{\beta}} f(x)dx\right] - (c - s)\end{aligned}$$

Let $\frac{\partial \pi_m}{\partial Q_m} = 0$, so $1 - F\left(\frac{Q_m}{\beta}\right) = \frac{c - s}{v - s} \Rightarrow \overline{F\left(\frac{Q_m}{\beta}\right)} = \frac{c - s}{v - s} \Rightarrow Q_m = \beta\overline{F^{-1}\left(\frac{c - s}{v - s}\right)}$.

4. **Analysis of Two Pricing Strategies.** Remember $\Delta\pi = \pi_t - \pi_m$, in which $\pi_t = (p_t - s)\left[\int_0^{Q_t} xf(x)dx - \int_0^{Q_t} Q_s f(x)dx + Q_t\right] - (c-s)Q_t$; $\pi_m = \beta(v-s)\left[\int_0^{\frac{Q_m}{\beta}} xf(x)dx - \int_0^{\frac{Q_m}{\beta}} \frac{Q_m}{\beta} f(x)dx + \frac{Q_m}{\beta}\right] - \beta(c-s)\frac{Q_m}{\beta}$. When $\beta = 0$, then $\Delta\pi > 0$, when $\beta = 1$, $\Delta\pi < 0$, so there must be a point β^*, let $\Delta\pi = 0$, $\frac{\partial(\Delta\pi)}{\partial\beta} = -(v-s)\int_0^{\overline{F^{-1}\left(\frac{c-s}{v-s}\right)}} xf(x)dx < 0$, we can know that $\Delta\pi(\beta)$ monotonically decreasing of β, and the unique solution $\beta^* = \frac{(p_t-s)\int_0^{Q_t} xf(x)dx}{(v-s)\int_0^{F^{-1}\left(\frac{c-s}{v-s}\right)} xf(x)dx}$. When $\beta = \beta^*$, $\Delta\pi(\beta^*) = 0$. Apparently, when $\beta > \beta^*$, $\Delta\pi(\beta^*) > 0$, retailers should take the high price strategy at this time; when $\beta < \beta^*$, $\Delta\pi(\beta^*) < 0$, at this point, retailers should adopt low price strategy in the regular period.

5. **Numerical Analysis.** Let $v = 8$, $s = 4$, $c = 5$, the market demand is normal distribution $N(400, 100^2)$, calculated, the critical point is $\beta = 0.123$. At this point, strategic consumers and myopic consumers expect the same profit.

(1) Suppose $\xi = 0.5$, analyze the relationship between the profit difference between the two pricing strategies and the proportion of short-sighted consumers β, as shown in Figure 1.

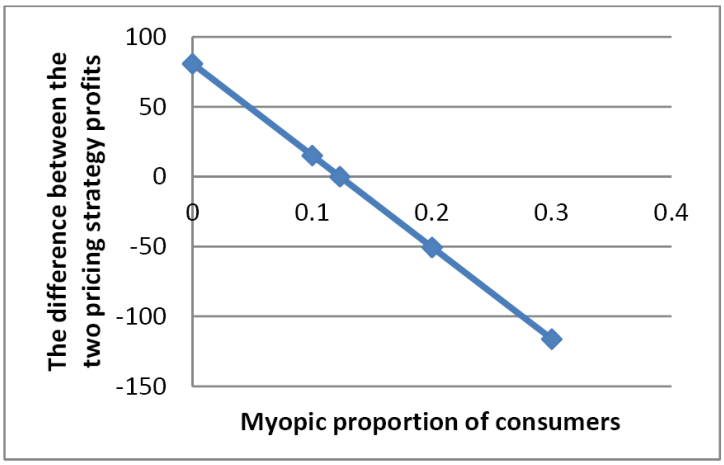

FIGURE 1. The difference between the profit of the two pricing strategies and the proportion of short-sighted consumers β

From the graph, when $\beta = 0.123$, the revenue of considering the return of strategic consumers is equal to considering only myopic consumers; when $\beta > 0.123$, $\Delta\pi < 0$, that means, as the short-sighted consumer increases, π_m increases faster than π_t, so retailers should take the pricing strategy that considers myopic consumers as the high price strategy; similarly, when $\beta < 0.123$, retailers should take the pricing strategy of strategic consumers, that is, the low-price strategy.

(2) The impact of strategic consumer risk perception on pricing strategy. Let $\xi = 0.1$, 0.3, 0.5, as shown in Figure 2.

As can be seen from the figure, when the proportion of myopic and strategic consumers is determined, the more optimistic strategic consumers are, the greater the influence of strategic consumers on retailer profits, so retailers should reduce their consideration of strategic consumers and adopt high-priced strategy; conversely, when there are more pessimistic strategic consumers, the majority of strategic consumers choose to buy commodities in the regular period, and taking the pricing decisions of strategic consumers into account will help to increase retailer's profits.

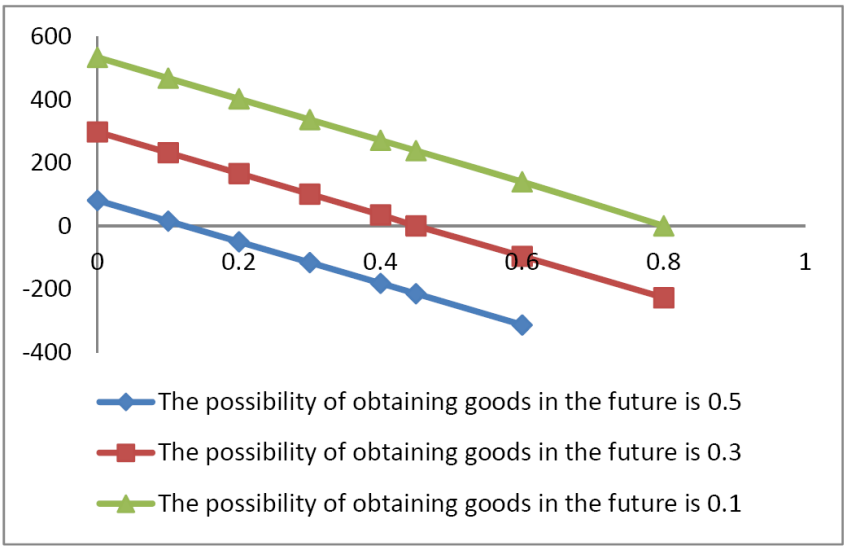

FIGURE 2. The difference between the profits of the two pricing strategies and the risk perception

6. **Conclusions.** In this paper, we study the pricing decision problem of a retailer with both strategic and myopic consumers, and that the strategic consumers have different risk perceptions. The main work and conclusions are as follows. (1) With the increasing proportion of myopic consumers, enterprises should take high pricing strategy. (2) When the market myopic and strategic consumers in a certain proportion, with optimistic consumers increased, the retailer should take high price strategy, that is to take account of the myopia consumers pricing strategy.

The existence of competitors and the interaction of purchasing behavior among different consumers will also affect pricing decisions. This paper does not take account of these factors, which will be the direction of future research.

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