# *Dynamic Pricing Considering Strategic Customers*

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***Abstract*— Dynamic pricing is increasingly applied to supply chain management and the key of successful application of dynamic pricing is to correctly understand consumer's behavior. In the face of a variety of dynamic pricing strategies, more and more consumers become smarter, and they forecast the future price before making a purchase decision. These types of consumers are called the strategic consumers, corresponding to the myopic consumers. In this paper, we study the dynamic pricing problem considering the strategic consumer behavior, and establish the game model between the retailer and consumers. First, we establish the dynamic pricing model of the retailer in the case of supply exceeding demand and demand exceeding supply. Second, we list the equilibrium conditions for the optimal dynamic pricing strategies, derive the optimal dynamic pricing strategies, and finally analyze the result with numerical simulation.**

***Keywords—strategic consumers ; dynamic pricing; game model; supply chain management***

## I. INTRODUCTION

As products market competition is increasingly fierce, in order to improve revenue, retailers are more and more pay attention to dynamic pricing strategy. However, consumers are more rational, they will compare prices at different stages, so as to decide whether to buy, when to buy. So strategic consumer behavior have a significant impact on revenue of retailers, drafting a valid dynamic pricing strategy considering consumers strategic has the vital significance to improve the retailer profits, and it is deserved to get concern of businesses and academics.

In reality, some large retailers have begun to focus on strategic consumer groups which are more and more huge, for example Best Buy, the electronics retailer, expressed great antipathy to such strategic customer behavior, saying customers who are patient to price promotions and discounts as "the devil", and those who act decisively as "angel" .this company has deliberately implemented a customer relationship management software in order to distinguish between "angel" and "devil"[1]. In addition to Best Buy, such as Bloomingdale's, Ann Taylor, Gap and Homepot et al, in response to consumers waiting strategy, they handle the sales of the final products through price optimization software. Spain's largest clothing retailer Zara takes advantage of lower inventory to force consumers to buy early [2].

In academia, since Coase put forward the differentiation of prices[3]. The dynamic pricing strategy problems considering consumer behavior has caused widespread concern of scholars. Literature can be divided into two categories.

### *A. The Research on The Impact of Strategy Consumer Behavior on Revenue or Design Mechanism to Reduce the Influence*

Su and Zhang On the basis of the newsboy model studied the effects of strategic consumers on supply chain performance. The results showed that: strategic consumer behavior enables retailers to reduce prices, inventories, and profits [4]. On the basis of the analysis of the impact, Cachon and Swinney proposed a rapid replenishment strategy to alleviate strategic consumer behavior[5], Aviv and Pazgal proposed price commitment strategy to deal with strategic consumer behavior [6], and Liu and Ryzin proposed the inventory constraint strategies to deal with strategic consumer behavior [7]. The above literatures are assumed that the market all are strategic consumers, and studied the impact of strategic consumers on retailers' revenue and gave policy to eliminate the impact, but the difference of this paper is that we consider that both strategic and myopic consumers exist at the same time, and analyze the proportion of strategic consumers in the market and the impact of strategic consumers behavior on retailers, and finally give the optimal equilibrium price.

### *B. The Research on Dynamic Pricing Considering Strategy Consumer Behavior*

The second type of literature study that when prices is decision variables , retailers adopt what kind of pricing strategy can allow retailers to obtain maximal profit considering strategic consumer behavior. Besanko and Winston[8]first introduced strategic consumer behavior into the study of the dynamic pricing, and studied trading behavior between customers and retailers from the angle of game research. Aviv and Pazgal put forward dynamic pricing problems based on strategic consumers and inventory constraint for the first time, considered the situation where Customers differ in their valuation or willingness to pay of the unit and analyzed the application of discount strategy based on inventory and fixed discount strategy in such a case [6]. Li Hao made a research on dynamic pricing of perishable goods considering strategic consumer behavior in a competitive environment, by means of dynamic optimization and game theory[9].Moorthy studied the two-stage game between strategic consumers and retailer, and it is concluded that pricing in the face of strategic consumers is lower than in the face of myopic consumer[11]. Li he extended

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the Besanko and Winston's research, found an equilibrium price range [12].

Compared with the above researches, we not only consider the situation where the consumers are all strategic consumers, but also the situation that is closer to the actual circumstances where consumers are the strategic consumers and myopic consumers; furthermore we focus on the demand that is certain, and then discussed various types of situation to derive dynamic pricing strategy of respective circumstances; we also take decreasing value of strategic customers into consideration.

## II. Model Descriptions And Assumptions

### A. Model Descriptions

In this section, we study a two-stage supply chain consisting of a monopoly retailer and consumers. Events occur in the following order:

He monopoly retailer sells Q units in a sales cycle. In the first stage of sales, the retailer forms belief $v^*$ over the customers' reserve price and makes price decisions $(p_1, p_2)$

When all consumers enter the market, strategic consumers observe sales prices, but they can not know the inventory of the second stage. They expect the probability of obtaining the product in the second stage, form the reserve price, and then decide whether to buy early, later, or never by comparing the reserve price $v^*$ and the prices $(p_1, p_2)$.

When the products are sold at the price $p_1$, the demand is fully or partially satisfied in the first stage. Over a period of time, the residual products are sold to the other consumers who don't buy products in the first stage at the price $p_2$ . This is a Stackelberg game between the retailer and customers.

### B. Model Assumptions

Based on the above descriptions, we make the following assumptions in order to study the dynamic pricing of strategic consumers:

The retailer has a fixed quantity $Q(Q > 0)$ of the product, and set price $(p_1, p_2) p_1 \geq p_2$to maximize revenue through the expectations of customer's reserve price $v^*$(the highest prices that customers are willing to pay)

A customer buys at most one unit of the product. Customers differ in their valuation or willingness to pay of the unit, and the valuations of potential customers in the market are uniformly distributed in $[0, b]$.this is captured by a downward sloping market demand function. Specifically, we assume a linear (inverse) demand function: $p = v - aq \left(\text{with } q \in \left[0, \frac{b}{a}\right], a, b > 0\right)$ where$q$ is the mass of the customers whose valuation is p or higher p and $\frac{b}{a}$ is the total number of potential consumers in the market

There are two types of consumers, the first type is the myopic consumers, and the proportion of it is$(1 - \theta)$; the second type is the strategic customers, and the proportion of it is$\theta$. The strategic customers expect the probability of obtaining the product in the second stage$\xi^*$.$\beta$ indicates decreasing value rate, and it is well known that customer valuation to a product changes with time. Generally, customer valuation to a product is high at the time of launching it and decreases gradually with time going on. For example, ipad 1 was sold at about 650 US dollars in January, 2010 in China. In March, 2011, Apple cut the price by 180 US dollars but it did not sell as well as they expected, which indicates that customers' value to it decreases much more[13].This article consider consumers' valuations.

Assume that All the aggregate-level information, such as a, b, and Q, is common knowledge, namely retailers and consumers have the same priority, while the individual customer's valuation of the product is privately known to her alone and the remaining inventory of the second stage is privately known to the retailer.

## III. The Model And Analysis

Sales process is a stackelberg game between the retailer and consumers, it is a two-stage sequential game where the retailer moves first by setting the prices$(p_1, p_2)$ and then customers follow by making their purchase decisions. The retailer's prices and each customer's purchase decision form the equilibrium of the game. Specifically, the equilibrium concept of the game is sub game-perfect equilibrium in the sense that one player's strategy constitutes a best response for every sub-game of the original game [10] this requires solving the game by backward induction.

### A. Supply Exceeds Demand

Total market demand is $\frac{b}{a}$, initial inventory is Q, and supply exceeds demand, namely,$Q \geq \frac{b}{a}$

Customers' decisions:

As for myopic consumers,

$v \geq p_1$, customers choose to buy in the first stage; the number of this type is as follows:

$$(1 - \theta)\frac{(b - p_1)}{a}$$

$p_1 \geq v \geq p_2$, consumers choose to buy in the second stage, the number of number this type is as follows:

$$(1 - \theta)\frac{(p_1 - p_2)}{a}$$

As for Strategic consumers,

Because $Q \geq \frac{b}{a}$, the probability of obtaining the product In the second stage $\xi = 1$ strategic consumers choose to wait, and buy in the second stage, the number of this type is as follows:

$$\frac{\theta(b - p_2)}{a}$$

The Retailer's decisions: the purpose of the Retailer's decisions (P1, P2) is to maximize revenue, and the retailer's revenue is as follows:

$$c(p_1, p_2) = p_1(1 - \theta)\frac{(b - p_1)}{a} + p_2\left[(1 - \theta)\frac{(p_1 - p_2)}{a} + \theta\frac{(b - p_2)}{a}\right]$$

We can obtain the optimal price by the first-order condition, and the optimal prices are as follows:

$$p_1 = \frac{b(2+\theta)}{(3+\theta)} \quad p_2 = \frac{b(1+\theta)}{(3+\theta)}$$

To have a sense that how the proportion of strategic consumers θ influents the retailer's revenue $c(p_1, p_2)$ and the optimal price $(p_1, p_2)$we analyze characteristic by numerical simulation as follows:

Let a=0.1, b=500, Q = 400

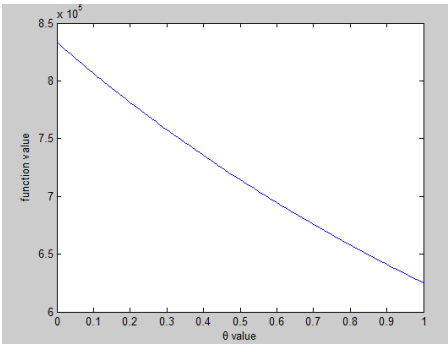


Fig. 1. The retailer's revenue changes with increasing θ

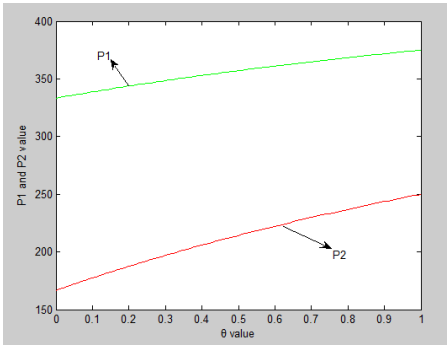


Fig. 2. The optimal prices changes with increasing θ

Conclusion: from Fig1, it's no hard to see that the retailer's revenue decreases with the increase of the proportion of strategic consumers; from Fig2, the optimal prices $(p_1, p_2)$ increase with the increasing proportion of strategic consumers. The above results indicate that strategic consumer behavior brings adverse effect to the retailer's revenue and have a significant impact on the pricing decisions

*B. Supply Exceeds Demand*

When supply exceeds demand, the influence of Strategic consumer behavior has been studied, When demand exceeds supply, we mainly derive the equilibrium conditions satisfied the optimal dynamic pricing strategies and discuss that how decreasing value rate influences the optimal decision and the maximum of the retailer's revenue, so we suppose θ=1, namely all consumers is strategic consumers in the market.

When Strategic consumers buy in the first stage, available surplus for them are as follows: $v^* - p_1$ When Strategic consumers buy in the second stage, available surplus are as follows: $\xi^* (\beta v - p_2)$

Proposition 1: For a given $\xi^*$, there is critical value$v^*$making consumers buy in the first stage when $v \geq v^*$, otherwise, consumers buy in the second stage

Proof:

Surplus in the first stage Equals Surplus in the second stage (namely, there is no difference between purchase of the first stage and purchase of the second stage):

$$v^* - p_1 = \xi^*(\beta v - p_2)$$

Rewriting the above equation, we have :

$$v^* - \xi^*(\beta v - p_2) = p_1 \quad (1)$$

$$v^* = \frac{p_1 - \xi^* p_2}{1 - \xi^* \beta} \qquad 0 \leq \xi^* \leq 1 \quad (2)$$

$$\xi^* = \frac{(v^* - p_1)}{(\beta v^* - p_2)} \quad (3)$$

Suppose$f(v) = v - \xi^*(\beta v - p_2)$, it's no hard to see that the $f(v)$ is a increasing function about $v$, so the critical value theorem is as follows:

$$v^* = \frac{p_1 - \xi^* p_2}{1 - \xi^* \beta}.$$

Case1: $Q \leq \frac{b - p_1}{a}$

Namely, total supply is less than demand in the first stage:

In this case, $\xi = 0$ strategic consumers choose to buy in the first stage; Retailers' revenue is as follows:

$$c(p_1) = p_1 \frac{(b - p_1)}{a}$$

We can obtain the optimal price by the first-order condition.

The optimal price is $p_1 = \frac{b}{2}$ and Corresponding retailers' revenue is $c\ (p_1) = \frac{b^2}{4a}$

Conclusion: it can be seen from the above analysis, In this case, retailers as long as set a optimal price p1,When the initial inventory is less, retailers can nearly ignore strategic consumer behavior, the optimal pricing decision is to achieve the maximum of the revenue of a single stage..

Case2:$\frac{b - p_2}{a} \geq Q \geq \frac{b - p_1}{a}$

Namely demand is met in the first stage, and demand is less than the supply in the second stage:

$b \geq v \geq v^*$ Strategic consumers buy the product in the first stage, the number of this type is$\frac{b - p_1}{a}$

$v^* \geq v \geq p_2$, strategic consumers buy in the second stage, the number of this type is$\frac{v^*-p_2}{a}$, and the probability of obtaining the product in the second stage is as follows:

$$\xi = \frac{Q-\left(\frac{b-v^*}{a}\right)}{\frac{v^*-p_2}{a}} \quad (4)$$

According to the theory of rational expectations equilibrium, when achieving equilibrium, the exception of the probability of obtaining products in the second stage$\xi^*$ is equal to the actual probability of obtaining products with price p2 in the second stage$\xi$,namely,

$$\frac{Q-\left(\frac{b-v^*}{a}\right)}{\frac{v^*-p_2}{a}} = \frac{v^*-p_1}{\beta v^*-p_2} \quad (5)$$

Based on the above analysis, we can derive the retailer's revenue function is as follows:

$c(p_1,p_2) = p_1\left(\frac{b-v^*}{a}\right) + p_2\left[Q-\left(\frac{b-v^*}{a}\right)\right]$ ( $v^*$ Obtained by the equation (5))

We can derive game equilibrium by backward induction, and the optimal price strategy (p1, p2) meet the following condition:

$$(p_1,p_2) = argc(p_1,p_2)$$

$$\text{st:} \quad b \geq p_1 \geq b - aQ \geq P_2 \geq 0$$

Conclusion: when the initial inventory is relatively more, strategic consumers form rational expectations of the probability of obtaining the product in the second stage. The retailers set a higher price in the first stage, and set relatively lower prices in the second stage. Under the condition of the rational expectations equilibrium, the total revenue is maximal.

Case3: $\frac{b}{a} \geq Q \geq \frac{b-p_2}{a}$

Namely Strategic consumers' need is satisfied:

$b \geq v \geq v^*$ , Strategic consumers buy the product in the first stage, the number of this type is $\frac{b-p_1}{a}$

$v^* \geq v \geq p_2$, strategic consumers buy in the second stage, the number of this type is $\frac{v^*-p_2}{a}$, the probability of obtaining the product in the second stage $\xi = 1$ the corresponding critical value is as follows:

$$v^* = \frac{p_1-p_2}{1-\beta}$$

Based on the above analysis, we can get profit function for retailers:

$$c(p_1-p_2) = p_1\left(\frac{b-v^*}{a}\right) + p_2\left(\frac{v^*-p_2}{a}\right)$$

We can obtain the optimal prices by the first-order condition, and the optimal prices are follows:

$$p_1 = \left(1-\frac{\beta}{2}\right)b \qquad p_2 = \frac{b}{2}$$

Corresponding retailer's revenue is as follows:

$$\frac{(1-\beta)\left(1-\frac{\beta}{2}\right)}{2a}b^2$$

Conclusion: the price of the first stage decreases with decreasing value rate β, decreasing value rate β reveal consumers' willingness to wait, the bigger β, the greater the willingness to wait. If the consumers' valuation diminishes slowly, the consumer surplus is greater in the second stage, the patience of waiting for lower prices is greater, and retailer's revenue decreases .This conclusion can help retailers to accurately grasp the strategic consumer behavior, and provide direction of eliminating strategic consumer behavior.

## IV. CONCLUSION

We derived the equilibrium conditions for the optimal dynamic pricing strategies by establishing a game model between retailers and consumers, and drew the following conclusion through the numerical simulation:

When supply exceeds demand, the retailer's revenue decreases with the increase of the proportion of strategic consumers, and the optimal prices $(p_1,p_2)$ increase with the increase of the proportion of strategic consumers.

When demand exceeds supply:

Case1: when the initial inventory is less, the retailer can nearly ignore strategic consumer behavior; the optimal pricing decisions are to achieve the maximum of the revenue of a single stage.

Case2: when the initial inventory is relatively more, strategic consumers form rational expectations of the probability of obtaining the product in the second stage. Retailers set a higher price in the first stage, and set relatively lower prices in the second stage, under the condition of the rational expectation equilibrium, the revenue is maximal.

Case3: when the initial inventory is sufficient, as decreasing value rate increases, the retailer's revenue decreases. In order to eliminate strategic waiting behavior of consumers, the retailer should set relatively lower price of the first stage to eliminate strategic waiting behavior of consumers.

We studied Demand in detail when demand is certain, in practice, the demand may be random, so further research can focus on the situation where demand is random; There are many factors influencing the strategic consumer behavior, we mainly consider that the consumers' valuations are heterogeneous that decrease over the sales cycle, so further research can focus on other factors, such as: risk preference.

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