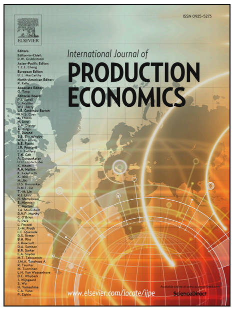


Pricing commitment versus most-favored-customer protection with disappointment aversion strategic customers

Ying Zhang, Juliang Zhang

PII: S0925-5273(17)30160-3

DOI: 10.1016/j.ijpe.2017.05.015

Reference: PROECO 6721

To appear in: *International Journal of Production Economics*

Received Date: 30 September 2015

Accepted Date: 30 May 2017

Pricing Commitment versus Most-favored-customer Protection with Disappointment Aversion Strategic Customers

Ying Zhang, Juliang Zhang[1]

Department of Logistics Management,
School of Economics and Management,
Beijing Jiaotong University, Beijing 100044, P. R. China

Ying Zhang, email: 13120614@bjtu.edu.cn
Juliang Zhang, email: zhangjl@bjtu.edu.cn Tel: 8610-51685062

Acknowledgements

This work was supported in part by the National Natural Science Foundation of China (Grant Nos. 71390334 and 71132008) and the Program for New Century Excellent Talents in University (NCET-13-0660).

[1] Corresponding author, email: zhangjl@bjtu.edu.cn

Strategic Customer Behavior with Disappointment Aversion Customers and Two Alleviation Policies

Ying Zhang, Juliang Zhang[1]

Department of Logistics Management,
School of Economics and Management,
Beijing Jiaotong University, Beijing 100044, China

Abstract: In this paper, we study the impact of strategic customers' disappointment aversion and decreasing valuation on strategic customer behavior and the effectiveness of two alleviation policies: pricing commitment and most-favored-customer protection. Consider a two-period model in which a seller makes the decisions of order quantity and sale price at the beginning of the first period. Customers will pay full price if they buy the product in the first period and the discounted price if they buy the product in the second period but their valuation decrease. However, the customers might not get the product when they decide to buy the product in the second period. Customers who can't get the product in the second period will feel disappointed. We show that strategic customers will decrease the order quantity, price and total profit. Furthermore, we study the effect of the price commitment policy to alleviate the strategic customer behavior, and identify the conditions under which the policy is effective. In addition, we compare the performance of the price commitment policy with that of the most-favored-customer protection policy and show that the latter is more beneficial to the seller. But both the two policies can't eliminate fully the strategic customer behavior.

Keywords: price commitment policy; most-favored-customer protection policy; strategic customers; disappointment aversion

[1] Corresponding author, Tel. 8610-51685062, email: zhangjl@bjtu.edu.cn
Address: Department of Logistics Management, School of Economics and Management, Beijing Jiaotong University, Beijing 100044, China

1. Introduction

In September 2010, iPhone 4 was out of stock after it was launched in China. At that time, "holding iPhone 4" was a fashion symbol and a great number of customers wanted to get it. Owning iPhone could bring customers psychological satisfaction, and many customers were disappointed because they could not get the mobile phone. Similar phenomenon can be seen in other fashion products including electronic products, clothing, etc.. With the rapid development of economy, people's living standard and consumption level are becoming higher and higher. More and more customers' purposes to buy some goods are not only to meet their basic physical needs but also to pursue their psychological satisfaction of owning these fashion products. These fashion-pursuing customers will be disappointed when they can't get the fashion product they want after the sale period.

Strategic customers can choose either to purchase the product in the regular sale period at the full price or to wait to buy the product at a discount price. If they buy the product in the regular sale period, their desire of owning the fashion product can be fulfilled, but with a higher cost. Otherwise, if they choose to wait to buy the product at the discount price in the clearance period, they will face uncertainty in the availability of the product and their desire cannot be fulfilled. They will be disappointed if they fail to get the product after the clearance period.

Generally, customers have a rational expectation on the economic outcomes when they make their decisions. But the real outcome is often inconsistent with the expectation because of uncertain environments. If the real outcome is below their expectation, disappointment will arise. Otherwise, elation will occur. The larger the gap between their expectation and the real outcome is, the stronger they will be disappointed or elated. This psychological disappointment or elation will make customers' economic utility decrease or increase in economic activities. Kahneman and Tversky (1979) showed that people tend to be disappointment aversion. How do sellers make the decisions on sale price and order quantity to maximize their profits facing such disappointment averse customers? What is the impact of customers' disappointment aversion on the strategic behavior? We shall study these problems.

In addition, the valuation of the customers to the product is not immutable, but gradually decreasing. For example, iPhone5s's price decreased from original 5300 yuan to 4100 yuan and the sale decreased also when iPhone6 was launched in China in October 2014. Lower valuation means that customers are not willing to pay more to the product, which forces sellers to set lower price. In this paper, we also consider customers' decreasing valuation.

It is well-known theoretically and practically that strategic customer behavior has negative impact on sellers. In order to alleviate such effect, many policies are adopted practically and analyzed theoretically, e.g., most-favored-customer protection policy (Png (1991)), price segmentation (Elmaghraby et al.(2008)), price commitment (Aviv and Pazgal (2008)), quantity commitment (Liu and van Ryzn (2008)) and capacity rationing (Liu and Van Ryzin(2008), Gallego and Sahin (2008), Liu and Shum (2013)), to name a few. Strategic customers' waiting behavior is mainly due to the price gap between the regular sale period and the clearance period. So, it is generally believed that the strategic customer behavior will be alleviated if a seller can promise a credible sale price until the end of the sale circle. This is the price commitment policy, which is used commonly in clothing industry. For example, Zara tends to use "fixed price" and "no negotiation" labels to mark some products at the regular sale period, which give customers the information that these products won't be discounted. However, the price commitment policy is difficult to be implemented in practice, because it requires for great reputation to make customers to believe that the seller's commitment is credible. Because of this, some sellers would prefer to the most-favored-customer protection policy, which means that customers can obtain price difference compensation from the sellers if the price decreases in a given time. In this paper, we study whether the price commitment policy can really alleviate the strategic customer behavior, and which policy can bring more profitable to the vendor, the price commitment policy or the most-favored-customer protection policy.

2. Literature Review

With the continuous development of market economy, the strategic customer behavior gets more and more attention from the industry and academic. A large number of scholars focus on how to ease the strategic customers' negative influence. Aviv (2009) pointed out that the profit obtaining from the dynamic price will be offset by the strategic customer behavior, nearly 20% profit will be lost if customers' strategic behavior cannot be well-considered. In fact, as early as in 1972, in the study of monopolistic pricing problem of durable goods, Coase suggested the price segmentation policy, that is, selling products to customers with high valuation at a high price, and to customers with low valuation at a low price, to alleviate the strategic customers' negative effect. Su and Zhang (2008) introduced rational expectation equilibrium hypothesis and the strategic customer behavior to the newsvendor model, and studied the seller's optimal pricing and inventory decisions. Liu and Van Ryzin (2008) generalized their model to the case with risk aversion customers and studied the effect of capacity rationing on the mitigation of strategic customers' behavior. Cachon and Swinney (2011) analyzed the value of the enhanced design and quick response under the strategic customer behavior and concluded the complementarity between enhanced design and quick response. The above researches assume invariable customers' valuation. Aviv and Pazgal (2008) showed that pre-announced fixed-discount strategies outperforms inventory contingent discounting strategies facing the strategic customers with decreasing customers' valuation. Cachon and Swinney (2009) studied the optimal dynamic pricing policy under quick response considering customers in the market including myopic customers, strategic customers and bargain-hunting customers, and each type of customers' value for the product being different in the two periods. Du, Zhang and Hua (2015) studied the single-period joint decision problem on inventory and pricing considering strategic customers with risk preference and decreasing valuation. All of the above researches do not consider the customers' disappointment aversion when they can't get the product after the second clearance period.

There are a lot of economic and decision literature studying decision-making psychologies and behaviors. Bell (1985), Loomes and Sugden (1986), Delquie and Cillo (2006), Koszegi and Rabin (2007) studied theoretic models for disappointment aversion. Loomes and Sugden (1987) and Sonsino (2008) studied disappointment aversion problem using experiments under different environments. However, there are few studies considering customers' disappointment aversion in operations management. Nasiry and Popescu (2012) studied how regret influences customers' purchase behavior, as well as the seller's optimal pricing policy under the background of advance selling from the perspective of marketing. Liu and Shum (2013) first studied the joint decision on pricing and inventory management assuming disappointment aversion strategic customers. These two papers assume customers' constant valuation and do not consider customers' valuation decreasing. Also they do not study the alleviation effects of the most-favored-customer protection policy and the price commitment policy on the strategic customer behavior. Inspired by Liu and Shum (2013), we studied the impact of strategic customers' disappointment aversion and decreasing valuation on the strategic customer behavior, and compares the effects of the price commitment policy and the most-favored-customer protection policy on alleviating the strategic customer behavior in this paper.

In this paper, we study the joint decision problem on the pricing and order quantity considering disappointment aversion strategic customers with decreasing valuation. We first study how strategic customers' disappointment aversion and decreasing valuation affect the order quantity, the sale price and the total profit. We show that strategic customers will decrease the order quantity, the price and the total profit. We also study the impacts of the disappointment aversion level and valuation decreasing rate on the optimal order quantity, the sale price and the profit. We further study the effect of the price commitment policy to alleviate the strategic customer behavior, and find that the policy is effective only when the cost is low and the disappointment aversion is low, or the customers' valuation is high and the disappointment aversion is low. In addition, we compare the performance of the price commitment policy with that of the most-favored-customer protection policy on the alleviation of the strategic customer behavior and show that the most-favored-customer protection policy is more beneficial to the seller. But these two policies can't eliminate fully the strategic customer behavior.

3. Impact of Strategic Customers

In this section, we will state the problem setting and mathematical model and study the impact of disappointment aversion level and valuation decreasing rate on the optimal price, the order quantity and the seller's profit.

3.1 Basic Model

Consider a monopoly market in which a seller will determine how much to order and what the sale price is facing random demand X. Let the distribution and density functions of the demand X be $F(x)$ and $f(x)$, respectively. The product will be sold in two periods: the first one is the regular sale period and the second one is the clearance sale period. In the first period, the seller determines the full sale price p and the order quantity Q based on the priori belief ξ_r over the customers' reservation prices. The unsold products in the first period will be sold in the second period with salvage price, s (here we assume constant salvage value based on the analysis of Aviv and Pazgal (2008)). Customers observe the sale price but not the stocking quantity. So they don't know the probability of getting the product in the second period. Let ξ_{prob} be the priori belief of this probability. Let v be the customers' valuation in the first period. However, when customers buy the product in the second period, their valuation decreases to αv $(0<\alpha<1)$. The valuation decreasing rate α depends on the nature of the product itself and the customers' loyalty to the product (see Aviv and Pazgal (2008), Cachon and Swinney (2011)). Let the unit production cost be c ($s<c$). Strategic customers can choose either to purchase in the first period at the full price p or to wait for the salvage price s in the second period. But customers who decide to buy in the second period may fail to get the product and will be disappointed. Let r be customers' reservation price, which depends on the belief on the valuation, the disappointment aversion degree and the probability of getting the product in the second period.

We adopt the model in Liu and Shum (2013) to describe the disappointment aversion on customer utility, which is a simple model of psychological disappointment and elation proposed by Bell (1985). In Liu and Shum (2013), a general two-outcome model is proposed as follows:

$$U=\begin{cases} u_1+e(u_1-\mu) & \text{with probability } \phi, \\ u_2-d(\mu-u_2) & \text{with probability } 1\text{-}\ \phi. \end{cases}$$

where $e\geq 0$ is the customer's elation effect and $d\geq 0$ is the customer's disappointment effect. Suppose that a customer can earn either a payoff of u_1 with probability ϕ or a payoff of u_2 with probability $1-\phi$, where $u_1>u_2$. Her expected payoff is $\mu=\phi u_1+(1-\phi)u_2$. Then the gap between μ and u_2 causes the customer's disappointment if she gets u_2 and the gap between μ and u_1 causes the customer's elation if she gets u_1 (Bell (1985)). Define $k=d-e$ to be disappointment aversion level, which represents the difference in the degree to which disappointment and elation affect the utility. Therefore, the customer's total expected utility is

$$U=\phi u_1+(1-\phi)u_2-\phi(1-\phi)k(u_1-u_2)\,. \tag{1}$$

When $k=0$, the customer is risk neutral; when $k>0$, the customer is disappointment aversion; when $k<0$, the customer is elation pursuing.

Suppose that customers are homogeneous and their decision tree is depicted as follows:

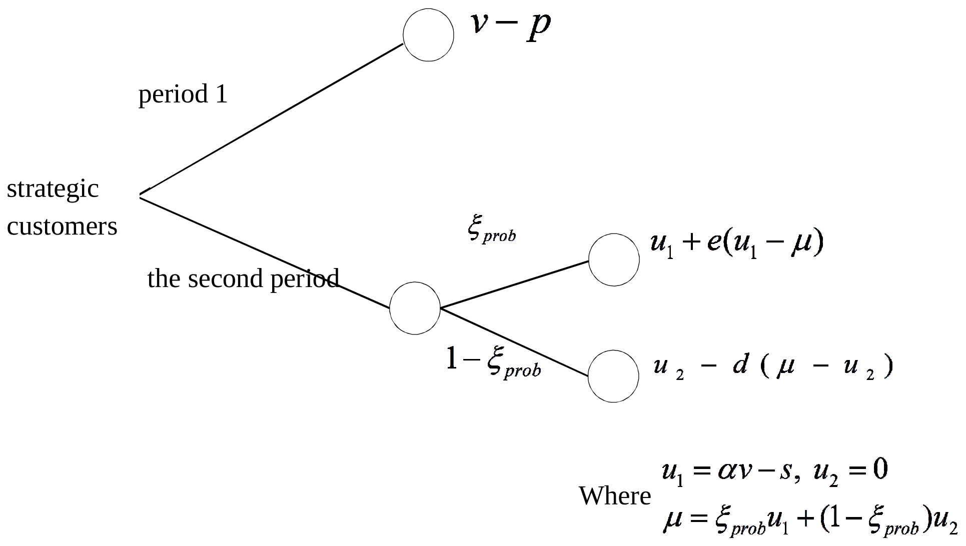


Figure 1. Decision tree of strategic customers

For a customer with valuation v and disappointment aversion level k, it follows from Figure 1 that the expected total utility if he/she chooses to wait to buy in the second period is $\xi_{prob}\left(1-k+k\xi_{prob}\right)\left(\alpha v-s\right)$. Customers' objective is to make the purchase decision to maximize their utility, that is, $\max\left\{v-p,\xi_{prob}\left(1-k+k\xi_{prob}\right)\left(\alpha v-s\right)\right\}$. We assume $\alpha v>s$ and $k<\frac{1}{1-\xi_{prob}}$ to rule out the trivial cases because nobody will buy in the second period if $\alpha v\le s$ or $k\ge\frac{1}{1-\xi_{prob}}$. Also we assume that customers are disappointment aversion, $k>0$. Obviously, customers will purchase in the first period rather than to buy in the second period if $v-p>\xi_{prob}\left(1-k+k\xi_{prob}\right)\left(\alpha v-s\right)$. Hence customers' reservation price r satisfies the following equation

$$v-r=\xi_{prob}\left(1-k+k\xi_{prob}\right)\left(\alpha v-s\right). \tag{2}$$

The seller needs to decide the order quantity Q and the full sale price p to maximize his profit $\Pi_s(Q,p)$, where

$$\begin{aligned}\Pi_s(Q,p)&=pE(X\wedge Q)+s(Q-E(X\wedge Q))-cQ\\&=(p-s)E(X\wedge Q)-(c-s)Q\end{aligned}. \tag{3}$$

It's easy to show that $\Pi_s(Q,p)$ is concave with respect to Q for a given price p. So the optimal order quantity Q_s can be determined by solving the equation $\frac{\partial\Pi_s(Q,p_s)}{\partial Q}=0$, i.e.,

$$\overline{F}(Q_s)=\frac{c-s}{p_s-s} \tag{4}$$

It is easy to see that the seller will set the price $p_s=\xi_r$ to maximize his profit if he know that the seller's anticipation of the customer reserve price is ξ_r.

In the subsequent, we use the concept of the Rational Expectations Equilibrium (RE Equilibrium) for further analysis. RE Equilibrium means that economic outcomes do not differ systematically from what people expect them to be. It is first proposed by Muth (1961) and applied by Su and Zhang (2008) to study the strategic customer behavior. From RE Equilibrium, the seller can predict customers' reserve price and customers can predict the availability in the second period. So we have $\xi_r = r$ and $\xi_{prob} = F(Q)$. Furthermore, we can get $p_s = \xi_r = r$. Then we have from (2) that

$$p_s = v - F(Q_s)\left(1-k+kF(Q_s)\right)\left(\alpha v - s\right). \tag{5}$$

Su (2008) obtained similar results assuming that $k=0$ and $\alpha=1$. We extend his results to the case with disappointment aversion and decreasing valuation.

3.2 Basic Analysis

In this section, we study the impact of strategic customers on the seller's optimal decisions and profit comparing with the classical newsvendor problem.

In the classical newsboy problem, all customers are myopic and their value is v . Hence, they'll purchase in the first period if $v-p \ge 0$. So the seller will set the price $p_t = v$ and the order quantity $\overline{F}(Q_t) = \dfrac{c-s}{v-s}$.

Proposition 1. $Q_s < Q_t$, $p_s < p_t$ and $\Pi_s^* < \Pi_t^*$.

Proof. We put all of the proofs in the Appendix.

Proposition 1 shows that strategic customers' behavior will decrease optimal order quantity, price and profit comparing with the classical newsvendor model. This is called the strategic customer behavior. The reason is that the discounted price in the second period is low and strategic customers can predict the price and make their purchase decisions to maximize their utility. If the full price is high and the quantity is large in the first period, strategic customers will postpone their purchases to the second period because their utilities resulting from purchasing in the second period will be large and their utilities resulting from purchasing in the first period will be small. This will result in large loss of the seller's profit. To force strategic customers to buy early, the seller will have to set a lower price and order less in the first period. This will result in low profit. Though customers' disappointment aversion will induce customers to buy early because customers worry about failing to get the product, it still can't eliminate fully the influence of the strategic customer behavior. Liu and van Ryzin (2008) and Su and Zhang (2008) got the same results without considering customers' disappointment aversion and decreasing valuation. Proposition 1 extends their results to consider the customers' disappointment aversion and decreasing valuation.

Proposition 2 shows how customers' disappointment aversion level and valuation decreasing rate affect the seller's decisions and profit.

Proposition 2. (1) *For a given* α *, the seller's optimal order quantity* Q_s *, the sales price* p_s *and the expected profit* Π_s^* *increase in* k *;*

(2) *For a given* k *, the seller's optimal order quantity* Q_s *, the optimal price* p_s *and the optimal profit* Π_s^* *decrease in* α *.*

Proposition 2 shows that when customers' disappointment aversion level is fixed, the slower the product valuation decreases, the less the seller should order, the lower the optimal full price should be and the smaller the profit will be. This is counter-intuition. Intuitively, the seller can get more profit if customers' valuation decreases slowly because the sale period will be long. Our results hold because customers with less valuation decreasing rate will be more patient to wait for discount since they can get more surpluses when they buy product in the second period with a lower price. Under this situation, the seller has to decrease sales price and order quantity to force them to buy in the first period, which results in the seller's lower profit. When customers' valuation decreasing rate is fixed, the higher the customers' disappointment aversion level is, the more the seller should order, the higher the optimal regular price should be and the greater the profit will be. This is intuitive. Because high customers' disappointment aversion level means customers' high desire for the product. This will lead to higher customers' reservation price in the first period. In other words, customers are very reluctant to face the risk of selling out and more inclined to buy the product in the regular sale period. Thus the seller can set a higher full price and order more to obtain more profit. This can also explain why some firms, e.g., Apple, adopt "hunger marketing" and intentionally announce that their production capacities are insufficient and their products will be out of stock, which can decrease the attainability in late periods and tempt disappointment aversion customers to buy early.

4. Policies for Alleviating Strategic Customer Behavior

4.1 The Price Commitment Policy

The price commitment policy is widely used to alleviate the negative effect of the strategic customer behavior in reality. For instance, Zara, one of the largest Spanish fashion sellers, is well known for using "one-price" or "no-haggle" policy to induce customers to pay the regular sale prices. In this subsection, we study the validity of the price commitment policy to alleviate the strategic customer behavior. To simplify the analysis, we consider only the case with constant customer value, which means $\alpha = 1$, in the basic model. Suppose that the seller sets a price p_p and promises that she never markdowns. If this promise is credible, customers would be willing to pay v in the first period and no one will buy in the second period. Therefore, under the price commitment policy, the model can be rewritten as below.

The seller's optimal full price is $p_p = v$

The seller's profit function is $\prod_p(Q) = vE(X \wedge Q) - cQ = (v-c)Q - v\int_0^Q F(x)dx$

The seller's optimal order quantity is $Q_p = \arg\max_Q \prod_p(Q) = F^{-1}(\frac{v-c}{v})$

In order to study the effect of the price commitment policy, we assume that the distribution $F(x)$ has increasing failure rate, i.e., $\frac{f(x)}{1-F(x)}$ increases in x. The commonly used distributions, e.g., the uniform, the exponential, the reflected exponential, the Erlang, the normal, and the truncated normal, satisfy the assumption (Su and Zhang (2008)).

Proposition 3 shows the effect of the price commitment policy on the alleviation of the strategic customer behavior.

Proposition 3. *Under the price commitment policy, for any given* v *and* s, *there exit* c_l, c_h $(c_l < c_h)$ *and* $\bar{k}$ *such that* $\prod_p^* > \prod_s^*$ *if* $c < c_l$ *and* $k < \bar{k}$, *and* $\prod_p^* < \prod_s^*$ *if* $c > c_h$ *or* $k > \bar{k}$.

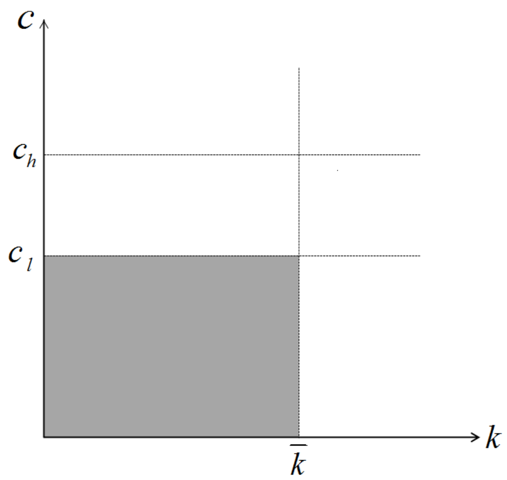


Figure 2. Conditions that the price commitment policy is effective

Proposition 3 means that the price commitment policy can alleviate the strategic customer behavior under some conditions. The seller can use the price commitment policy to induce customers to purchase early when the production cost and customers' disappointment aversion level are relatively low. Then strategic customer behavior can be alleviated. Otherwise, this policy has no effect on the strategic customer behavior. In other words, for fashion production with high production cost or high customers' disappointment aversion, this policy can't mitigate the strategic customer behavior. For example, facing customers who desire iPhone strongly, Apple never uses the price commitment policy. The reason is as follows: although the price commitment policy can attract some strategic customers to buy early, it is essentially equivalent to a newsvendor problem with lost unsatisfied customers and zero salvage if the policy is credible since there is no one buying in the second period. The price commitment policy is beneficial to the seller only when there are many customers buying in the first period and there is small loss resulting from not to sell in the second period. The policy can attract sufficiently many customers to buy early only when customers' disappointment aversion is low, and the profit loss resulting from not to sell in the second period is sufficiently small only when the production cost is low. Hence the price commitment policy can bring larger profit only when these two conditions hold. Su (2008) showed that the price commitment policy has some effect when production cost is low. Proposition 3 generalizes his results to the case with customers' disappointment aversion. Figure 2 depicts the conditions under which the price commitment policy can alleviate the strategic customer behavior.

Similar to Proposition 3, we have the following proposition.

Proposition 4. *Under the price commitment policy, for any given* c *and* s*, there exist* v_l, v_h $(v_l < v_h)$ *and* $\bar{k}$ *such that* $\prod_p^* > \prod_s^*$ *if* $v > v_h$ *and* $k < \bar{k}$*, and* $\prod_p^* < \prod_s^*$ *if* $v < v_l$ *or* $k > \bar{k}$.

Proposition 4 implies that when the customers' valuation is relatively high and their disappointment aversion level is relatively low, it is beneficial for the seller to use the price commitment policy. However, this policy will decrease the seller's profit otherwise. The reason is that when customers' valuation is high and disappointment aversion level is low, the price commitment policy can attract more customers to buy early, which can result in more profit than the profit loss resulting from not to sell in the second profit. In this case, the policy is beneficial to the seller. Su (2008) stated that the price commitment policy is valid under high customers' valuation. Propositions 4 shows that whether the price commitment policy is beneficial to the seller depends on not only customers' high valuation but also low customers' disappointment aversion level. Figure 3 depicts the conditions.

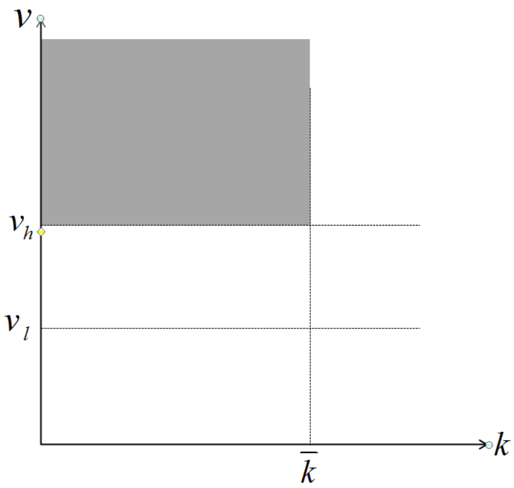


Figure 3. Conditions that the price commitment policy is effective

Now we compare the performance of the price commitment policy with that of the classical newsvendor model.

Proposition 5. *The price commitment policy can't fully eliminate the influence of strategic customer behavior. i.e.,* $\Pi_p^* \le \Pi_t^*$.

From Propositions 3 and 4, we know that the price commitment policy can alleviate the strategic customer behavior and bring more profit to the seller under some conditions. However, it cannot completely eliminate the strategic customer behavior comparing with the classical newsvendor model. The reason is that the price commitment policy is essentially equivalent to the newsvendor problem with zero salvage but the classical newsvendor problem has nonzero salvage for excess inventory. Then the order quantity under the price commitment policy is less than that in the classical newsvendor problem. Hence the profit under the policy is less than that in the classical newsvendor problem.

As pointed out by Su and Zhang (2008), sellers using the price commitment policy should have a good reputation. Otherwise, customers will question the sellers without mechanism to ensure them to keep their promise. In order to avoid this difficulty, many sellers choose the most-favored-customer protection policy. But, which policy is more effective, the price commitment policy or the most-favored-customer protection policy? In the next subsection, we shall compare the performance of these two policies.

4.2 Comparing with the Most-favored-customer Protection Policy

Under the most-favored-customer protection policy, the customers' expected utility is $v-p+(p-s)\xi_{prob}$ when they purchase in the first period at the regular price, is $\xi_{prob}\left(1-k+k\xi_{prob}\right)(\alpha v-s)$ when they wait to buy in the second period. A customer will purchase in the first period rather than to wait to buy in the second period if the former gives her a higher expected utility than the latter; that is $v-p+(p-s)\xi_{prob} \ge \xi_{prob}\left(1-k+k\xi_{prob}\right)(\alpha v-s)$. Then customers will buy the product in the first period when p_m satisfies $p_m \le \frac{1-\alpha\xi_{prob}}{1-\xi_{prob}}v+k\xi_{prob}(\alpha v-s)$. Meanwhile, the customers' expected utility must be positive when they purchase in the first period, that is $v-p \ge 0$. Note that $\frac{1-\alpha\xi_{prob}}{1-\xi_{prob}}v+k\xi_{prob}(\alpha v-s) > v$, the customers' reserve price in the first period is

$$p_m = v \tag{6}$$

Under the most-favored-customer protection policy, the seller will sell the product at a discount in the second period if and only if the realized demand in the first period, X, is very small comparing to the seller's inventory, Q. That is, the profit earned in the second period through discounting is more than the refund to the customers bought in the first period, i.e., $s(Q-X) \geq (p-s)X$. So, customers who choose to wait to buy in the second period will have the probability $F\left(\frac{sQ}{p}\right)$ to obtain the product.

According to RE Equilibrium, the probability of obtaining the product in the second period the customers believe is $\xi_{prob} = F(\frac{sQ}{p})$. So the seller's profit function is

$$\Pi_m\left(Q, p_m\right) = s\int_0^{\frac{sQ}{p_m}} Qf\left(x\right)dx + p_m\int_{\frac{sQ}{p_m}}^{Q} xf\left(x\right)dx + p_m\int_Q^{+\infty} Qf\left(x\right)dx - cQ\,. \tag{7}$$

Proposition 6. $p_m = p_p$ *and* $\Pi_m^* > \Pi_p^*$. *That is, the most-favored-customer protection policy can bring more benefit to the seller than the price commitment policy.*

From Proposition 6, we can see that the seller can get more profit by using the most-favored-customer protection policy than the price commitment policy when customers are disappointment aversion. The reason is that the seller has the choice of selling the product at a discounted price in the second period under the most-favored-customer protection policy while she can only sell the product in the first period under the price commitment policy. Then the seller can order more and get higher profit under the most-favored-customer protection policy. As pointed out by Su and Zhang (2008), it is more difficult to implement the price commitment policy. Hence the seller should adopt the most-favored-customer protection policy rather than the price commitment policy when she faces disappointment aversion strategic customers.

Proposition 7. *The most-favored-customer protection policy can't fully eliminate the influence of the strategic customer behavior. i.e.,* $\Pi_m^* \leq \Pi_t^*$.

Although the most-favored-customer protection policy performs better than the price commitment policy, it cannot fully eliminate the influence of the strategic customer behavior either. The reason is that if the seller sells the product in the second period under the most-favored-customer protection policy, she will have to refund the customers bought in the first period. However, in the classical newsvendor problem, the seller can sell the product in the second period but has no refund. That is why the seller can get more profit in the classical newsvendor problem.

Png (1991) compared the performance of the most-favored-customer protection with that of the price discrimination by using a two-period selling model and concluded that the most-favored-customer protection policy is more beneficial when capacity is large and the price discrimination should be chosen when customers are more uncertain about the degree of excess demand in the first period. Here we show that the most-favored-customer protection policy is more beneficial than the price commitment policy when the seller faces disappointment aversion strategic customers.

5. Conclusion

The strategic customer behavior is affected by complex psychological factors. Customers' psychological satisfaction tends to affect their economic utility and therefore influences their purchasing decisions. Generally speaking, fashion-pursuing customers will feel disappointed if they can't obtain the product their wanted after the clearance period and this kind of disappointment is generally averse for most customers. In this paper, we analyze the impacts of disappointment aversion level and customers' valuation decreasing rate on the decisions of pricing and order quantity based on the newsvendor model. We show that the strategic customer behavior can cause adverse effect to the seller's profit, and the smaller the customers' disappointment aversion level is, or the more slowly the customers' valuation decreases, the more the profit will lose caused by the strategic customer behavior. Furthermore, we investigate the effect of the price commitment policy, which used extensively in reality, on the alleviation of the strategic customer behavior. We show that the price commitment policy is not always effective and identify the conditions under which the policy is effective. Moreover, we compare the performance of the price commitment policy with that of the most-favored customer protection policy and show that the most-favored customer protection policy can bring more profit to the seller. Comparing with the classical newsboy problem, these two policies can't eliminate fully the strategic customer behavior.

In this paper, we assume that all customers in the market are homogeneous and with disappointment aversion ($k>0$). Generalizing the results in this paper to the case with heterogeneous customers and/or elation pursuing customers is an interesting research topic. For example, under customer disappointment aversion, the most-favored-customer protection policy is more beneficial to sellers than the price commitment policy. For the case with elation pursuing ($k<0$), which is better? We need to study further. In addition, our study is based on the classical newsvendor model, which is a single period model. Extending the research to the setting with multi-period is also needed to study further.

Acknowledgements. This work was supported in part by the National Natural Science Foundation of China (grant numbers 71390334 and 71661167009) and Beijing Logistics Informatics Research Base.

Reference

[1] Aviv, Y., A. Pazgal. 2008. Optimal pricing of seasonal products in the presence of forward-looking consumers. *Manufacturing & Service Operations Management*, 10(3): 339-359.

[2] Aviv, Y., Y. Levin, M. Nediak. 2009. Counteracting strategic consumer behavior in dynamic pricing systems. *Consumer-Driven Demand and Operations Management Models*, Springer US.323-352.

[3] Bell, D. 1985. Disappointment in decision making under uncertainty. *Operation Research,* 33(1): 1-27.

[4] Cachon, G. P., R. Swinney. 2009. Purchasing, pricing, and quick response in the presence of strategic consumers. *Management Science*, 55(3): 497-511.

[5] Cachon, G. P., R. Swinney. 2011. The value of fast fashion: quick response, enhanced design, and strategic consumer behavior. *Management Science*, 57(4): 778-795.

[6] Cachon, G. P., A. G. Kok. 2007. Implementation of the newsvendor model with clearance pricing: How to (and how not to) estimate the salvage value. *Manufacturing Service Operations Management*, 9(3): 276-290.

[7] Coase, R. H. 1972. Durability and monopoly. *Journal of Law Economics*, 15(1): 143-149.

[8] Delquie, P., A. Cillo. 2006. Expectations, disappointment, and rank-dependent probability weighting. *Theory and Decision,* 60(2): 193-206.

[9] Du, J., J. Zhang, G. Hua, 2015. Pricing and inventory management in the presence of strategic customers with risk preference and decreasing value. *International Journal of Production Economics*, 164(1): 160-166.

[10] Koszegi, B., M. Rabin. 2007. Reference dependent risk attitudes. *American Economic Review,* 97(4): 1047–1073.

[11] Liu, Q., G. van Ryzin. 2008. Strategic capacity rationing to induce early purchases. *Management Science*, 54(6): 1115-1131.

[12] Liu Q, Shum S. 2013. Pricing and capacity rationing with customer disappointment aversion. *Production and Operations Management*, 22(5): 1269-1286.

[13] Loomes, G., R. Sugden. 1986. Disappointment and dynamic consistency in choice under uncertainty. *Review Economic Studies*, 53(2): 271-282.

[14] Loomes, G., R. Sugden. 1987. Testing for regret and disappointment in choice under uncertainty. *Economic Journal*, 97(1): 118-129.

[15] Muth, J. F. 1961. Rational expectations and the theory of price movements. *Econometri*ca, 29(3): 315-335.

[16] Nasiry, J., I. Popescu. 2011. Dynamic pricing with loss averse consumers and peak-end anchoring. *Operation Research*, 59(6): 1361-1368.

[17] Nasiry, J., I. Popescu. 2012. Advance selling when consumers regret. *Management Science,* 58(6): 1160-1177.

[18] Png, I. P. 1991. Most-favored-customer protection versus price discrimination over time. *Journal of Political Economy*, 99(5): 1010-1028.

[19] Popescu, I., Y. Wu. 2007. Dynamic pricing strategies with reference effects. *Operation Research*, 5(3): 413-429

[20] Sonsino, D. 2008. Disappointment aversion in internet bidding decisions. *Theory and Decision*, 64(2): 363-393.

[21] Su, X. 2007. Inter-temporal pricing with strategic customer behavior. *Management Science*, 53(5): 726-741.

[22] Su, X., F. Zhang. 2008. Strategic customer behavior, commitment, and supply chain performance. *Management Science,* 54(10): 1759-1773.

[23] Su, X., F. Zhang. 2009. On the value of commitment and availability guarantees when selling to strategic consumers. *Management Science*, 55(5): 713-726.

[24] Yin, R., Y. Aviv, A. Pazgal, C. S. Tang. 2009. Optimal markdown pricing: Implications of inventory display formats in the presence of strategic customers. *Management Science,* 55(8): 1391-1408.

Appendix

A.1 Proof of Proposition 1

Since $\overline{F}(Q_t)=\dfrac{c-s}{v-s}$ and $\overline{F}(Q_s)=\dfrac{c-s}{p_s-s}$, then

$$\overline{F}\left(Q_s\right)-\overline{F}\left(Q_t\right)=\frac{c-s}{p_s-s}-\frac{c-s}{v-s}. \tag{8}$$

Since $0<k<\dfrac{1}{1-\xi_{prob}}$ and $\xi_{prob}=F(Q_s)$, $1-k+kF(Q_s)>0$. Hence from (5), we have

$$p_s=v-F(Q_s)\left(1-k+kF(Q_s)\right)\left(\alpha v-s\right)<v=r=p_t.$$

Therefore $\overline{F}\left(Q_s\right)-\overline{F}\left(Q_t\right)=\dfrac{c-s}{p_s-s}-\dfrac{c-s}{v-s}>0$, i.e., $\overline{F}\left(Q_s\right)>\overline{F}\left(Q_t\right)$. So $Q_s<Q_t$.

Define $\Pi_t(Q)=\Pi_t(Q,p_t)$ and $\Pi_s(Q)=\Pi_s(Q,p_s)$. It follows from $\frac{d\Pi_t}{dQ}=(p_t-s)\overline{F}(Q)-(c-s)$, $\frac{d\Pi_s}{dQ}=(p_s-s)\overline{F}(Q)-(c-s)$ and $p_s<p_t$ that $\frac{d\Pi_t}{dQ}>\frac{d\Pi_s}{dQ}$ for all Q. Note that $\Pi_t(0)=\Pi_s(0)=0$, then $\Pi_t(Q)>\Pi_s(Q)$, $\forall Q>0$. We have $\Pi_s^*(Q_s)<\Pi_t^*(Q_s)\le\Pi_t^*(Q_t)$.

A.2 Proof of Proposition 2

From (4) and (5), we have $p_s=v-(1-\frac{c-s}{p_s-s})\left(1-\frac{k(c-s)}{p_s-s}\right)(\alpha v-s)$. Taking the derivative of both sides of the above equation, we have

$$\begin{aligned}
dp_s &= -\frac{c-s}{(p_s-s)^2}\left(1-\frac{k(c-s)}{p_s-s}\right)(\alpha v-s)\,dp_s+\left(\frac{c-s}{p_s-s}-1\right)\left[-\frac{c-s}{p_s-s}dk+\frac{k(c-s)}{(p_s-s)^2}dp_s\right](\alpha v-s)\\
&\quad+v\left(\frac{c-s}{p_s-s}-1\right)\left(1-\frac{k(c-s)}{p_s-s}\right)d\alpha\\
&=\left(1-\frac{c-s}{p_s-s}\right)\frac{c-s}{p_s-s}(\alpha v-s)\,dk+v\left(\frac{c-s}{p_s-s}-1\right)\left(1-\frac{k(c-s)}{p_s-s}\right)d\alpha\\
&\quad+(\alpha v-s)\frac{c-s}{(p_s-s)^2}\left(\frac{2k(c-s)}{p_s-s}-k-1\right)dp_s
\end{aligned}\tag{9}$$

Since $\alpha v>s, c<p_s, k<\frac{1}{1-\xi_{prob}}$ and $\xi_{prob}=F(Q_s)=1-\frac{c-s}{p_s-s}$, we have $\frac{\partial p_s}{\partial k}>0$ and $\frac{\partial p_s}{\partial\alpha}<0$. So p_s increases in k and decreases in α.

From (4), we have $\frac{\partial\overline{F}(Q_s)}{\partial p_s}<0$, which means that $\overline{F}(Q_s)$ decreases in p_s. So Q_s increases in p_s. Then, we know that Q_s increases in k and decreases in α.

From (3) and (5), we can get $\Pi_s=\left[v-F(Q)(1-k+kF(Q))(\alpha v-s)-s\right]E(X\wedge Q)-(c-s)Q$.

By the Envelope Theorem, we can get $\frac{\partial\Pi_s^*}{\partial\alpha}=-vF(Q_s)(1-k+kF(Q_s))E(X\wedge Q_s)<0$ and

$\frac{\partial\Pi_s^*}{\partial k}=F(Q_s)[1-F(Q_s)](\alpha v-s)E(X\wedge Q_s)>0$. So Π_s increases in k and decreases in α.

A.3 Proof of Proposition 3

From Proposition 2, we know that Π_s^* increases in k. Since $\Pi_p(Q,p)=pE(X\wedge Q)-cQ$, Π_p^* is independent on k. We proceed the proof as the following two cases:

(a) $k = \frac{1}{1-\xi_{prob}}$,

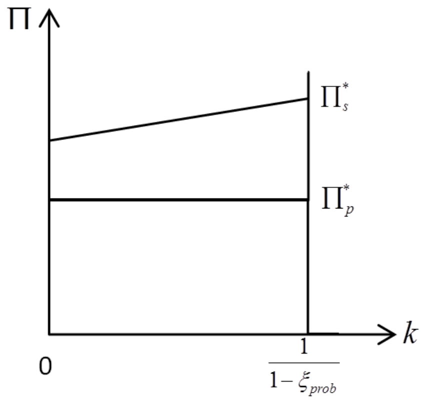
Since $\Pi_p(Q) = vE(X \wedge Q) - cQ$ and $\Pi_s(Q) = (v-s)E(X \wedge Q) - (c-s)Q$, then

$$\Pi_s(Q) - \Pi_p(Q) = -sE(X \wedge Q) + sQ \geq 0,$$

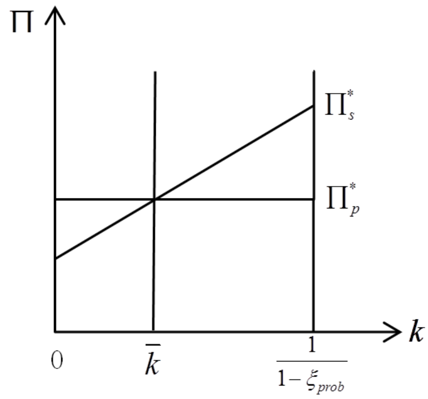
i.e., $\Pi_s(Q) \geq \Pi_p(Q)$ always holds when $k = \frac{1}{1-\xi_{prob}}$. It implies that $\Pi_p^* \leq \Pi_s^*$.

When $0 < k < \frac{1}{1-\xi_{prob}}$, there are two subcases we should consider:

(1) $\Pi_p^* \leq \Pi_s^*$ when $k = 0$. In this case, $\Pi_p^* \leq \Pi_s^*$ always holds for $k \in \left(0, \frac{1}{1-\xi_{prob}}\right)$. This case is depicted in Figure 4(1).



(1)



(2)

Figure 4. Comparison between Π_p^* and Π_s^*

(2) $\Pi_p^* > \Pi_s^*$ when $k = 0$. In this case, there exists a threshold $\bar{k}$ such that $\Pi_p^* < \Pi_s^*$ for $k > \bar{k}$ and $\Pi_p^* > \Pi_s^*$ for $k < \bar{k}$.

Now we discuss the case that $k = 0$.

(b) $k = 0$

It follows from (5) that the seller's optimal price is $p_s = v - (v-s)\left(1 - \overline{F}(Q_s)\right)$ when $k = 0$. From this and (4), we have $p_s = \sqrt{(v-s)(c-s)} + s$. The seller's profit is $\Pi_s(Q_s) = \sqrt{(v-s)(c-s)}E(X \wedge Q_s) - (c-s)Q_s$.

By the Envelope Theorem, we can get

$$\frac{\partial \Pi_s^*}{\partial c} = \frac{1}{2}\sqrt{\frac{v-s}{c-s}} E(X \wedge Q_s) - Q_s = \frac{1}{2\overline{F}(Q_s)} E(X \wedge Q_s) - Q_s .$$

Taking the derivative of Π_s^* with respect to Q_s, we have

$$\frac{\partial \Pi_s^*}{\partial c \partial Q_s} = \frac{1}{2}\left[\frac{f(Q_s)}{\left(\overline{F}(Q_s)\right)^2} E(x \wedge Q_s) - 1\right].$$

Since we assume that $\frac{f(x)}{1-F(x)}$ increases in x, $\frac{f(Q_s)}{\left(\overline{F}(Q_s)\right)^2} E(x \wedge Q_s)$ increases in Q_s. Then there exists a threshold $\overline{Q_s}$ such that $\frac{\partial \Pi_s^*}{\partial c \partial Q_s} \le 0$ for $Q_s < \overline{Q_s}$ and $\frac{\partial \Pi_s^*}{\partial c \partial Q_s} \ge 0$ for $Q_s > \overline{Q_s}$. Meanwhile, we know that Q_s decreases in c, i.e., $\frac{\partial Q_s}{\partial c} \le 0$. So there exists a threshold $\bar{c}$ such that Π_s^* is convex in c for $c \le \bar{c}$ and Π_s^* is concave in c for $c \ge \bar{c}$.

Under the price commitment policy, the seller's profit is $\Pi_p(Q) = vE(X \wedge Q) - cQ$. By the Envelope Theorem, we can get $\frac{\partial \Pi_p^*}{\partial c} = -Q_p$ and $\frac{\partial^2 \Pi_p^*}{\partial c^2} = \frac{-dQ_p}{dc} > 0$. So Π_p^* is convex and decreases in c.

Note that $c \in [s, v]$, $\Pi_p^* > 0 = \Pi_s^*$ when $c = s$ and $\Pi_s(Q) - \Pi_p(Q) = -sE(X \wedge Q) + sQ > 0$, i.e., $\Pi_p^* \le \Pi_s^*$ when $c = v$.

Thus, when $k = 0$, for given v and s, there exist c_l and c_h （$c_l < c_h$） such that $\Pi_p^* > \Pi_s^*$ for $c < c_l$ and $\Pi_p^* < \Pi_s^*$ for $c > c_h$.

Summarizing above, we can get the proposition.

A.5 Proof of Proposition 5

Since $\Pi_p(Q) = vE(X \wedge Q) - cQ$ and $\Pi_t(Q) = (v-s)E(X \wedge Q) - (c-s)Q$, we have $\Pi_t(Q) - \Pi_p(Q) = -sE(X \wedge Q) + sQ \ge 0$.This means that $\Pi_t(Q) \ge \Pi_p(Q)$ for all $Q \ge 0$, which implies that $\Pi_p^* \le \Pi_t^*$.

A.6 Proof of Proposition 6

Simplifying (7) we can get

$$\prod_m (Q, p_m) = s\int_0^{\frac{sQ}{p_m}} Qf(x)dx + p_m\int_0^{Q} xf(x)dx - p_m\int_0^{\frac{sQ}{p}} xf(x)dx + p_m\int_0^{+\infty} Qf(x)dx - p_m\int_0^{Q} Qf(x)dx - cQ$$
$$= \int_0^{\frac{sQ}{p_m}} (sQ - p_m x) f(x)dx + p_m Q - p_m\int_0^{Q} (Q-x) f(x)dx - cQ$$
$$= p_m\left[Q - \int_0^{Q} (Q-x) f(x)dx\right] + \int_0^{\frac{sQ}{p_m}} (sQ - p_m x) f(x)dx - cQ$$
$$= p_m E(X \wedge Q) + \int_0^{\frac{sQ}{p_m}} (sQ - p_m x) f(x)dx - cQ$$

Note that $\prod_p(Q) = vE(X \wedge Q) - cQ$, we have

$$\prod_m (Q, p_m) - \prod_p (Q) = (p_m - v)E(X \wedge Q) + \int_0^{\frac{sQ}{p_m}} (sQ - p_m x) f(x)dx \tag{10}$$

From (6), we know that $p_m = v$. Thus, $\prod_m (Q, p_m) - \prod_p (Q) > 0$ for all Q. Then we can get $\prod_m^* > \prod_p^*$.

A.6 Proof of Proposition 7

Since $\prod_m (Q) = p_m E(X \wedge Q) + \int_0^{\frac{sQ}{p_m}} (sQ - p_m x) f(x)dx - cQ = vE(X \wedge Q) + \int_0^{\frac{sQ}{v}} (sQ - vx) f(x)dx - cQ$,

$\prod_t (Q) = (v-s)E(X \wedge Q) - (c-s)Q$ and $v > s$, we have

$$\begin{aligned}\prod_t (Q) - \prod_m (Q) &= -sE(X \wedge Q) - \int_0^{\frac{sQ}{v}} (sQ - vx) f(x)dx + sQ \\ &= -s\left[Q - \int_0^{Q} (Q-x) f(x)dx\right] - \int_0^{\frac{sQ}{v}} (sQ - vx) f(x)dx + sQ \\ &= \int_0^{Q} (sQ - sx) f(x)dx - \int_0^{\frac{sQ}{v}} (sQ - vx) f(x)dx \\ &\geq 0\end{aligned}$$

This means that $\prod_t (Q) \geq \prod_m (Q)$ for all $Q \geq 0$, which implies that $\Pi_m^* \leq \Pi_t^*$.

Highlights

1. Study the pricing and inventory decisions under disappointment aversion strategic customers
2. Show that price commitment policy can't really alleviate strategic customer behavior
3. Compare the effects of price commitment and most-favored-customer protection policies
4. Show that the most-favored-customer protection policy is more beneficial to the seller